Appendix A: BMP Fact Sheets

May 2016 Version - Updates and errata will be published as necessary

Introduction

This appendix contains Fact Sheets that describe stormwater controls, or stormwater Best Management Practices (BMPs), that can be used to meet the stormwater management performance requirements in the *San Francisco Stormwater Management Requirements and Design Guidelines* (SMR). Most of the BMPs included here are runoff reduction strategies known as green infrastructure. Green infrastructure is multi-purpose: it not only provides the core stormwater management functions of pollutant removal, peak flow reduction, and runoff volume reduction; it can also enhance urban habitat, improve overall watershed health, and provide aesthetic benefits.

The Fact Sheets are provided as general guidance for typical stormwater BMPs and are not intended to be exhaustive or prescriptive – creative design and future innovation will generate new kinds of BMPs to meet stormwater management requirements. For more information on BMP selection, see the BMP Hierarchies in *Chapters 5: Combined Sewer Area Performance Requirements* and *Chapter 6: Separate Sewer Area Performance Requirements*. San Francisco Public Utilities Commission (SFPUC) and Port of San Francisco (Port) project review staff will be happy to work with project teams that propose new design ideas that may not be included here.

Each Fact Sheet includes a labeled schematic diagram; a snapshot of the level of pollutant removal, volume reduction, and peak flow reduction provided by a given BMP; technical information about the benefits, limitations, siting, design considerations, inspection and maintenance requirements; and a list of references and resources.

The Fact Sheets are aimed at informing planning-level design decisions, including BMP siting and sizing considerations. They are not meant to be used as the sole basis for creating construction drawings. *Appendix B: Green Infrastructure Typical Details and Specifications* provides specific guidance for selected BMPs that can be used in developing construction drawings (available for download at www.sfwater.org/smr).

Low Impact Design and Green Infrastructure

Low Impact Design is a planning and design approach that seeks to manage stormwater as close to its source as possible. LID employs principles such as minimizing and disconnecting impervious area, and uses landscape-based technologies to create site drainage that treats stormwater as a resource rather than a waste product.

The term "**green infrastructure**" refers collectively to the actual technologies that are used to infiltrate, evapotranspire, treat, and/or reuse stormwater. Individual GI facilities, such as cisterns, rain gardens, permeable pavement, and vegetated roofs, are also referred to as "**best management practices" (BMPs)** or "**stormwater controls**" throughout this document.

Leland Avenue in San Francisco features permeable paving and bioretention in the right-of-way. Photo: Robin Scheswhol

Important Definitions

The following terms appear throughout the fact sheets:

Design volume The runoff volume that the stormwater BMP must manage to meet performance requirements. For combined sewer areas, the design volume is based on the 1-year and 2-year, 24-hour storms. For separate sewer areas, the design volume is based on the 90th percentile storm depth in the SFPUC's jurisdiction and the 85th percentile storm depth in the Port's jurisdiction.

Design flow rate The runoff flow rate that the stormwater BMP must manage to meet performance requirements. For combined sewer areas, the design flow rate is based on the runoff from the 1-year and 2-year, 24-hour storms. For separate sewer areas, the design flow rate is based on the 90th percentile storm intensity in the SFPUC's jurisdiction and the 85th percentile storm intensity in the Port's jurisdiction.

Drawdown time The time it takes for a BMP to drain the design volume and return to maximum capacity. Generally, BMPs should have a drawdown time of 48 hours or less to inhibit mosquito breeding. For planted BMPs, the drawdown time within the planted and root-zone portion of the BMP should be 24 hours or less. Specific drawdown time requirements are provided in each BMP fact sheet.

Offline Configuration in which the BMP receives only the design flow from the contributing area, while higher flows bypass the BMP and go directly to the collection system.

Online Configuration in which the BMP receives all flows from the contributing drainage area.

Design Requirements

The SMR requires that BMPs reuse, infiltrate, or treat the applicable design storm depending on a project's location in the combined or separate sewer area and whether it is in SFPUC or Port jurisdiction. The respective performance requirements are described in *Chapters 5: Combined Sewer Area Performance Requirements* and *Chapter 6: Separate Sewer Area Performance Requirements*. Designers are responsible for ensuring that larger flows are safely accommodated by the project.

Siting Requirements for Infiltration-Based BMPs

In San Francisco, the use of infiltration-based BMPs must comply with specific siting and design requirements. In addition, the potential for using infiltration-based BMPs may be limited in Maher Ordinance areas (areas with the potential for contaminated groundwater or sediment areas underlain by bay fill, current or previous industrial areas, or areas near major highways, hazardous waste sites, or underground storage tanks), which are shown on the 2015 Expanded Maher Area map at http://www.sf-planning.org/ftp/files/publications_reports/library_of_cartography/Maher%20Map.pdf. Infiltration potential is also limited in landslide hazard areas. These requirements and other design guidance for infiltration-based BMPs are provided in *Appendix C: Criteria for Infiltration-based BMPs.*

This infiltration trench doubles as stormwater art in Portland, OR. *Photo: Ken Kortkamp*

BMP Categories

The stormwater controls outlined in this appendix are broken down into categories for use in San Francisco:

The following BMPs are generally appropriate for **all projects**, including typical residential, commercial, or mixed-use projects:

- Rainwater harvesting
- Vegetated roof
- Permeable pavement
- Bioretention (including flow-through planters and bioretention swales)
- Subsurface infiltration system
- Infiltration trench
- Media filter
- Detention tank

The following BMPs typically require larger footprints with larger contributing areas and thus are only generally applicable to **larger parcel and multi-parcel projects**, such as parks, open spaces, and industrial areas:

- Infiltration basin
- Detention pond
- Wet pond
- Constructed wetland

The following BMPs are approved for use **as pretreatment facilities** for other BMPs or for use with limitations, as noted within the appropriate fact sheet:

- Conveyance swale
- Vegetated buffer strip
- Swirl separator
- Drain insert
- Water quality inlet

BMPs Generally Appropriate for All Projects

Rainwater Harvesting

Also known as: rainwater collection, rainwater reuse (includes cisterns and associated system components)

Leaf screen 1

Pump 2

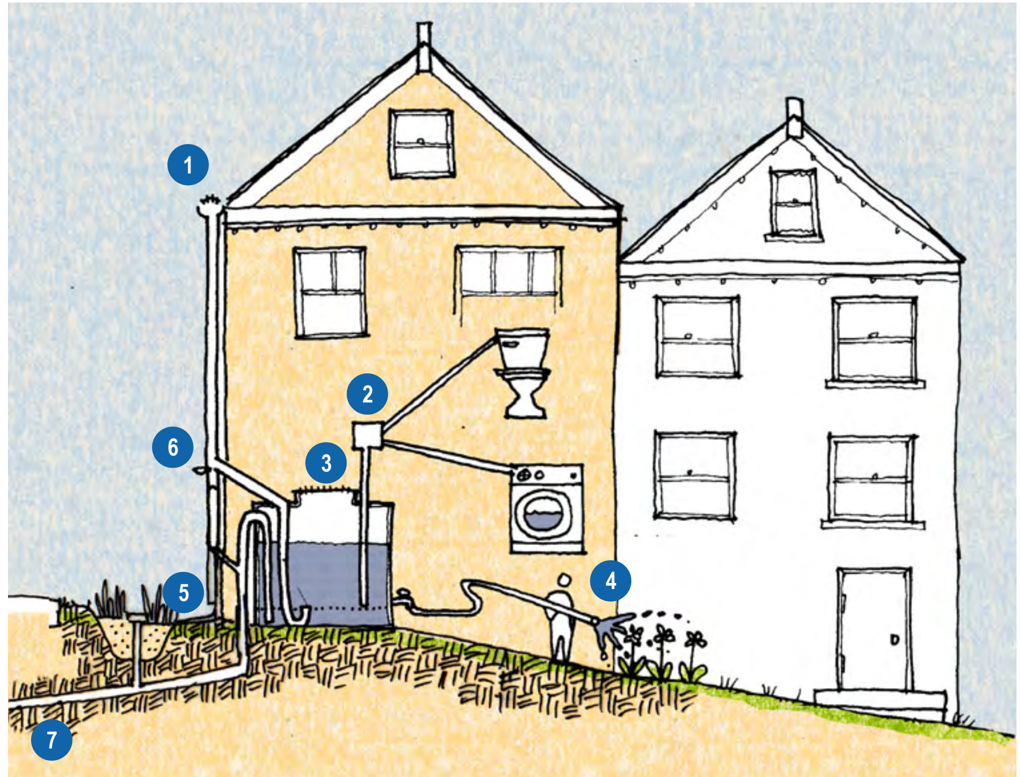
Screened maintenance opening 3

Water reused for non-potable uses 4

Splash block 5

First flush diverter 6

Overflow to collection system 7



Description

Rainwater harvesting is the practice of collecting and using rainwater from various surfaces, such as roofs and patios. It is an age-old technology; communities in ancient Rome were designed with paved courtyards that captured and fed rainwater to individual cisterns to augment supply from the city's aqueducts. Today, rainwater harvesting is growing in popularity as people look for ways to use water resources more efficiently. Many rural areas around the world rely on rainwater as their primary water source, but areas served by reliable municipal water supplies have historically overlooked rainwater until recently. San Francisco would like to promote rainwater harvesting in our urban setting.

As of 2005, it is legal to divert rainwater and stormwater away from San Francisco's combined sewer system in accordance with amendments to the San Francisco Plumbing Code. Rainwater and stormwater can now be directed to alternative locations such as rainwater harvesting cisterns and other stormwater BMPs.

Rainwater harvesting systems used in projects that are subject to the SMR are typically large-scale cisterns that are custom-built on site. The systems may range from several thousand gallons on small sites up to hundreds of thousands of gallons in large developments or beneath parks. The systems can be installed above or below ground or even on a roof, depending upon site conditions. Water from cisterns can be used for irrigation, heating and cooling, toilet flushing, and other non-potable uses if properly connected to indoor/outdoor plumbing.

Benefits

- Reduces the volume of potable water used for non-potable applications, such as irrigation and toilet flushing. Can be designed to greatly minimize or altogether eliminate certain non-potable demands.
- Keeps relatively clean stormwater out of the City's collection systems, thereby reducing the volume and peak flows of stormwater entering the sewer. This helps reduce flooding and combined sewer discharges.
- Good for sites where infiltration is not an option.
- Good for sites where indoor non-potable, dual-plumbing systems are required.
- Reduces the energy and chemicals needed to treat stormwater in the City's sewage treatment plants.
- Reduces the energy expended transporting potable water from distant sources.

Rain Barrels

In contrast to the large cisterns used for projects subject to the SMR, rain barrels are small containers, typically ranging from 50 to 100 gallons. Rain barrels are inexpensive, easy to install and maintain, and well-suited to small residential-scale sites that fall below SMR thresholds. The SFPUC's Rainwater Harvesting Program webpage (http://sfwater.org/rainwater) provides general guidance for people interested in installing a residential rainwater harvesting system and also includes information about the SFPUC's Free Residential Rain Barrel Program.

Transbay Transit Center

Whole Foods - Market Street

SFPUC Headquarters. *Photos: SFPUC 2015*

San Francisco's Non-Potable Water Use Ordinance

Projects using non-potable water from alternative water sources, such as rainwater harvesting, must comply with San Francisco's Non-Potable Water Use Ordinance (codified in San Francisco Health Code Article 12C) and the San Francisco Department of Public Health's (SFDPH's) rules and regulations. Article 12C applies to sites containing non-residential and multi-family residential buildings; it does not apply to single-family or duplex residences or sites where rainwater is used only for subsurface or drip irrigation or non-spray surface applications. As of November 1, 2015 the Non-Potable Water Use Ordinance requires all new buildings with 250,000 square feet or more of gross floor area, located within the boundaries of San Francisco's designated recycled water use area, to install non-potable water reuse systems to treat and reuse available alternate water sources for toilet and urinal flushing as well as irrigation. This requirement expands to the entire city the following year, on November 1, 2016.

Projects subject to the ordinance require approvals from the SFPUC and permits from both the Department of Public Health (SFDPH) and Department of Building Inspection (DBI) to verify compliance with the requirements and local health and safety codes. SFPUC approval is obtained by submitting a Non-Potable Project Water Budget Application to the SFPUC's Non-Potable Water Program. The Non-Potable Water Budget Application requires a description of the proposed alternate water source system and the type and quantities of source water and non-potable applications proposed. If Article 12C applies, the project proponent must also submit an Engineering Report to SFDPH. Once the Engineering Report (if needed) is approved, project proponents may apply for a plumbing permit and other applicable building permits from DBI, as well as an encroachment permit from the Department of Public Works for placement of pipelines or other work within the public right-of-way. Following a cross-connection test, projects subject to Article 12C must obtain a permit to operate from SFDPH.

The Non-Potable Water Budget Application is available on the SFPUC website at http://sfwater.org/np, along with the following technical and regulatory guidance resources:

- The Non-Potable Water Program Guidebook, with step-by-step instructions for permitting and other interactions with regulating agencies,

- Non-potable water calculators to help estimate the project's potable and non-potable water demands, as well as the availability of on-site water sources, and

- A grant assistance program that provides up to $500,000 to projects meeting grant eligibility criteria.

Chapter 2: Regulatory Context contains more information about these and other codes relevant to rainwater harvesting. Rainwater harvesting systems can be used to meet the requirements of both the SMR and the Non-Potable Water Use Ordinance.

Limitations

- Requires dual plumbing systems for indoor non-potable use.
- May require on-going operating support and/or ongoing monitoring after construction.
- Requires infrastructure (pumps, valves, pipes) to distribute stored water.

Siting

Above-ground cisterns, commonly used at schools and single-family residences, must be sited on a stable, flat area and may not block the path of travel for fire safety access. Tanks should be opaque and placed in a cool, shaded area or underground to avoid algal growth. Overflow locations, which can include rain gardens, additional cisterns, or a discharge point to the collection system, must be designed to direct outflow away from building foundations and prevent nuisance flows onto adjacent properties. Overflows may not discharge water across a public right-of-way.

In many commercial applications, cisterns are located within or pre-cast into basements or below-grade parking garages. Tanks should be located on a flat concrete pad or floor that is capable of supporting the tank and its contents. The tank anchors and support system must be designed for seismic load conditions. The required height above the tank for maintenance access, the overflow connection layout, and the placement of isolation valves and drains should also be considered. Setbacks between tanks and adjacent walls as well as setbacks for treatment and distribution system components should adhere to manufacturer's requirements.

A disconnected downspout and rain barrel. *Photo: Clean Air Gardening*

Installation of a cistern in Sausalito, CA. *Photo: Sherwood Engineers*

The rainwater harvesting system at New Traditions Elementary School in San Francisco, CA overflows to a vegetated area before flowing into the sewer system. *Photo: Polly Perkins*

Design Considerations

Proper design and sizing of rainwater designed in accordance with the "**Nonpotable Rainwater Catchment Systems" chapter of the California Plumbing Code**, available at http://codes.iapmo.org. Project proponents should be familiar with treatment and monitoring requirements for each type of planned reuse (for example, toilet flushing versus spray irrigation versus drip irrigation, etc.), as required by the California Plumbing Code and the *San Francisco Department of Public Health Director's Rules and Regulations* harvesting systems are critical to ensuring full stormwater management benefits. These systems must be *Regarding the Operation of Alternate Water Source Systems*.

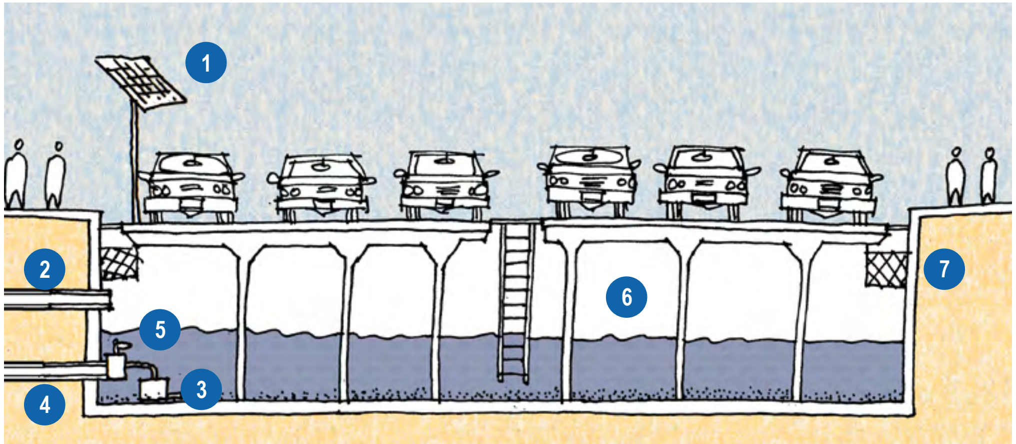
Components: Regardless of the size, all rainwater harvesting systems include the following basic components: debris separation, conveyance, storage, and distribution. Rainwater from roofs or other drainage areas is conveyed through pipes to a storage area. Some pretreatment (e.g., leaf screens and first-flush diverters) is required to prevent clogging before the stormwater enters storage. Water is stored in the system until it is distributed either by gravity or by a pump.

All openings in the rainwater storage facility should be screened or adequately sealed to prevent litter, mosquitoes, or other vectors from entering. Generally, pre-made cisterns have an operable manhole opening on the top to allow access for maintenance and monitoring. All rainwater harvesting system pipes and valves must be purple and labeled "CAUTION: NONPOTABLE RAINWATER, DO NOT DRINK" in yellow letters (in accordance with the California Plumbing Code chapter titled "Water Supply and Distribution"). The table below provides a list of typical system components for cisterns and their associated requirements.

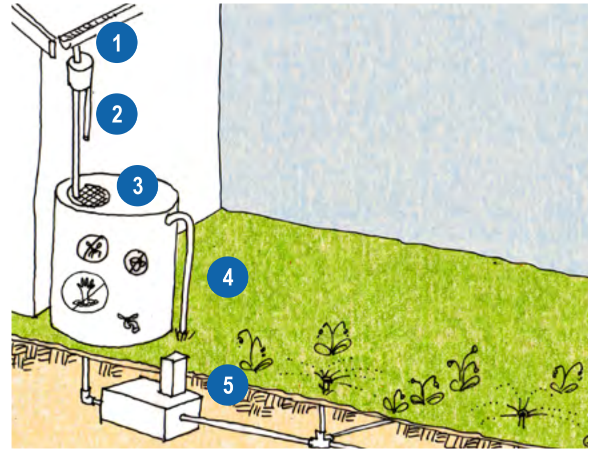
Typical Rainwater Harvesting Components
1. Roof surfaces serving as catchments for watering shall not include materials treated with fungicides or herbicides. Roof surfaces containing metals may cause an accumulation of zinc, copper, and/or other potentially phytotoxic heavy metals in irrigated soils. Owners are recommended to test soils for heavy metals at the beginning and end of each rainy season.
2. Cisterns must be opaque, water tight, vented, and installed in accordance with the California Plumbing Code.
3. All openings must be screened.
4. For above-ground systems, spigot and/or hose bibb for drawing water must be at least 2 inches from the bottom.
5. Overflow device must be equal in size to the total of all inlets and must lead to an approved discharge location with approved air gap.
6. First flush diverter must be automatic self-draining with clean out.
7. Systems must include safety labels (Caution: Nonpotable Rainwater, Do Not Drink). If system includes a hose bib, a nonpotable water icon must also be displayed in accordance with the California Plumbing Code.
8. Buildings containing rainwater harvesting systems must install a reduced-pressure principle (RP) backflow prevention assembly within 25 feet of the potable water meter. An additional RP must also be installed at the point of potable make-up to the non-potable system.

* Only if connected to indoor plumbing

Assembling a rainwater harvesting system at Cesar Chavez Elementary School, San Francisco, CA. Photo: Urban Watershed Management Program



*In urban areas, **underground cisterns** can store stormwater runoff from paved surfaces.*



***Above-ground cisterns** can be attached to irrigation systems in residential settings*

1. Solar panel to power pump
2. Overflow drains to collection system
3. Pump
4. Outflow to nonpotable use
5. Valve to drain for maintenance
6. Design storm elevation
7. Trash rack

1. Screen on gutter prevents large debris from entering cistern
2. First flush diverter
3. Screened access prevents mosquite breeding
4. Overflow to collection system
5. Pump with maintenance access

Sizing: To meet the performance requirements outlined in the SMR, rainwater harvesting systems must be appropriately sized. BMP Sizing Calculators are available for download on the SFPUC website at www.sfwater.org/smr; the BMP Sizing Calculators contain separate worksheets for rainwater harvesting. The rainwater harvesting worksheet simulates daily inflows to the cistern over a 10-year period using historical rainfall data and calculates the percent of annual runoff captured and the percent of annual non-potable demand met by the system. Because the cistern's long-term performance is simulated directly, there is no maximum drawdown time requirement associated with meeting the stormwater performance requirements. These worksheets are to be used for planning purposes and for sizing a system to comply with the SMR; they are not intended to provide final detailed design and layout.

In general, rainwater harvesting systems can be designed for daily demands (such as toilet flushing or heating and cooling) or seasonal demands (such as dry-weather irrigation). Storage tanks are usually smaller in rainwater harvesting systems that reuse stormwater for daily demands; much larger tanks are typically needed to store stormwater over an entire wet season for use during the dry season.

Inspection and Maintenance

Rainwater harvesting systems, including drainage management areas and gutters, must be kept clear of debris, and screens must be properly maintained to exclude mosquitoes and other vectors. Cisterns should be cleaned annually with a non-toxic cleaner, such as vinegar. The system owner is responsible for ensuring that backflow prevention assemblies are tested annually by an authorized backflow prevention assembly tester approved to work in San Francisco (see approved testers at: https://www.sfdph.org/dph/files/EHSdocs/ehsCrossflowdocs/CertifiedTesters.pdf).

Sizing Rainwater Harvesting Systems to Maximize Non-Potable Water Offset

Rainwater harvesting systems differ from other stormwater controls in that they should be designed with dual purposes in mind: to meet stormwater management requirements AND to offset as much non-potable demand as possible. To meet this second goal, project proponents should consider sizing cisterns to maximize the percentage of non-potable demand met by rainwater harvesting.

Examples of Rainwater Harvesting

In San Francisco, CA

The Exploratorium In 2013, the internationally-renowned Exploratorium moved to a 330,000-square-foot, indoor and outdoor exhibit space on Pier 15 in San Francisco. The LEED Platinum Exploratorium has a 38,600-gallon cistern that captures rainwater from the roof for toilet flushing. The rainwater harvesting system can save up to 364,000 gallons annually, reducing water usage by about 30 percent in a year of average rainfall.

Market Street Place In this 283,940-square-foot, six-level retail center, rainwater is to be used for cooling tower make-up water and for toilet flushing. Scheduled to open in 2016, the system is planned to offset an estimated 446,000 gallons of potable water a year.

Public Safety Building (PSB) This 300,000-square-foot project consists of a new six-story building and the restoration of Fire Station 30. The PSB reuses water from multiple alternative sources. The project treats a combined flow of greywater and condensate drainage for toilet flushing. A rainwater harvesting system collects rainwater from the building's roofs and conveys it to a 44,500-gallon cistern in the basement. After filtration and disinfection, the rainwater is used for subsurface irrigation and as make-up water for a closed-loop cooling tower system. The system offsets an estimated 415,000 gallons of potable water a year.

Public Safety Building *Photo: SF Department of Public Works*

The Exploratorium *Photo: Port of San Fancisco*

Photo: Market Street Place

Regular inspection is required to confirm that all the parts of a rainwater harvesting system are operable and not leaking. For further information about inspection

Typical Inspection Activities for Rainwater Harvesting	
Activity	*Schedule*
Check that all parts are structurally sound, operational, and not leaking.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect and test backflow prevention assemblies using a certified tester approved by the City and County of San Francisco (see approved testers at: (https://www.sfdph.org/dph/files/EHSdocs/ehsCrossflowdocs/CertifiedTesters.pdf).	Annually
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

Typical Maintenance Activities for Rainwater Harvesting	
Activity	*Schedule*
Remove algae growth if present	Semi-annually or as needed
Clean prescreening devices, first flush diverters, and storage tank interiors with a non-toxic cleaner, such as vinegar.	Annually
Clear litter, sediment, visible contaminants, debris, and any overhanging vegetation from drainage management area, gutters, collection and conveyance system, and screens.	As needed
Replace or repair any damaged or non-functioning parts.	As needed
Use stored water periodically during the rainy season to ensure that storage is available for the next rain event.	As needed
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional maintenance activities.	As needed

Example of Rainwater Harvesting (Cont.)

In Cambria, CA

Cambria, a coastal community north of San Louis Obispo, has stringent water quality and erosion prevention requirements imposed by the California Coastal Commission. When Cambria Elementary School expanded its campus and athletic fields, it needed a way to limit stormwater runoff. The school settled on an innovative rainwater harvesting system that captures and stores all stormwater from its 12-acre campus in large pipes under the 130,000 square feet of new athletic fields. The proprietary pipe system can store up to 2 million gallons of rainwater and provide irrigation for the fields year round. The fields have a 5-inch-deep soil/sand profile to filter rainwater and are surrounded by a 6-inch berm to provide temporary storage in case of torrential rains.

Photo: WaterWorld

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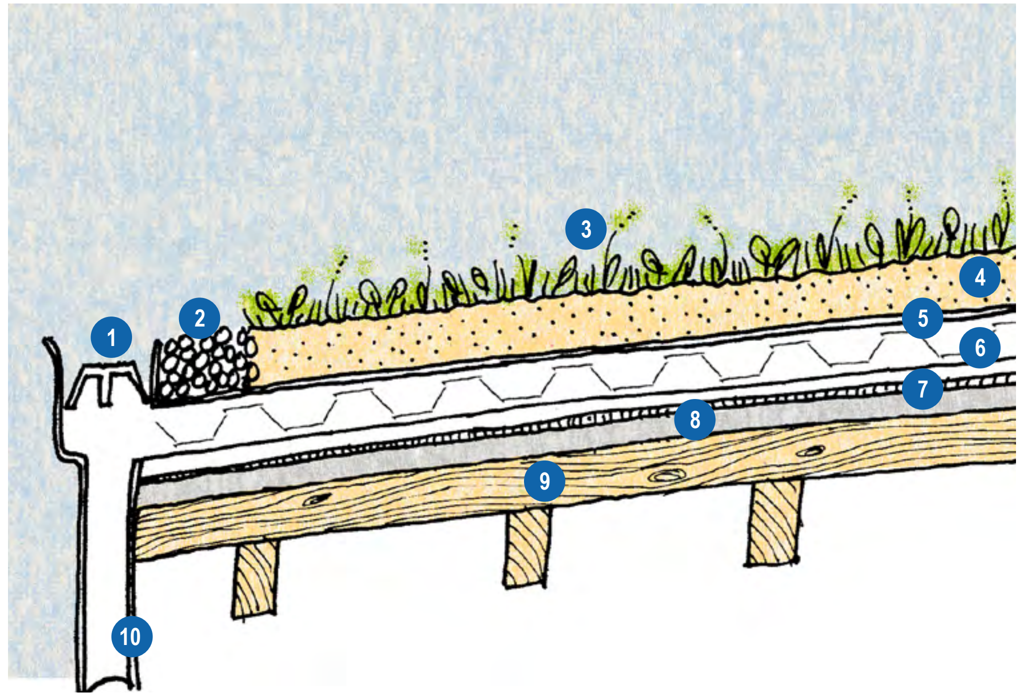
Vegetated Roof

Also known as: living roof, eco-roof, green roof

- Leaf screen 1
- Gravel 2
- Drought-tolerant plants 3
- Growing medium 4
- Filter membrane 5
- Drainage and storage 6
- Root barrier and waterproof membrane 7
- Insulation 8
- Roof structure 9
- Gutter system for overflow 10



Description

Vegetated roofs are roofs that are entirely or mostly covered with vegetation and soils. Vegetated roofs have been popular in Europe for decades and have recently gained popularity in the U.S. because of the multiple environmental benefits they provide. Vegetated roofs improve water quality by filtering contaminants as the runoff flows through the growing medium or via direct plant uptake. Studies have shown that after establishment, vegetated roofs can decrease the concentrations of suspended solids, copper, zinc, and polycyclic aromatic hydrocarbons in roof runoff. In addition, because the engineered soils or media absorb rainfall and release it slowly, total runoff volumes are reduced and peak flows delayed. Rainfall retention and detention volumes are influenced by the depth of the engineered soil or media, storage capacity of the engineered soils, antecedent moisture conditions, and rainfall intensity and duration. Vegetated roofs have been found to retain 40 to 60 percent of annual rainfall and to reduce volumes and peak flows of large rain events (those exceeding 1.5 inches) by 15 to 40 percent.

Vegetated roofs can also greatly enhance habitat value and green space, with reductions of heat island effects and improved insulation of roofs. The City supports vegetated roofs as part of various roof improvement policies. The term "living roof" (rather than "green roof") is becoming more common within the City to help promote an understanding of the diverse range of aesthetics they exhibit.

Vegetated roofs typically fall into three categories: intensive, semi-intensive, or extensive. Intensive roofs, or rooftop gardens, are generally deeper than 6 inches and are heavier systems that can support larger vegetation. Extensive vegetated roofs are shallower and lighter-weight systems less than 6 inches deep that incorporate smaller plants, such as grasses and sedums. Semi-intensive vegetated roof have both shallow and deep areas and have a wider range of plant and eco-system biodiversity.

The Academy of Sciences building in San Francisco has a has a nearly 2.5-acre vegetated roof.
Photo: Ken Kortkamp

Vegetated Roof Example

In San Francisco, CA

The City of San Francisco is working to encourage roof improvement projects, including vegetated roofs, and to create sustainable roof requirements and guidelines for new development. The Planning Department website (http://www.sf-planning.org/index.aspx?page=3839) showcases nine case studies of completed green roofs in San Francisco and provides an interactive map that tracks completed projects citywide.

Twitter Headquarters When social media company Twitter relocated its headquarters to the historic Market Square building at 1355 Market in 2012, architects and engineers removed part of the existing roof and used a portion of the ninth floor to plant a 12,000 square foot semi-intensive green roof. Drought-tolerant sedums and Blue Fescue grass are planted in a growing medium that varies from six to eight inches in depth. The irrigation system is controlled through a satellite weather feed, and maintenance staff regularly checks that drains are clear. The open roof area also contains artificial turf and seating, making it a popular meeting and lunch spot for employees.

Photo: Inhabit

Intensive vegetated roofs can provide usable open space in addition to their stormwater management function. *Photo: Rosey Jencks*

Benefits

- Encouraged by City planning policies to promote improvements to commonly neglected and under-utilized spaces.
- Creates habitat and increase biodiversity in the city.
- Provides aesthetics as part of recreational amenities.
- Extends the life of the roof: a green roof can last twice as long as a conventional roof, saving replacement costs and landfill of materials.
- Provides noise reduction.
- Reduces the urban heat island effect.
- May provide insulation and can lower a building's cooling costs.
- May lower the temperature of stormwater runoff in separate sewer areas, which helps maintain cooler water temperatures for fish and other aquatic life.

Limitations

- May require additional structural support to bear the added weight. Requires a structural engineering evaluation.
- Soil depth is limited by the increase in seismic risk associated with the increase in weight.
- Irrigation likely needed to establish plants and maintain them during the dry season.
- Vegetation requires maintenance, without which it may become overgrown or weedy; seasonally, vegetation can appear dormant.
- Generally limited to roof slopes less than 20 degrees (5-in-12 pitch). (Note: Can be designed on steeper slopes by an experienced designer.)
- Potentially long payback time for installation costs.

Siting

Vegetated roofs can be installed on most types of multi-family residential, commercial, and industrial structures, as well as on single-family homes, garages, and sheds. Vegetated roofs can be used for new construction or to re-roof existing buildings. Candidate roofs for a "green" retrofit must have sufficient structural support to hold the additional weight of the vegetated roof, which is generally 15 to 30 pounds per square foot, saturated, for extensive roofs and more for intensive roofs. Based on findings from the City of Portland (2009) and the City of New York (2007), extensive vegetated roofs can be designed to function on slopes up to 40 degrees, although slopes between 2 and 20 degrees are most suitable.

Design Considerations

An intensive vegetated roof may consist of shrubs and small trees planted in deep soil (greater than 6 inches but typically 9 to 12 inches). In contrast, an extensive vegetated roof has a shallow layer of soil (5 to 6 inches) with low-growing vegetation and is more appropriate for roofs with structural limitations. For wood-framed structures, the SFPUC may grant approval for shallower systems on a case-by-case basis.

Both categories of vegetated roofs are assembled in several typical layers. The top layer includes the engineered soils and the plants. The soil is a lightweight mix that includes minimal organic material. Under the soil is a drainage layer that includes filter fabric to keep the soil in place and a core material that stores water and allows it to drain off the roof surface. Next is the root barrier, which prevents roots from puncturing the waterproof membrane that lies below it, then a layer of insulation, and finally there is the roof structure. The most critical layer of the entire system is the waterproof membrane. Ideal vegetation for vegetated roofs has the following characteristics: drought tolerance, self-sustainability, heartiness over a range of temperatures and moisture conditions, minimal maintenance requirements, fire resistance, and perennial life cycle.

The BMP Sizing Calculators, which are hosted on the SFPUC website at www.sfwater.org/smr, can be used to determine the soil media depth required to meet performance requirements. However, the calculator is not intended to provide detailed dimensions that account for structural accessibility and other site-specific design considerations.

Vegetated Roof Examples (cont.)

In Chicago, IL

Chicago's first green roof, constructed in 2000, covered the 20,000-square-foot roof of City Hall. In 2005, the city launched its Green Roof Grant Program, awarding $5,000 each to 20 residential and small commercial green roof projects (each with a footprint of less than 10,000 square feet). As of August 2010, more than 359 public and private green roofs were counted as part of a city-wide image survey of Chicago rooftops, totaling nearly 5.5 million square feet of green roofs. Chicago also developed policies that encourage green roof development in the city. For example, all new and retrofit roofs in the city must meet a 0.25 solar reflectance requirement, which green roofs are capable of, but traditional roofs are not. Also, the city offers a density bonus for roofs that have at least 50 percent vegetative cover.

A vegetated roof atop the Peggy Notebaert Museum.
Photo: Ken Kortkamp

Wildflowers grow among other plants on the Griffith Pump Station vegetated roof in San Francisco. Photo: Urban Watershed Management Program

Vegetated roofs can be designed to be visible from the street to add unique textures and colors to building design. Photo: Rosey Jencks

While the SFPUC does not yet have typical details or design standards for vegetated roofs, we refer to the design guidance distributed by Green Roofs for Healthy Cities (http://www.greenroofs.org). This program has created a detailed training process promoting the certification of Green Roof Professionals and has published a Green Roof Design and Installation Resource Manual for individuals registered for their course work. Refer to the San Francisco Planning Department Green Roofs website (http://www.sf-planning.org/index.aspx?page=3839) for additional vegetated roofs requirements and guidance.

Inspection and Maintenance

Each vegetated roof installation should have specific inspection and maintenance guidelines provided by the manufacturer or installer. Intensive vegetated roofs generally require more continued maintenance than extensive roofing systems, depending on the proposed planting. In the first few years, watering, light weeding, and occasional plant feeding will help the roof vegetation become established.

Routine inspection of the waterproof membrane and the drainage systems is important to extend the life of the roof. According to the United States Environmental Protection Agency, the membrane under a vegetated roof – the limiting factor in the lifespan of the roof – is expected to last between 30 and 50 years. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

Vegetated Roof

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Vegetated Roof	
Activity	*Schedule*
Periodically inspect vegetation and irrigation (if present). Water as-needed to ensure vegetation becomes established.	First year or until vegetation is established
Inspect visible drainage features and collection and conveyance structures to ensure drainage is free-flowing and not blocked or clogged with sediment	Semi-annually and/or following large storm events
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

Typical Maintenance ical Maintenance Activities for Vegetated Roofs	
Activity	*Schedule*
Clean visible drainage features and collection and conveyance structures.	Semi-annually or as needed
Maintenance of permanent irrigation (if present), including monitoring of irrigation schedule.	Semi-annually or as needed
Replace dead vegetation and remove weeds or excessive leaf litter, visible contaminants, sediment, debris, or trash.	Annually or as needed
Repair eroded areas.	Annually or as needed
Reseed and apply mulch to bare spots.	Annually or as needed
Consult with a licensed professional pest control service if rodent or animal damage is observed.	Annually or as needed
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

Vegetated Roof Examples (cont.)

In Toronto, Ontario

In 2009, the City of Toronto adopted its Green Roof Bylaw, which requires and governs the construction of green roofs on new development. The bylaw applies to new building permit applications for residential, commercial, institutional, and industrial development buildings with a gross floor area of more than 21,500 square feet. In addition, the city's Eco-Roof Incentive Program offers grants to green roof projects of $75 per square meter up to a maximum of $100,000.

An extensive living roof atop a Subway Station in Toronto. Photo: City of Toronto

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Permeable Pavement

Also known as: pervious paving, porous pavement, permeable unit pavers, pervious concrete, pervious asphalt, grass pavers, green parking, porous turf blocks

Overflow to collection system 1

Pavers with open spaces filled with fine gravel 2

Fine gravel leveling course (wearing course) 3

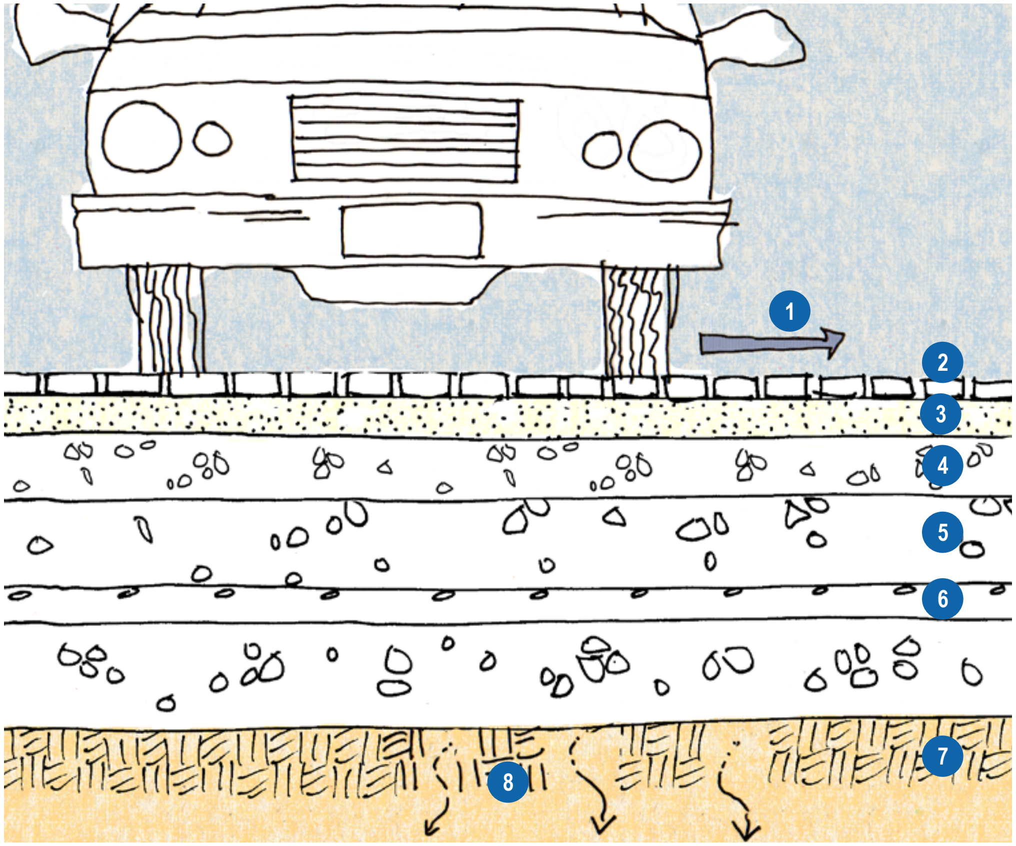
Base course (medium gravel) 4

Coarse gravel reservoir course 5

Underdrain (if necessary) 6

Subgrade 7

Infiltration where feasible 8

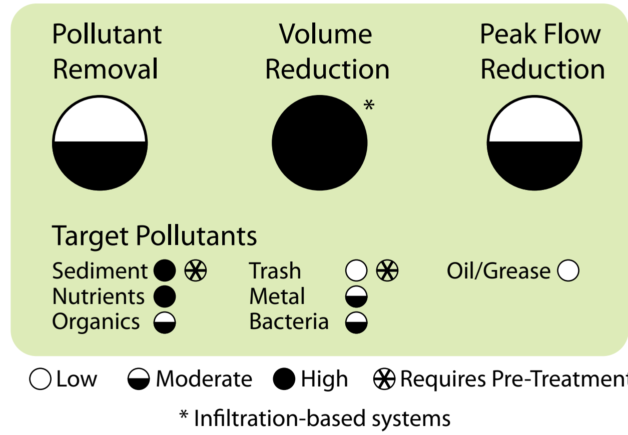


Description

Permeable pavement is any porous load-bearing surface that temporarily stores rainwater prior to infiltration or drainage to a controlled outlet. Stormwater is stored in an underlying aggregate layer until it either infiltrates the soil below, facilitating groundwater recharge, or is slowly released to the collection system through an underdrain or overflow system. Research and monitoring projects have shown that permeable pavement reduces annual runoff volumes by approximately 60 percent, attenuates peak flows, and improves water quality by removing oil and grease, metals, and suspended solids. Permeable pavement does not typically remove nutrients.

Permeable pavement systems are most appropriate in pedestrian areas or areas with light- to medium-duty vehicular loads, such as parking lots, street-side parking areas, driveways, bike paths, patios, and sidewalks. In San Francisco, these systems are allowed in alleyway traffic lanes, if approved by the San Francisco Department of Public Works (SFDPW), but not in traffic lanes of streets classified as arterials or collectors. Refer to the SFDPW Permeable Pavement Director's Order (pending release 2016) for City requirements and public right-of-way (ROW) locations where permeable paving may be allowed with SFPUC and SFDPW approval.

Permeable pavement systems installed in the City should follow the specifications defined in the *Appendix B: Green Infrastructure Typical Details and Specifications*, available at www.sfwater.org/smr.



Benefits

- Reduces runoff volume and attenuates peak flows.
- Facilitates groundwater recharge.
- Improves water quality by reducing fine-grained sediment, organic matter, and trace metals.
- Can be used as a design element to provide aesthetic benefits.
- Reduces the heat island effect.
- Provides noise reduction.
- Can increase driving and pedestrian safety by reducing ponding.

"Country Lanes" in Vancouver, Brtitish Columbia enhance the alley's aesthetic quality and reduce stormwater discharge to the City's stormsewer system by allowing runoff to flow over vegetation and infiltrate into the ground. Photo: Rosey Jencks

Limitations

- Limited to paved areas with pedestrian or light-to-moderate vehicular loading.
- 4- to 10-foot minimum vertical separation from the bottom of the aggregate system to the seasonally-high groundwater elevation is required, depending on location (see *Appendix C: Criteria for Infiltration-based BMPs* for more detailed information about this requirement).
- Depth to bedrock must be over 4 feet from the bottom of the aggregate system.
- Maintenance costs can be greater than for traditional paving.

Siting

Site conditions, including type of soil, depth to bedrock, slope, and adjacent land uses (e.g. adjacent structures), should be assessed to determine whether infiltration is appropriate. Permeable pavement should be installed in locations that will not receive off-site runoff with high sediment and pollutant loads to ensure long-term performance.

Slope: Permeable pavement should be used on relatively flat sites to facilitate infiltration and minimize erosion. The permeable pavement surface, called the "wearing course," should have a minimum slope of 0.5 percent, to allow for surface overflow, and a maximum slope of 5 percent for porous asphalt, 10 percent for pervious concrete, and 12 percent for permeable pavers. Subsurface check dams are recommended on subgrade slopes exceeding 5 percent.

Drainage Area: To limit the amount of sediment and debris flowing onto and through the permeable pavement, direct run-on from landscaped areas is discouraged and all run-on should be minimized; see the table below for maximum run-on ratios. Concentrated run-on (such as from a downspout) should either be dispersed before it discharges to a permeable pavement facility or routed directly into the permeable pavement's underlying aggregate layer.

Run-on ratios for various types of permeable pavement		
Permeable pavement wearing course	Preferred Run-On Ratio(1) (Contributing Area: Permeable Pavement Area)	Maximum Run-on Ratio (Contributing Area: Permeable Pavement Area)
Pervious Concrete and Porous Asphalt	0:1 (no run-on)	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 Unit Pavers(2) (≤1/8" gaps)	0:1	0:1 (no run-on)

Source: *Appendix B: Green Infrastructure Typical Details and Specifications*, available at www.sfwater.org/smr.
Notes:
(1) Most product and material manufacturers recommend no run-on to ensure long-term performance.
(2) Porous unit pavers are pre-cast concrete blocks with minimal-to-no gaps that allow infiltration through the unit pavers themselves.

Soils: Permeable pavement should be designed with an underdrain system if the infiltration rate of the underlying soil is less than 0.5 inches per hour. Soils should also be able to sustain the anticipated traffic loading without excessive deformation.

Setbacks: A discussion of setbacks and a table showing standard and conditional setback requirements are provided in *Appendix C: Criteria for Infiltration-based BMPs*.

Groundwater protection: A minimum vertical separation of 4 or 10 feet, depending on location, from the facility bottom to the seasonally high groundwater elevation or bedrock is required to protect groundwater quality (*Appendix C: Criteria for Infiltration-based BMPs* contains more information on this requirement). To minimize risk of groundwater contamination, permeable pavement should not be used in areas with potentially hazardous materials or high pollutant loading, such as fueling stations, maintenance yards, heavy industrial sites, or chemical storage areas.

This Habitat for Humanity construction project features curb-to-curb permeable paving along a private residential road. Photo: Krystal Zamora

Permeable pavers are used in parking spaces in Germany. *Photo: Rosey Jencks*

Pervious asphalt in Portland, OR. *Photo: Rosey Jencks*

Design Considerations

Permeable pavement can be integrated into a variety of installations such as roads (both in driving lanes and parking lanes), sidewalks, plazas, terraces and patios, and other hardscape features. The permeable paving system must be designed with a stable base and appropriate structural edge constraints to ensure long-term smoothness for Americans with Disabilities Act (ADA) compliance. Permeable pavements are available in a variety of colors and patterns and can aesthetically enhance public spaces.

Permeable pavement should be designed in accordance with *Appendix B: Green Infrastructure Typical Details and Specifications*, available at www.sfwater.org/smr. A summary of this design information is provided below.

Materials: Permeable pavement consists of a series of layered elements that allow percolation of stormwater. From top to bottom, these layers are a wearing course, leveling course (also called a bedding, or choking, layer), base course (or transition layer), optional reservoir course (or subbase layer) of permeable base rock or gravel, and prepared native soil subgrade.

Common materials for the **wearing course** include:

- Porous asphalt: similar to standard hot-mix asphalt but with reduced aggregate fines (typically 2.5 inches thick).
- Pervious concrete: similar to standard concrete, but without the fine aggregate (sand and finer) and with optional special admixtures incorporated (typically 4 to 8 inches thick, depending on loading).
- Permeable pavers: Several varieties of permeable pavers exist, with new types continuing to be developed. The most common unit pavers are:
    - Permeable unit pavers (with gaps): pre-cast concrete blocks with interlocking tabs that form gaps wide enough to allow infiltration; gaps are filled with clean joint filler aggregate. The type of joint filler (e.g., American Society for Testing and Materials [ASTM] No. 9, 89, or 8) is critical for long-term performance, with the aggregate size selected based on the width of the joint gap. [Generally ADA compliant]

- Porous unit pavers (no gaps): pre-cast concrete blocks with minimal to no gaps that allow infiltration through the unit pavers themselves; joints are filled with a fine joint filler for structural stability. [Generally ADA compliant]

- Other pre-cast concrete systems: pre-cast concrete blocks in various forms and with larger openings; openings are either filled with soil and grass or gravel. [Not ADA compliant]

Beneath the wearing course is a **leveling course** (i.e., bedding layer or choker course) of fine gravel (ASTM No. 8) that must be between 1.5 and 2 inches thick. This layer provides a setting bed for unit pavers; it is typically omitted in porous asphalt and pervious concrete installations.

Below the leveling course (for permeable unit pavers) or the wearing course (for porous asphalt and pervious concrete) is a 4- to 6-inch thick **base course** (i.e., structural base) of ⅜-inch- to ¾-inch-diameter crushed stone (ASTM No. 57). The base course should be clean, washed, open-graded crushed stone. The thickness of the base course must be determined to meet the design loading requirements. In a pervious concrete installation, the base course should conform to the requirements of ASTM No. 57 or 3.

Underneath the base course is an optional **reservoir course** (i.e., storage layer) of gravel or crushed stone (ASTM No. 2 or 3, or additional thickness of ASTM No. 57). The reservoir course should be as thick as required to store the design volume and should be of clean, washed, open-graded crushed stone. Generally, filter fabric is not required underneath the reservoir course, but it might be advisable in some cases to prevent fines in the subgrade from migrating upward and potential settlement. The project's civil engineer is required to specify the filter fabric, if needed.

If the infiltration rate of the underlying soils is less than 0.5 inches per hour; a perforated underdrain system should be used.

Overflow: Overflow systems that convey excess flows to an approved discharge point should be included with all proposed permeable pavements. For soils with an infiltration rate below 0.5 inches per hour, an overflow system comprised of underdrain or overflow structure is required. *Appendix B: Green Infrastructure Typical Details and Specifications* Sheets PC 3.1 through PC 3.3 provide guidance for overflow design.

Permeable concrete installed as part of the Cesar Chavez Streetscape Improvement Project in San Francisco, CA.
Photo: Robin Scheswhol

Permeable pavement surrounding planters in the public right-of-way in San Francisco, CA. *Photo: Krystal Zamora*

Sizing: Permeable pavement footprint and storage depth can be sized using the BMP Sizing Calculators, which are hosted on the SFPUC website at www.sfwater.org/smr. The Calculators are intended for stormwater sizing for SMR compliance only and do not provide design recommendations to address structural loading or accessibility requirements. The maximum allowable drawdown time is 48 hours. In separate sewer areas, the depth of the reservoir course below the underdrain should be sized to capture the design event if the system is underdrained.

Inspection and Maintenance

Permeable pavement requires periodic maintenance to retain its infiltration capacity. Pavement should be tested to determine if it is clogged at least once a year. At least once or several times a year, depending on sediment loading conditions, the pavement should be vacuumed as a preventative maintenance measure. Vacuuming has been found to be most effective when sediments are dry. If routine vacuuming does not maintain infiltration rates, the surface can be pressure washed and vacuumed using specialized vacuum equipment. If this procedure does not restore infiltration rates, partial or full reconstruction of the pervious surface might be required. Maintenance also includes replacing broken or damaged pavement. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Permeable Pavement	
Activity	*Schedule*
Inspect to ensure pavement is functioning properly.	Post-construction
Inspect adjacent landscaped areas for potential erosion or vegetation damage.	Post-construction
Inspect porous areas for clogging with sediment, debris, or trash.	Semi-annually
Ensure that pavement section dewaters between storms.	Semi-annually
Inspect surface for structural deterioration and settlement.	Annually
Inspect underdrain and outlet structures/sand traps for clogging.	Annually
Measure infiltration rate.	Annually
Check the level of the jointing aggregate in the voids of interlocking pavers, and refill when necessary, particularly after vacuuming.	Quarterly

Typical Maintenance Activities for Permeable Pavement	
Activity	*Schedule*
Vacuum permeable surface.	Semi-annually (beginning and end of rainy season)
Replace or repair damaged or settled pavement.	Annually or as needed
Maintain planted areas adjacent to pavement	Annually or as needed
Lift surface paving units to clean and/or replace underlying aggregate - may require special disposal if containing metals or hazardous materials.	Every 10-15 years or as needed
If routine maintenance does not restore the infiltration rate, rehabilitate pavement by removing and replacing clogged section.	Upon failure (expected to be > 20 years)

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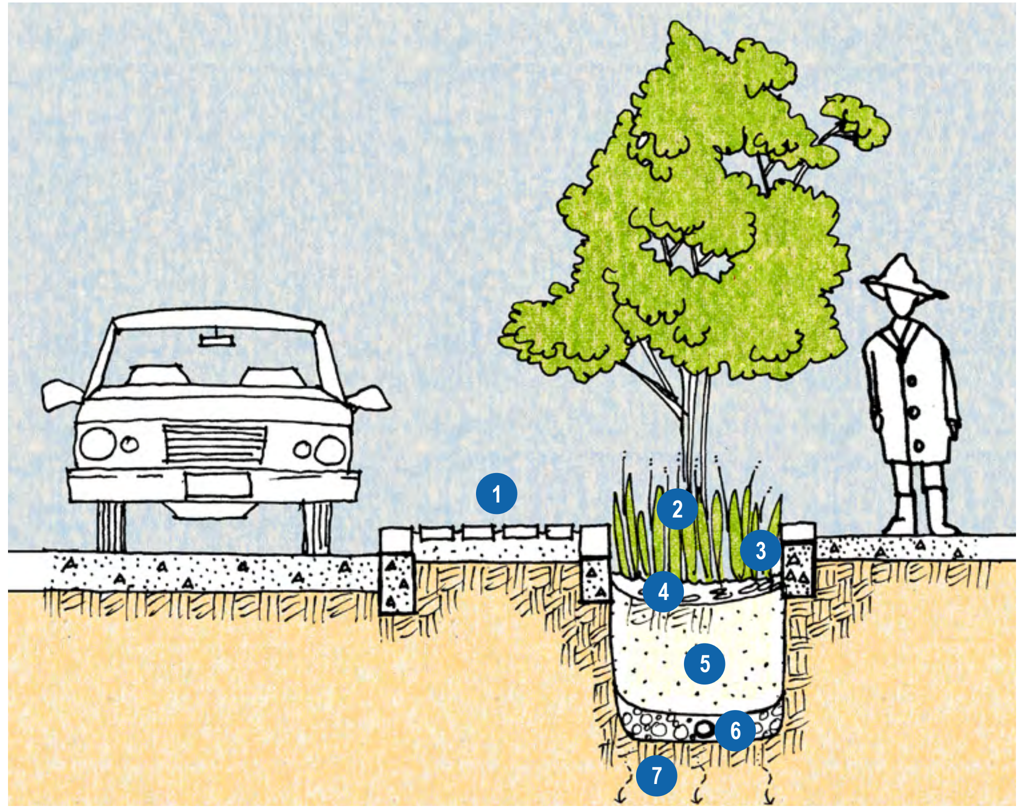
This plaza features permeable paving and bioretention in San Francisco, CA. Photo: Sherwood Design Engineers

Bioretention

Also known as: bioretention cell, bioretention basin, bioretention planter, flow-through planter, stormwater planter, rain garden, bioretention swale

1. Parking egress zone with curb cut
2. Dense wet- and dry-tolerant vegetation
3. 6-inch maximum ponding depth
4. 2- to 3-inch mulch depth
5. 18-inch bioretention planting soil
6. Perforated underdrainin gravel layer (if infiltration of native soils is <0.5inches per hour)
7. Infiltration where feasible



Bioretention Terminology

There are three general types of bioretention facility terminology used in the City: "rain gardens," also known as "bioretention basins," which are installed directly in the ground in a depressed area of the landscape with no hard edges; "bioretention planters," which are located in a curb or hard-walled container; and "bioretention swales," which are linear, sloped bioretention systems. All terms can be encompassed by "bioretention cell."

Description

Bioretention refers to the use of stormwater facilities that rely on vegetation and engineered soils to capture, infiltrate, transpire, and remove pollutants from runoff. Through these functions, bioretention systems reduce stormwater volume, attenuate peak flow, and improve stormwater quality. Bioretention BMPs contain engineered soils with high organic content and feature vegetation that can tolerate periodic inundation. If designed properly, these BMPS can enhance aesthetics and habitats while managing stormwater.

Bioretention BMPs can be designed as infiltration-based systems if the native soils beneath the facility are sufficiently permeable and there are no other constraints to infiltration, such as soil contamination or shallow depth to groundwater. If the infiltration rate of native soils is less than 0.5 inches per hour, an underdrain system is required. If infiltration is not feasible, these systems can be designed as flow-through systems in which soils and aggregates are contained within an impermeable liner and an underdrain directs treated runoff to the collection system.

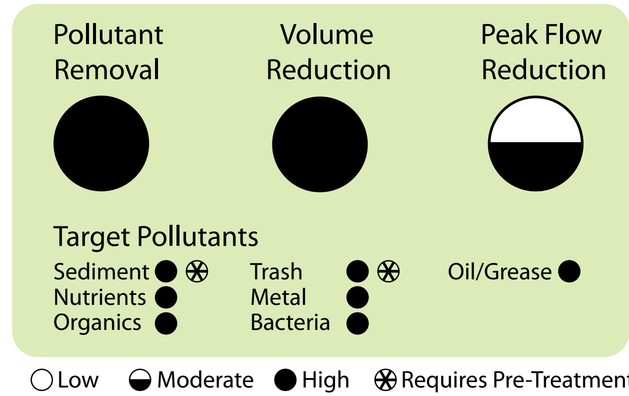
Benefits

- Easy to install and reasonably cost effective.
- Reduces runoff volume where infiltration is feasible and attenuate peak flows.
- Wide range of scales and site applicability.
- Can increase the effectiveness of permeable surfaces in managing runoff in highly urbanized areas.
- Improves water quality.
- Creates habitat and increases biodiversity in the city.
- Provides aesthetic amenities.
- Facilitates groundwater recharge (infiltration-based systems only).
- Facilitates evapotranspiration.

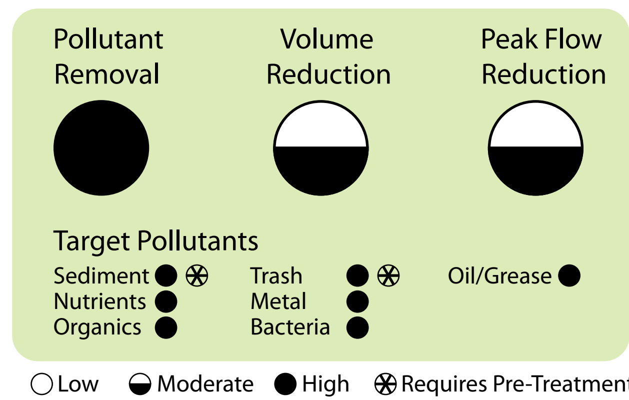
Limitations

- Requires relatively flat sites and sufficient hydraulic head for filtration.
- Vegetation requires maintenance and can look overgrown or weedy; seasonally it may appear dormant.

Infiltration-based



Flow-through



A rain garden captures and infiltrates stormwater from the paved surface in Mint Plaza, San Francisco. Photo: Rosey Jencks

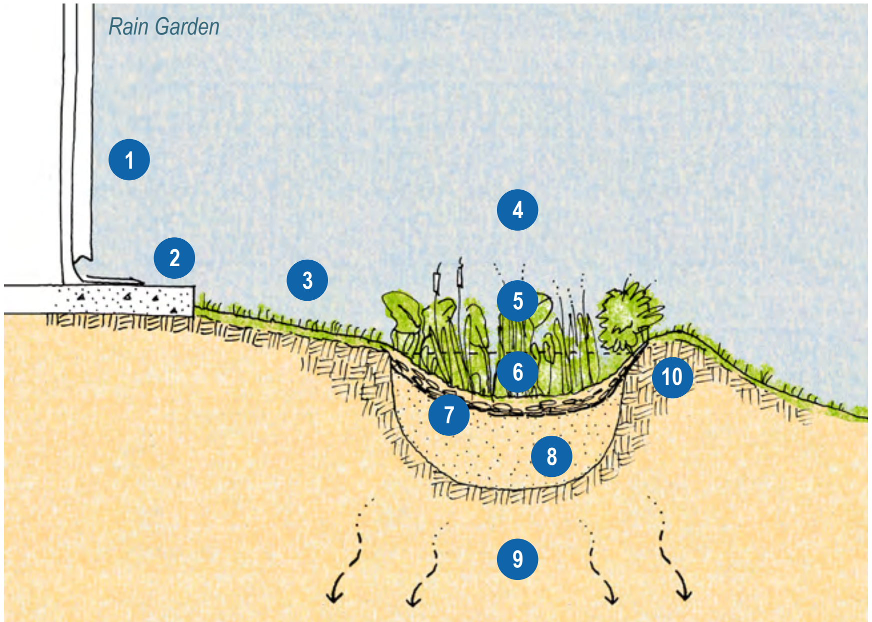
Siting

Because they tend to be relatively small and versatile, bioretention systems can be used in a variety of contexts, including urban plazas, residential courtyards, office and commercial storefronts, parks, roadway median strips and rights-of-way, parking lots, and other landscaped areas. These systems are also easily integrated into highly urban retrofit projects. For further siting information, see *Appendix B: Green Infrastructure Typical Details and Specifications* for Bioretention Systems.

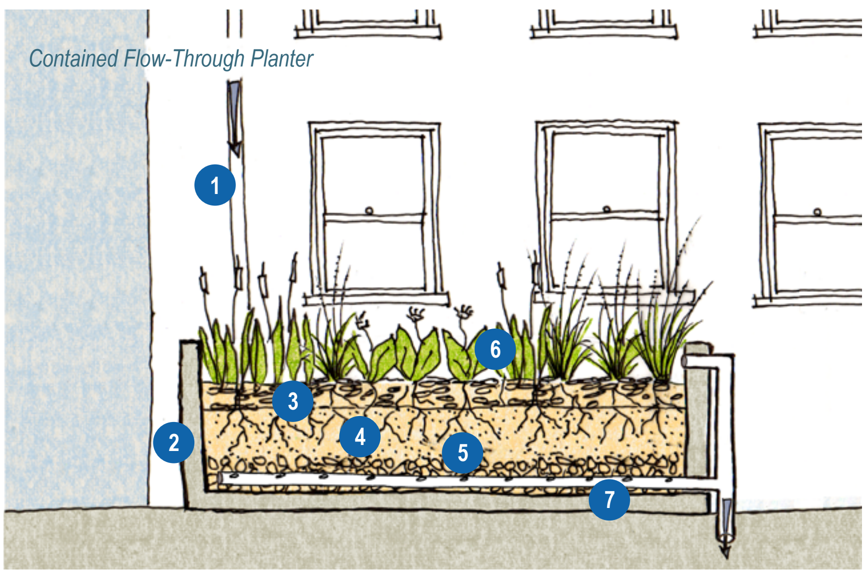
In separate sewer areas, lined bioretention systems with underdrains (i.e., flow-through planters) may only be used at sites where infiltration is infeasible due to specific site conditions, such as impermeable soils; documented high concentrations of pollutants in underlying soils or groundwater; locations where infiltration could contribute to a geotechnical hazard; and locations on elevated structures, such as piers over water. Refer to the Separate Sewer Area BMP Hierarchy in *Chapter 6: Separate Sewer Area Performance Requirements* and *Appendix C: Criteria for Infiltration-based BMPs* for more detail on the impact of infiltration on BMP selection.

Drainage area: Drainage management areas (DMAs) vary greatly depending on location, whether in confined urban settings or open space areas. A DMA less than 0.25 acres is preferred, however a single bioretention cell receiving runoff from more than 1 acre of DMA may be allowed when the proposed design is enhanced with elements such as sediment forebays, multiple inlets, flow distribution networks, and/or conveyance swales. Multiple bioretention cells (basins or planters) can be used to treat stormwater from larger contributing areas if proposed with the enhanced design elements previously mentioned. Multiple bioretention cells managing multiple 1-acre DMAs should not replace appropriately designed centralized stormwater controls, such as constructed wetlands or other forms of centralized stormwater treatment facilities.

Setbacks: Standard and conditional setback requirements for infiltration-based bioretention systems are provided in *Appendix C: Criteria for Infiltration-based BMPs* There are no setback requirements for waterproof, lined, flow-through systems or for planted areas with no run-on, provided a waterproof separation barrier is used between the bioretention aggregate and adjacent building foundations. Flow-through systems can be integrated into a building's foundation walls either at grade within a curb or above ground using a contained planter. These systems are typically placed where the building frontage meets the public right-of-way.



1. Water from paved or landscaped surfaces and roof
2. Splash pad
3. Setback from foundation (see previous page for setback requirements)
4. 1-foot minimum bottom width
5. Dense, wet- and dry-tolerant vegetation
6. Ponding depth, 6 to 12 inches
7. Mulch, 2- to 3-inch depth
8. 18-inch bioretention planting soil
9. Native soils suitable for infiltration
10. Berm



1. Inlet from roof or other source
2. Water-tight container
3. Mulch, 2- to 3-inch depth
4. 18-inch bioretention planting soil
5. 8- to 12- inches gravel
6. Wet- and dry-tolerant plants
7. Underdrain to collection system

Bioretention Swale

A bioretention swale is a linear, sloped bioretention system. As with all bioretention systems, its stormwater management function occurs through infiltration of stormwater through specified bioretention soil media and aggregate layers. The SMR distinguishes "bioretention swales" from "conveyance swales", the latter of which function through pollutant filtration as runoff flows horizontally through swale vegetation and do not require bioretention media layers. Because of changes in San Francisco's 2013 NPDES Phase II Municipal Separate Storm Sewer System Permit, conveyance swales no longer meet the separate sewer area requirements and are considered pretreatment facilities (see the Conveyance Swale fact sheet in the Pretreatment BMPs section of this appendix). Bioretention swales reduce peak flow and runoff volumes, making them better suited to meet SMR performance requirements than conveyance swales. Thus, bioretention swales are the only type of swale provided as a BMP option in the BMP Sizing Calculators. Conveyance swales are included as a pretreatment facility in the BMP Sizing Calculators.

Bioretention swales can be designed as part of a stormwater conveyance system and help minimize the need for curbs, gutters and storm drains in appropriate locations. They are also well-suited to capture runoff from roads and parkways because of their linear nature.

Bioretention swales should generally have a trapezoidal shape with a flat bottom to promote even flow across the entire width of the swale. The bottom width should be between 1 and 10 feet; the minimum provides an adequate planted area for treatment and the maximum prevents the formation of small channels within the swale bottom. Side slopes are generally designed to be 3:1 (horizontal:vertical) or greater to minimize erosion and slow runoff entering the swale from the sides. However, if an architectural edge is desired and runoff does not enter from the swale sides, hardscaped vertical sides may be designed. The recommended longitudinal slope for swales is typically between 1 percent and 6 percent, with a slope around 2 percent being preferred. Check dams should be installed if the longitudinal slope exceeds 5 percent.

Formal rain garden in Portland, OR frames an outdoor patio area. Photo: Rosey Jencks

Slope and soils: Bioretention facilities are best suited to sites that have less than a 5 percent slope. On slopes greater than 5 percent, they may have additional terracing and should incorporate check dams to slow flow and encourage retention. Systems must incorporate underdrains if the infiltration rate of the native soils is less than 0.5 inches per hour. There are no native soils requirements for lined, flow-through systems.

Groundwater protection: If designed for infiltration, the facility bottom must be at least 4 or 10 feet, depending on location, above the seasonally high groundwater elevation to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* or more information about this requirement). In addition, the bottom of the facility must be at least 4 feet above bedrock.

Residential rain garden in Maplewood, MN captures and infiltrates runoff from both residential yard and the street.
Photo: City of Maplewood

Design Considerations

Design guidance and drawings for bioretention systems are provided in *Appendix B: Green Infrastructure Typical Details and Specifications*, available at www.sfwater.org/smr.

Materials: The surface of a bioretention facility is typically covered in a 2- to 3-inch layer of mulch or compost, in which some filtration occurs and microorganisms degrade hydrocarbons and organic material. In very urban settings, pea gravel or river rock might be a more appropriate surface material to reduce mulch erosion or maintenance needs. This upper layer captures larger solids and can be replaced fairly easily. However, for systems capturing only roof runoff, additional pretreatment is recommended for all bioretention systems. Typical pretreatment methods for bioretention systems include vegetated buffer strips, swales, and sediment forebays. Curbside bioretention systems capturing street runoff should have, at minimum, a depressed rock cobble splash-pad at the curb inlet to capture larger solids and protect the system from erosive flows.

Beneath the surface layer is a layer of bioretention planting medium at least 18 inches deep. The bioretention medium must sustain a minimum infiltration rate of 5 inches per hour throughout the life of the project (i.e., the medium must have a long-term design hydraulic conductivity of 5 inches per hour). See the Bioretention Soil Specifications in *Appendix B: Green Infrastructure Typical Details and Specifications* for more details about the requirements (available for download at www.sfwater.org/smr).

Underdrained bioretention systems must have a layer of clean gravel below the planting medium. In combined sewer areas, the gravel must be specified as 3 to 4 inches ASTM #9 (choking layer) over ASTM #7 aggregate, for a total depth of 8 to 12 inches. In separate sewer areas, the gravel must be at least 12 inches deep and may be either ASTM #9 over ASTM #7, as noted above, or Caltrans Class 2 Permeable aggregate for the entire layer to promote stormwater treatment. Other components include splash blocks, flow spreaders, or other energy dissipation devices to prevent erosion at the flow inlet. *Appendix B: Green Infrastructure Typical Details and Specifications* provide more information regarding the design of energy dissipation devices.

Vegetation: Where possible, native vegetation should be used to provide habitat for local insects, birds, and other species. The plant palette should be selected for viability in well-drained soil, as well as periods of inundation during the rainy season. Vegetation should also be drought-tolerant, especially plants at the edges of the bioretention system, which remain relatively dry. All plantings might require irrigation during initial establishment and during the dry season, depending on the application and species used. Trees planted in above-ground bioretention planters (systems contained within a hard-walled container) require more intensive maintenance and often have limited growth and vigor. For this reason, containers should not be used for street tree plantings except in limited situations with underground constraints and where sidewalks are wide enough to accommodate large containers. Examples of vegetation appropriate for bioretention systems can be found in *Appendix D: Vegetation Palette for Bioretention BMPs.*

Overflow: During large storm events, runoff collects in the bioretention system until the water reaches the elevation of an overflow device, typically a weir or a riser. Excess flows are conveyed to the collection system or to another BMP. *Appendix B: Green Infrastructure Typical Details and Specifications* provide guidance about overflow design (www.sfwater.org/smr).

Sizing: Bioretention facilities can be sized using the BMP Sizing Calculators, which are hosted on the SFPUC website at www.sfwater.org/smr. The total storage volume within the bioretention system, including the aggregate layer beneath the media, should empty (achieve drawdown) within 48 hours. However, to minimize impacts due to inundation of plants and roots, the drawdown of the ponding depth and bioretention soil medium should be 24 hours or less, with 3 to 12 hours being optimal.

Inspection and Maintenance

Like all landscape features, the vegetation in bioretention facilities must be pruned, mulched, and watered until the vegetation is established. Semi-annual plant maintenance is recommended, including weeding, mulching, and the replacement of diseased or dead plants. Mulch and compost improve the planting medium's ability to capture water. Because some of the sediment that enters the planters can form a surface crust, some raking of the mulch and soil surface might also be necessary to maintain high infiltration rates. Periodic removal of debris and trash might also be necessary. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Bioretention

Activity	*Schedule*
After first storm event, inspect for proper drainage, erosion, and proper inlet and outlet functioning.	Post-construction
Monitor vegetation to ensure successful root establishment.	Semi-annually (beginning and end of rainy season)
Inspect for erosion, clogging, and vegetation damage.	Semi-annually (beginning and end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

The Portland Convention Center in Portland, OR exhibits a number of drought-tolerant bioretention features. Photo: Becky Lithander

Typical Maintenance Activities for Bioretention	
Activity	*Schedule*
Regularly water during the first three months as vegetation establishes roots.	Post-construction
Trim vegetation as needed to maintain desired appearance.	Monthly or as needed
Remove visible contaminants, debris, and trash from inlets and outlets to avoid clogging.	Semi-annually (beginning and end of rainy season)
Add mulch to bare areas and remove any mulch that has become fouled with sediment, oil and grease, or other hazardous material.	Semi-annually (beginning and end of rainy season)
Prune vegetation obstructing line of site at roadway or intersection.	Quarterly
Replace dead, damaged, or diseased plants and provide weed control.	Annually
Regrade soil surface if erosion or scouring has occurred.	Annually
Till or aerate soil and replant if the system does not drain within the design drain time.	As needed (expected to be 3 to 5 years)
Repair or replace damaged or detached impermeable liners, if applicable.	Semi-annually or as needed
Consult with a licensed professional pest control service if rodent or animal damage is observed.	Annually or as needed
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed

References and Resources

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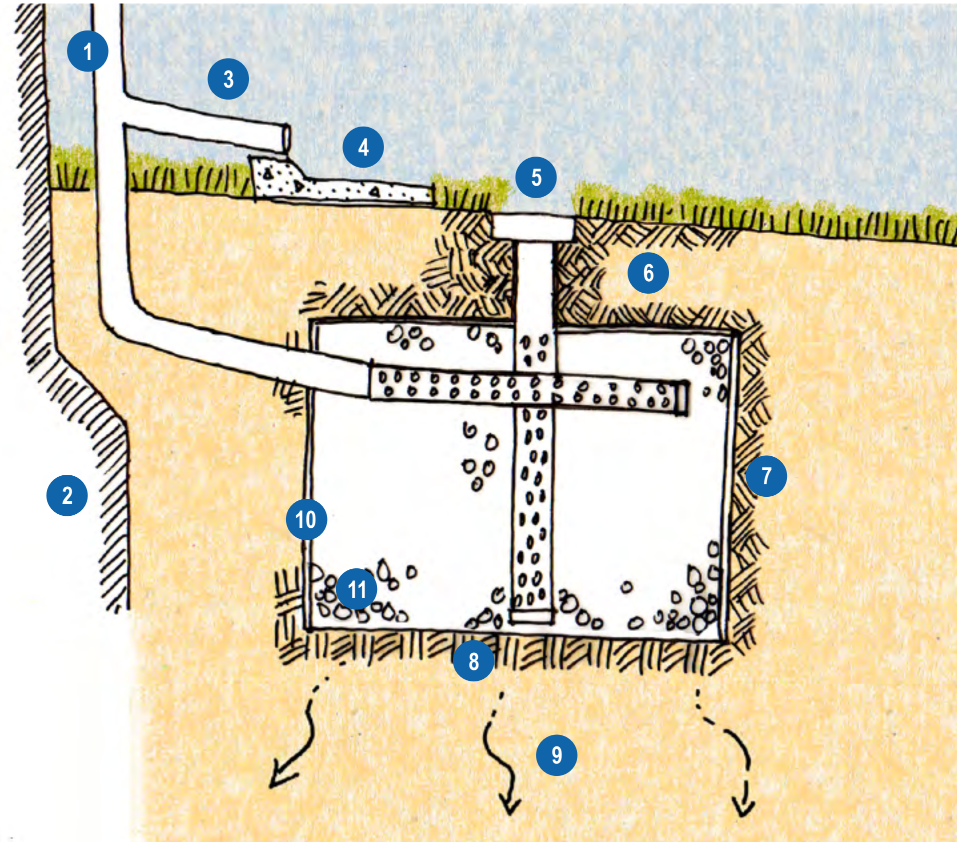
Subsurface Infiltration System

Also known as: dry well, stormwater drainage well, stormwater injection well, infiltration gallery, seepage pit



Roof leader 1

Building foundation 2

Overflow pipe 3

Splash block 4

Observation well 5

1-foot soil cover typical 6

Minimum 2-foot depth 7

2 to 5-foot diameter typical 8

Minimum infiltration rate of 1/2-inch per hour 9

Non-woven geotextile fabric or well walls 10

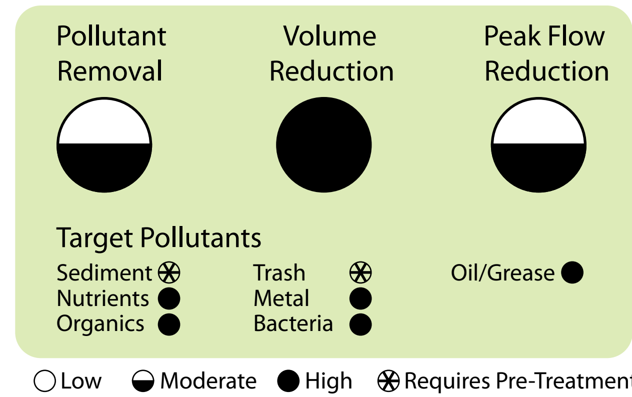
Coarse aggregate 11

Description

A subsurface infiltration system is an underground stormwater storage structure that receives inflow through sub-surface piping. All subsurface infiltration systems are considered Class V injection wells, defined by the U.S. Environmental Protection Agency (USEPA) as "any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (an infiltration system with piping to enhance infiltration capabilities)." Class V wells, and therefore all subsurface infiltration systems, must register with USEPA Region 9 (http://www.epa.gov/region09/water/groundwater/injection-wells-register.html) and submit an inventory form (http://www.epa.gov/region09/water/groundwater/uic-pdfs/7520-16.pdf).

There are two main types of subsurface infiltration systems:

- Gravel-filled systems consist of an excavated area filled with clean gravel (as described in the Materials section of this fact sheet). Small systems (typically a few feet in width) are known as dry wells; larger systems (typically 10 to 100 feet in width) are referred to as infiltration galleries.
- Open chamber systems allow greater storage volume than gravel-filled systems occupying the same footprint. Chambers can be concrete, metal, or plastic with perforated sides and bottom to allow infiltration. This type of system is typically used for small installations (e.g. dry wells).



Benefits

- Easy to install and cost effective.
- Reduces runoff volume and attenuates peak flows.
- Improves water quality if designed to remove fine sediment.
- Enhances groundwater recharge.
- Minimal space requirements: can be installed under outdoor programmed space.
- Visually unobtrusive.

Limitations

- Must have minimum soil infiltration rate of 0.5 inches per hour, so not appropriate for Hydrologic Soil Groups C and D (impermeable soils).
- May require a pre-treatment sediment control structure.
- If infiltration rates exceed 5 inches per hour, runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable in areas with contaminated groundwater or soils.
- Siting challenges in urban areas - can be only sited where free of underground utilities, structures, and within setbacks (see "Setbacks" in Siting section).

Siting

Subsurface infiltration systems are often used to manage stormwater runoff from roofs and parking lots. Systems that infiltrate runoff from roof downspouts are typically successful over the long term because roof runoff contains little sediment. Subsurface infiltration systems can be used in a variety of other applications, but pre-treatment is often required.

Drainage area: Small systems (e.g., dry wells) are recommended for small drainage areas with low pollutant loadings, such as rooftops less than 0.25 acres in size. Larger systems (e.g., infiltration galleries) may be sized to receive runoff from drainage areas typically up to 5 acres based on enhanced design considerations.

Setbacks: A discussion of setbacks and a table showing standard and conditional setback requirements are provided in *Appendix C: Criteria for Infiltration-based BMPs*.

Soils and infiltration rate: Subsurface infiltration systems can be implemented where infiltration rates are 0.5 inches per hour or greater. However, if the field-tested infiltration rate exceeds 5 inches per hour, then runoff should be fully treated (i.e., with one or more upstream BMPs or by installing 18 inches of sand meeting ASTM C33 at the base of the facility) before infiltration to protect groundwater quality. Geotechnical reports should also be used to determine how stormwater runoff will move in the soil (horizontally and vertically), and whether there are any geological conditions that could inhibit the movement of water. As a general rule, native soils should not have more than 30 percent clay content or 40 percent clay and silt combined. If they do, it may be necessary to choose a different BMP that does not rely on infiltration.

Groundwater protection: Because these systems facilitate infiltration, the potential for groundwater contamination must be carefully evaluated. There should be a minimum vertical separation of 4 or 10 feet, depending on location, from the facility bottom to the seasonally-high groundwater elevations to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* for more information on this requirement) and depth to bedrock should be at least 4 feet from the facility bottom. They are also unsuitable for sites that use or store chemicals or hazardous materials, unless those materials can effectively be prevented from entering the infiltration system. If this cannot be accomplished, other BMPs that do not allow interaction with the groundwater should be considered.

Installation of a pre-cast drywell, note the holes to allow stormwater infiltration. Photo: Lake George Association

Design Considerations

Materials: Gravel-filled subsurface infiltration systems should be filled with double-washed locally available rock with a diameter range of ¾ to 3 inches (ASTM No. 57, 2, or 3, etc.). To minimize sedimentation from lateral soil movement, the sides and top of the gravel matrix can be lined with a permeable filter fabric. The bottom of the subsurface infiltration system should remain open to maximize infiltration, unless otherwise required by a civil engineer.

Pre-Treatment: Sediment and trash accumulation can markedly shorten the operating life of the system, requiring more frequent, large-scale rehabilitation. In areas with high sediment loads (e.g. roads, driveways, or other at-grade surfaces), runoff must pass through an approved stormwater pretreatment measure to remove coarse sediment that can clog the void spaces between the stones and render the system ineffective. See the Pretreatment section of this appendix for a description of selected pretreatment BMPs.

Overflow and Access: Subsurface infiltration systems should be constructed to operate offline, allowing 0flows that exceed storage capacity to bypass the system through an overflow pipe routed directly to the collection system or another downstream BMP. Offline systems also allow access and maintenance during wet seasons if required. Where possible, they should have a perforated observation well or vertical standpipe through which the facility can be pumped out. The observation well will also allow inspectors access to monitor the drawdown rate and the overall performance of the facility.

Sizing: Subsurface infiltration systems can be sized using the BMP Sizing Calculators, which are hosted on the SFPUC website at www.sfwater.org/smr. Systems should have a minimum depth of 2 feet, typically with at least one foot of soil cover on top. The system should be designed to drain within 48 hours.

Inspection and Maintenance

Subsurface infiltration system longevity can be increased by careful geotechnical evaluation prior to construction, and by designing and implementing an inspection and maintenance plan. They should only be constructed after the entire area draining to the facility has been stabilized. During construction, care should be taken to divert sediment-laden runoff away from the system. Good construction practices should be used to minimize over-compaction, sediment generation, and smearing. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Subsurface Infiltration Systems	
Activity	*Schedule*
Check observation wells 48 hours after the end of a wet weather event. Failure to drain within this time period indicates clogging.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Post-construction and semi-annually (beginning and end of rainy season)
Check structural and operational integrity of subsurface infiltration system, including access lid or hatch, access ladder, and other major components.	Post-construction and semi-annually (beginning and end of rainy season)
Ensure that pretreatment devices are online and operable.	Post-construction and semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Subsurface Infiltration Systems	
Activity	*Schedule*
Remove sediment and oil / grease from pretreatment devices and overflow structures.	Semi-annually or as needed
If subsurface infiltration system has not drained within 24-48 hours after end of a wet weather event, drain system via pumping, clean perforated piping and gravel media, and excavate soil walls of unlined subsurface infiltration system to expose clean soil (typically 2 inches).	Upon failure (expected to be > 10 years)
Remove visible contaminants, debris, and trash from inlets and outlets to avoid clogging.	Semi-annually (beginning and end of rainy season)

References and Resources

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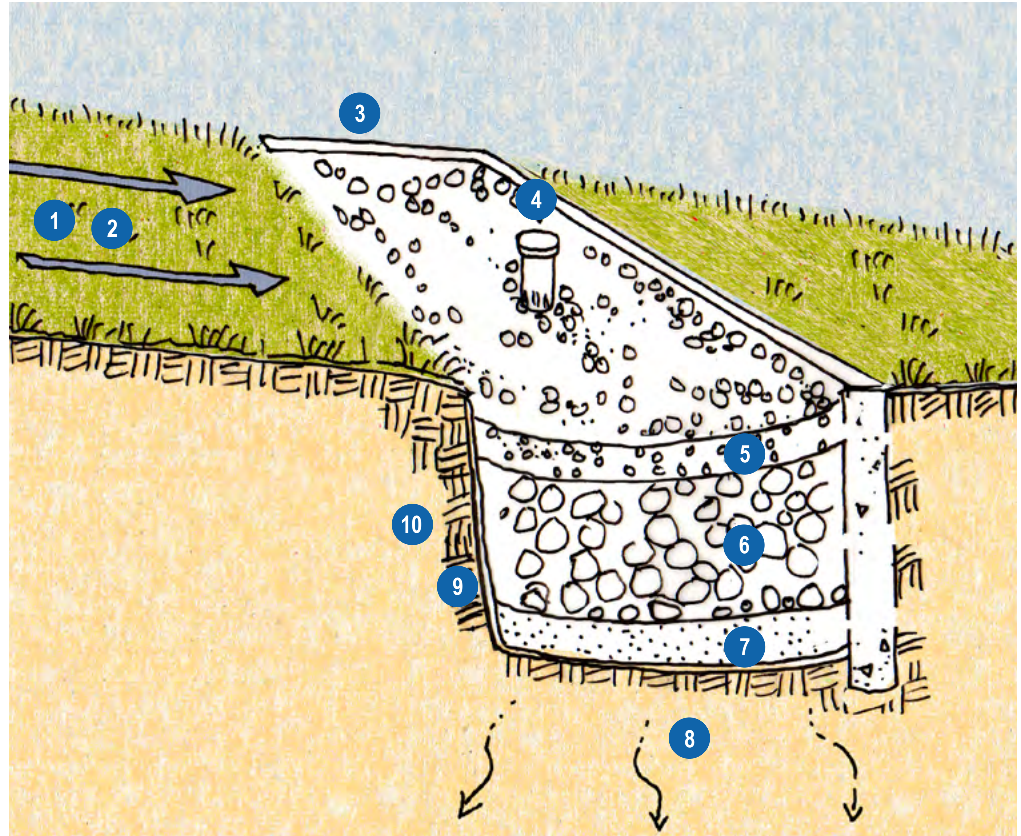
Subsurface Infiltration System

Infiltration Trench

Also known as: soakage trench

- Pre-treatment required to limit clogging 1
- Surface flow 2
- 25-foot maximum trench width 3
- Observation well 4
- Pea gravel surface 5
- Coarse aggregate 6
- 6-inch sand filter 7
- Minimum infiltration rate of 1/2-inch per hour 8
- Optional filter fabric 9
- 3- to 8-foot trench depth 10



Description

An infiltration trench is an unvegetated, rock-filled trench that receives surface stormwater runoff and allows it to infiltrate. Infiltration trenches are typically designed with no outlet other than a high-elevation overflow. Before entering the trench, runoff should pass through stormwater pretreatment measures to remove coarse sediment that can clog the void spaces between the stones and render the trench ineffective. Pretreated runoff is stored in the void spaces and slowly filters through the bottom of the trench into the soil matrix, thus contributing to groundwater recharge.

Infiltration trenches perform well for removal of fine sediment and associated pollutants. As with any infiltration BMP, the potential for groundwater contamination must be assessed.

Pollutant Removal	Volume Reduction	Peak Flow Reduction
●	●	●

Target Pollutants

Sediment	○ ⊛	Trash	○ ⊛	Oil/Grease	●
Nutrients	●	Metal	●		
Organics	●	Bacteria	●		

○ Low ◒ Moderate ● High ⊛ Requires Pre-Treatment

Benefits

- Improves water quality by removing sediment, nutrients, organic matter, and trace metals.
- Reduces runoff volume and attenuates peak flows.
- Improves urban hydrology and facilitates groundwater recharge.
- Low construction and maintenance costs.

Limitations

- Suitable for drainage areas of approximately 1 acre or less.
- Must have minimum soil infiltration rate of 0.5 inches per hour, not appropriate for Hydrologic Soil Types C and D (impermeable soils).
- If native soil infiltration rates exceed 5 inches per hour, runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites, steep slopes, contaminated soils, industrial sites, or sites where spills are likely to occur.
- Siting challenges in urban areas – can be only sited where free of underground utilities, structures, and within setbacks (see "Setbacks" in Siting section).

This infiltration trench doubles as a parking strip along the Sustainable Streetscapes and Fish Habitat Enhancement Project: Crown Street, Vancouver, British Columbia. Photo: Rosey Jencks

Siting

Drainage area: Infiltration trenches are most successful when used for relatively small drainage areas, typically less than 1 acre. These areas can have high impervious cover.

Soils and infiltration rate: Infiltration trenches can be implemented where infiltration rates are 0.5 inches per hour or greater. However, if the field-tested infiltration rates are greater than 5 inches per hour, runoff should be fully treated (e.g., with one or more upstream BMPs or by providing 18 inches of sand meeting ASTM C33 at the base of the facility) prior to infiltration to protect groundwater quality. Infiltration rates can be determined through geotechnical investigations. Geotechnical reports should also be used to determine how stormwater runoff will move in the soil (horizontally and vertically), and whether there are any geological conditions that could inhibit the movement of water. As a general rule, native soils should not have more than 30 percent clay content or 40 percent clay and silt combined. If they do, it may be necessary to choose a different BMP that does not rely on infiltration.

Setbacks: A discussion of setbacks and a table showing standard and conditional setback requirements are provided in *Appendix C: Criteria for Infiltration-based BMPs*.

Groundwater protection: There should be a minimum vertical separation of 4 or 10 feet, depending on location, from the facility bottom to the seasonally high groundwater elevation to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* for more information about this requirement) and depth to bedrock should be at least 4 feet from the facility bottom. If hazardous materials and other harmful substances are stored or used within the contributing drainage area, an infiltration trench should not be used unless these materials can be effectively prevented from entering stormwater draining to the trench. If this cannot be accomplished, other BMPs that do not allow interaction with the groundwater should be considered.

Design Considerations

Materials and Dimensions: Infiltration trenches are generally between 3 and 8 feet deep and typically not more than 25 feet wide. They should have a flat surface and bottom to promote uniform infiltration across the trench. The top two inches should be a pea gravel filter layer. Trench fill material should be double washed locally available rock with a diameter range of 3/4 to 3inches and a porosity of about 35 percent (ASTM No. 57, 2, or 3). To avoid classification as a Class V injection well (as are all subsurface infiltration systems), all inflows should be from surface runoff; there should be no subsurface piping in an infiltration trench other than a cleanout/observation well. The sides of the trench can be lined with filter fabric to prevent adjacent soils from clogging the rock.

Pretreatment: Pretreatment measures to remove coarse sediment, oils, and greases before runoff reaches the infiltration trench are critical to prevent clogging and failure. The upstream drainage should be completely stabilized before the trench is constructed, and construction techniques should minimize compaction of trench bottom. See the Pretreatment section of this appendix for a description of selected pretreatment BMPs.

Overflow and Access: Infiltration trenches should be designed to operate offline, such that only design flows are directed to the trench and the remainder is directed to the collection system. Where possible, infiltration trenches should have a drainage mechanism, such as a perforated observation well or vertical standpipe through which the facility can be pumped out in case of clogging. The observation well will also allow inspectors access to monitor the drawdown rate and the overall performance of the facility.

Sizing: Infiltration trenches can be sized using the BMP Sizing Calculators, which are hosted on the SFPUC website at www.sfwater.org/smr. The system should be designed to drain within 48 hours.

An infiltration trench along a roadway in Lino Lakes, MN.
Photo: Minnesota Pollution Control Agency

Inspection and Maintenance

Proper soil conditions, sufficient pretreatment measures, and well-designed inspection and maintenance programs are the key to implementing successful and long-lasting infiltration trenches. These maintenance-reducing features should be incorporated into infiltration trenches and, as with all BMPs, infiltration trenches should have a direct access path for maintenance activities. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Infiltration Trench

Activity	*Schedule*
Check observation wells 48 hours after the end of a wet weather event. Failure to drain within this time period indicates clogging.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Post-construction and semi-annually (beginning and end of rainy season)
Confirm that cap of observation well is in place and sealed.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Infiltration Trench	
Activity	*Schedule*
Remove sediment and oil / grease from pretreatment devices and overflow structures.	As needed
Replace gravel when clogged.	As needed
Rehabilitate trench to original storage capacity and 24-48-hour drain rate by removing trench rock, tilling the bottom of the trench, and replacing the bottom layer of sand.	Upon failure
Remove visible contaminants, debris, and trash from inlets and outlets to avoid clogging.	Semi-annually (beginning and end of rainy season)
Repair any erosion within the facility or surrounding areas.	Annually

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Media Filter

Also known as: organic media filter, sorptive media filter, compost stormwater filter, peat filter, resin filter, sand filter, cartridge filter

Inlet 1

Temporary ponding level 2

Permanent pool level 3

Access grates 4

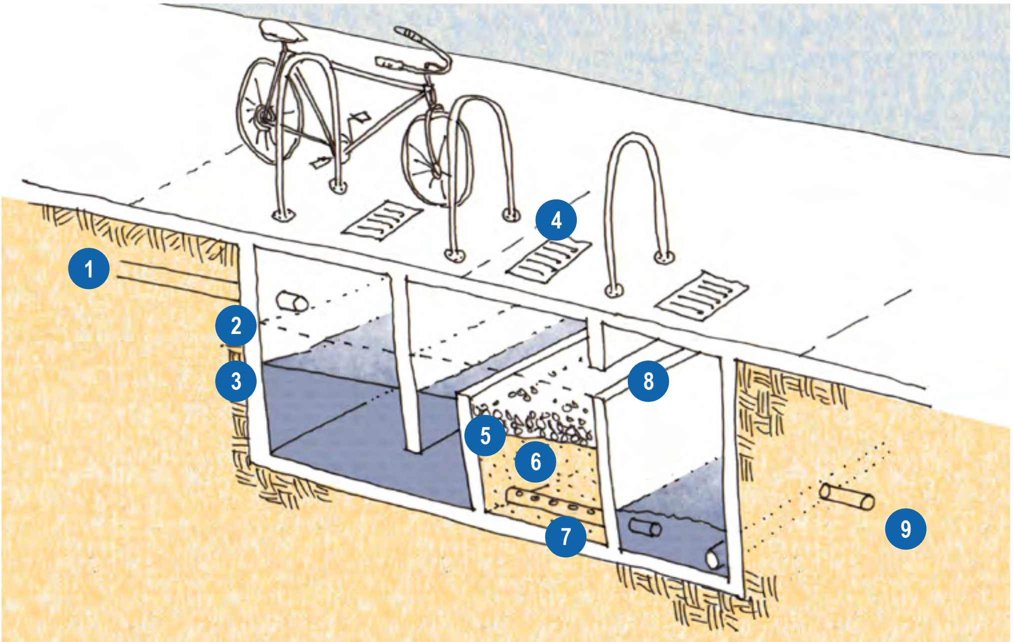
Gravel bed 5

Sand bed 6

Perforated underdrain 7

Overflow 8

Outlet pipe 9



Description

Media filters detain and treat stormwater via filtration and adsorption of pollutants to the filter media. Filter media can be sand, organic materials such as compost and peat, or inorganic mineral materials such as iron-amended resin, activated carbon, and zeolite.

Media filters containing sand are generally two-chambered treatment devices consisting of a pretreatment sedimentation area to remove larger solids and a filtration area to remove fine solids, metals, organics, and some bacteria. Media filters are estimated to remove 80 percent of total suspended solids, 50 percent of total phosphorus, 25 percent of total nitrogen, 40 percent of fecal coliform, and 50 percent of heavy metals from typical stormwater runoff.

Media filters containing both organic and mineral filtration materials generally have greater ion exchange capacity than sand media filters and therefore can more effectively remove soluble metals and other dissolved pollutants. This makes media filters particularly effective for roadways and highly industrial sites that produce higher concentrations of metals in stormwater runoff, particularly zinc and copper. These filters have been shown to consistently remove over 85 percent of oil and grease, 82 percent of heavy metals, and around 40 percent of total phosphorus. A range of proprietary media filters of this type are available (e.g., Aqua-Filter Stormwater Filtration System, Contech's StormFilter, BayFilter, etc.).[1]

Any media filter proposed for use in a San Francisco project must be certified by the Washington State Technical Assistance Protocol – Ecology (TAPE) program and meet additional requirements as dictated by the SFPUC or Port. A list of proprietary media filters currently holding TAPE certification can be obtained from the Washington Department of Ecology's website at http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html.

Media filters can be designed as either flow-based or volume-based treatment devices. Volume-based filters are designed with storage to completely capture the design volume and then filter it through the media within a desired drawdown time (typically 48 hours). Flow-based filters are designed with filtration rates that are sufficient to treat the design flow rate without requiring storage. Flow-based designs require the use of specialized media with very high hydraulic conductivities, and, therefore, flow-based designs are typically only used in proprietary media filters.

1 Examples are provided for reference only and do not represent an endorsement of these or any other proprietary product.

Pollutant Removal	Volume Reduction	Peak Flow Reduction
●	○	◒

Target Pollutants

Sediment	●	Trash	●	Oil/Grease	●
Nutrients	◒	Metal	●		
Organics	◒	Bacteria	●		

○ Low ◒ Moderate ● High ⊛ Requires Pre-Treatment

Tree box filters

Tree box filters are a type of media filter in which runoff is directed to a tree box, where it is cleaned by vegetation and high-rate filter material composed of an engineered soil medium before entering a catch basin. In separate sewer area projects, stormwater treatment provided by tree box filters is considered equivalent to that of media filters. Tree box filters require SFPUC or Port approval to be implemented at sites that demonstrate other BMPs are infeasible using the Separate Sewer Area BMP Selection Form (available at www.sfwater.org/smr). Tree box filters are not intended for use in the combined sewer area, as they do not contribute to meeting performance requirements.

Benefits

- Effective removal of suspended solids, oil and grease, and debris.
- Effective removal of dissolved stormwater pollutants (organic and mineral media filters only); certain types of media may target specific pollutants if desired.
- Applicable in most soil types, appropriate in areas with poor infiltration.
- Easily customizable to varying site size and dimension constraints.
- Readily available materials (sand filters).

Limitations

- Minimal stormwater volume reduction, some peak flow attenuation.
- Requires flat site and sufficient hydraulic gradient to support gravity flow.
- Limited ability to remove dissolved pollutants, such as soluble metals (e.g., copper and zinc) (sand filters).
- Provides low to moderate level of nitrogen removal and may increase nitrate levels.
- Potential need for costly maintenance activities and servicing programs.

Siting

As a high-rate treatment BMP, media filters are not effective at reducing runoff volumes and peak flows to meet the combined sewer area performance requirements. In separate sewer areas, they may only be used for compliance at sites at which other BMPs are demonstrated to be infeasible using the Separate Sewer Area BMP Selection Form (available at www.sfwater.org/smr). *Chapter 6: Separate Sewer Area Performance Requirements* provides more information about BMP selection requirements in separate sewer areas.

Drainage area and slope: The maximum drainage area treated by media filters is typically 5 acres. Media filters are best-suited for relatively flat sites (less than 5 percent slope) but must have sufficient hydraulic head (3 to 5 feet) to allow runoff to flow through the filter. The scale of the filter may affect its functionality; large-scale, sand-based systems may provide some detention, while subsurface cartridge filters can be more easily integrated into a dense urban environment as flow-through treatment facilities.

Design Considerations

Materials: Non-proprietary media filters typically include 18 to 24 inches of filter medium above a 12-inch gravel underdrain layer. In peat systems, the filter medium generally includes an upper layer high in organic content, an intermediate layer of peat mixed with sand, and a lower layer composed primarily of sand. Compost filters typically consist of an 18-inch layer of mixed compost material. These organic media have a high cation exchange capacity, which helps capture dissolved constituents. For inorganic media filters other than sand, most products are proprietary and come with manufacturer instructions to guide design considerations.

Pretreatment: As with other filtration systems, sediment will accumulate on the media surface, thus slowing the filtration capacity of the filter over time. To reduce maintenance frequency and extend the life of the filter, the filter chamber should be preceded by pretreatment devices to remove trash, suspended particles, oil, and grease. See the Pretreatment section of this appendix for a description of selected pretreatment BMPs.

Drainage: Media filters can connect directly to the collection system or can provide pretreatment for detention or storage BMPs.

Media filter media can be customized to target specific pollutants. Photo: Contech

Media filter installation. Photo: Storm Water Solutions

Overflow: Media filters may be designed as online or offline devices however, when in the right-of-way, the SFPUC may request an offline configuration. In the online configuration, all flows from the contributing drainage area are routed to the media filter. Flows greater than the design event are captured by an overflow device and conveyed back to the collection system. In the offline configuration, only the volume or flow treatable by the filter is diverted into the device; all excess flows are directed to the collection system. This configuration limits exposure to large storm events and erosive flows, which can shorten the effective life of the filter media. In areas with flow control requirements, it may be preferable to design media filters as offline devices and direct larger flows to detention or infiltration BMPs, such as detention vaults or ponds and constructed wetlands.

Sizing: If a media filter is approved for use at a site by the SFPUC or Port, the maximum allowed design filtration rate is 10 inches per hour for vegetated systems and 1 gallon per minute per square foot for non-vegetated systems (e.g., cartridge filters). When sizing the filter area, the design flow rate is based on a rainfall intensity of 0.24 inches per hour in SFPUC areas and 0.2 inches per hour in Port areas. The design flow rate is equal to the rainfall intensity times the contributing drainage area times the percent imperviousness of the drainage area. The treatment capacity of the flow-based media filter should be greater than or equal to the design flowrate of the contributing drainage area. It is highly recommended that the manufacturer be contacted directly and that their instructions be used to size proprietary flow-based media filters. Media filters can be sized using the Separate Sewer Area BMP Sizing Calculator, which is hosted on the SFPUC website at www.sfwater.org/smr.

Inspection and Maintenance

Typical maintenance of media filters involves replacing the top 2 to 3 inches of media every few years and cleaning out the sediment from the sedimentation chamber. This sediment is removed and disposed of in a manner similar to street catch basin maintenance. Maintenance for proprietary media filter systems is defined by the manufacturer. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Media Filters

Activity	*Schedule*
Check that the filter surface is not clogged and that the filter is draining within the design drawdown time (typically 24-48 hours).	Post-construction and semi-annually (beginning and end of rainy season)
Check that the storage chamber does not leak when standing water is present.	Post-construction and semi-annually (beginning and end of rainy season)
Check to ensure that filter bed is clean of debris and that sediment storage zone in sedimentation chamber is not more than 6 inches deep or 50 percent full.	Annually
Inspect grates, inlets, outlets, and overflow spillways for clogging, erosion, cracking, or water damage.	Annually
Check structural and operational integrity of vault, access lid or hatch, access ladder, and other major components.	Post-construction and semi-annually (beginning and end of rainy season)
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

Typical Maintenance Activities for Media Filters	
Activity	*Schedule*
Remove trash and debris from inlet, outlet, sedimentation chamber, filter bed, and overflow devices to prevent clogging.	Semi-annually (beginning and end of rainy season)
Remove sediment from sedimentation chamber when depth exceeds 6 inches or 50 percent of storage capacity.	Annually or as needed
Repair or replace damaged or clogged parts of filter membrane or cartridge.	As needed
If water fails to drain after 48 hours, clean or replace clogged filter media.	As needed (expected to be >3 years)
Properly dispose of contaminated or saturated sediment, cartridges, or membranes after cleaning - may require special disposal if contains metals, pathogens, or trace organic compounds.	As needed (expected to be >3 years)
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional maintenance activities.	As needed

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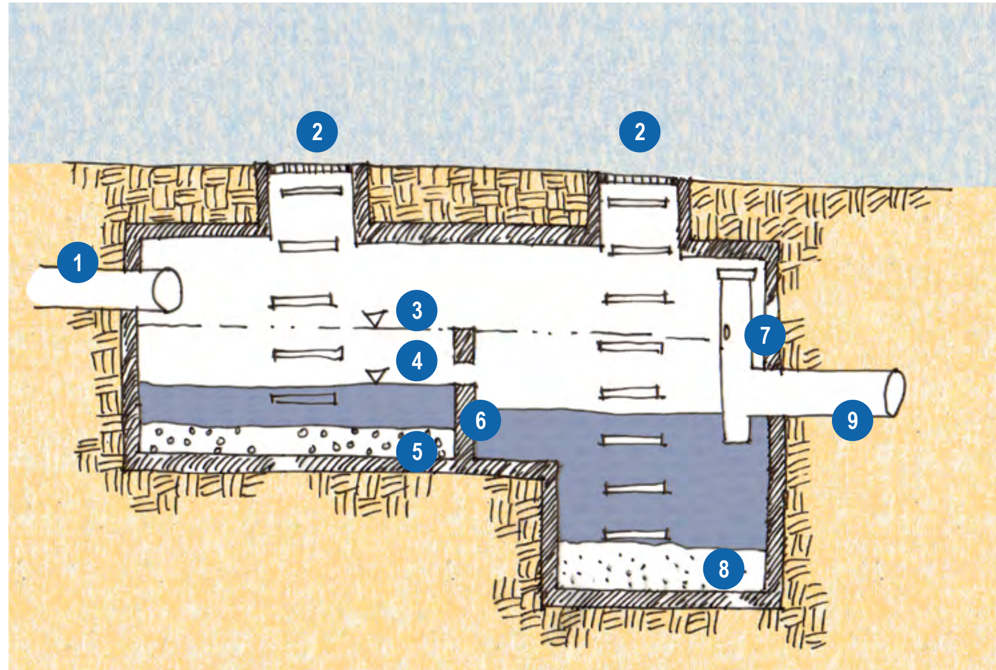
Detention Tank

Also known as: detention vault, detention pipe

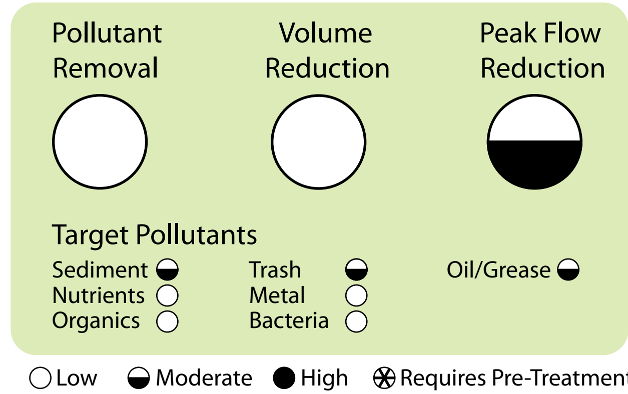


- Inlet 1
- Maintenance access and ladders 2
- Live storage 3
- Permanent pool 4
- Coarse sediment 5
- Baffle at 25 to 50% of volume 6
- Flow restrictor sized to drain in 48 hours 7
- Fine sediment 8
- Outflow to collection system 9

Description

A detention tank, which could also be designed as a vault or pipe, is typically an underground stormwater storage facility designed to accommodate a volume of water temporarily so as to reduce peak flows. Inflow can come from a drain grate located at the ground surface or from a subsurface storm drain pipe. A manhole with a sump or manufactured debris separator should also be installed immediately upstream of the detention tank to control inflow and capture grit and larger sediment. Only slight, if any, removal of nutrients, metals, and organic pollutants is typically achieved.

A flow restrictor at the downstream end of a system limits outflow, causing runoff to be temporarily "stored" in the detention tank. For extended detention, the flow restrictor at the outlet is designed to release water over the course of 48 hours following the end of each storm. A detention tank bottom is typically at least 0.5 feet below the outlet to provide dead storage for sediment.



Benefits

- Reduces flooding and peak flow rate.
- Simple and reasonable cost-effective solution for detention.
- Few space limitations: can be placed underground in most areas.
- Appropriate for areas that are unsuitable for infiltration.
- Versatile: wide variety of appropriate scales and locations.
- Minimal long-term maintenance requirements.

Limitations

- Detention tanks, alone, will not meet separate sewer area performance requirements.
- Potential for high excavation and installation costs in dense urban areas.
- Minimal water quality treatment achieved.
- Single purpose: no ecological or aesthetic benefits.
- Tank must be large enough to meet minimum confined space entry requirements set by the Occupation Safety and Health Administration.

Siting

Detention tanks can be sized to treat any drainage area, but they are most practical for drainage areas less than 10 acres. They are typically constructed of structural reinforced concrete and are designed for H-20 traffic loading, which enables them to be installed beneath streets and parking lots. Because they are underground, they may be expensive to install, especially in existing built areas. However, detention tanks can detain a significant volume of stormwater, more so than many other BMPs.

Construction of an underground stormwater detention basin beneath the City Hall parking lot in downtown Oshkosh, Wisconsin. Photo: Precast-Prestressed Concrete Institute

Detention tanks may be used to meet peak flow reduction requirements in the combined sewer area. However, they may not be used for compliance with the separate sewer area performance requirements.

Design Considerations

Dimensions: Detention tanks are usually rectangular with a length to width ratio of 2:1 or greater; however, some are circular. Detention systems that are pipes are typically greater than 3 feet in diameter. Detention systems that are vaults are usually greater than 7 feet in internal height and typically range from 4 to 10 feet in width, but these dimensions can vary significantly based on site conditions, project resources, and design intent. Manhole covers over the inlet and outlet of a vault allow entry for maintenance. Detention vault floors should be sloped at least 5 percent from the edges towards the center axis, as well as sloped longitudinally towards the inlet to facilitate sediment removal. Inlets and outlets should be placed at opposite corners of the vault to maximize the flow path length.

Pretreatment: Detention tanks should be designed with pretreatment to prevent clogging and minimize maintenance. See the Pretreatment section of this appendix for a description of selected pretreatment BMPs.

Flow Configuration: Detention tanks can be designed as offline or online devices. In the offline configuration, only flows less than or equal to the design treatment capacity are directed to the vault. In the online configuration, all flows are routed to the device, but the tanks typically contain an internal bypass to direct high flows around the sedimentation area. This helps to prevent re-suspension of settled sediment. Designs often include baffles and peak flow bypasses to improve retention of solids and floatables.

Sizing: Detention tanks can be sized using the Combined Sewer Area BMP Sizing Calculator, which is hosted on the SFPUC website at www.sfwater.org/smr.

Inspection and Maintenance

Detention tanks should be inspected for debris, sediment, and petroleum product accumulation twice during the first wet season of operation following construction. Results of these inspections should be used to establish an annual inspection and maintenance schedule. Because accumulated sediment reduces the available detention volume over time, removal of accumulated material with a vactor truck may be required every one to two years. Floatables may need to be removed separately due to the presence of petroleum products. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Detention Tanks	
Activity	*Schedule*
Inspect vault twice during first wet season of operation, setting cleaning frequency accordingly.	Post-construction
Inspect for cracks, inlet or outlet area erosion, and clogging.	Semi-annually
Check to ensure pretreatment devices are online and working properly.	Annually
Check structural and operational integrity of vault, access lid or hatch, access ladder, and other major components.	Post-construction and semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Detention Tanks	
Activity	*Schedule*
Remove litter, oil, and grease from inlet and outlet areas.	Semi-annually (beginning and end of rainy season)
Remove accumulated sediment when the 0.5 to 1-ft deep sediment storage zone is full – may require special disposal if sediment contains metals or trace organic compounds.	Bi-annually or as needed
Remove trash and debris from inlet, outlet, and overflow devices to prevent clogging.	Semi-annually (beginning and end of rainy season)

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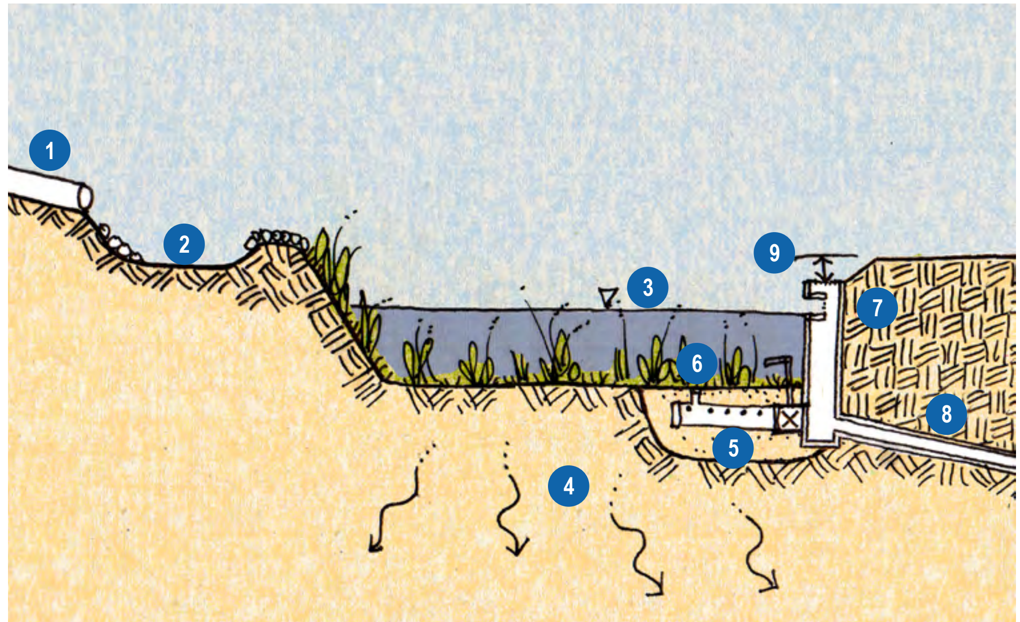
BMPs Appropriate for Multi-Parcel Projects

Infiltration Basin

Also known as: soakage basin, infiltration pond

1. Inlet
2. Forebay (pretreatment and energy dissipation)
3. Design volume level
4. Minimum infiltration rate of 1/2-inch per hour
5. Underdrain with shut-off valve (for maintenance if bottom clogs)
6. Underdrain cleanout
7. Overflow structure with screened inlets
8. Outlet to collection system, catch basin, or receiving water
9. Minimum 1 foot freeboard



Description

An infiltration basin is a shallow impoundment over permeable soil that captures stormwater, stores it, and allows it to infiltrate. This practice has a high removal efficiency for fine sediment and associated pollutants. However, sediment and oils will plug the basin and should be removed using appropriate pretreatment practices, such as conveyance swales, before runoff reaches the basin. A forebay at the entrance to the basin will also extend the basin's longevity and reduce maintenance costs. In addition to reducing stormwater volumes and flows, infiltration basins also help recharge groundwater. As with any infiltration BMP, the potential for groundwater contamination must be carefully considered, especially if groundwater is used for human consumption or agricultural purposes. In addition to stormwater management, if designed properly infiltration basins can provide recreational, wildlife habitat, and aesthetic benefits.

Pollutant Removal	Volume Reduction	Peak Flow Reduction
●	●	●

Target Pollutants

Sediment	○ ⊛	Trash	○ ⊛	Oil/Grease	●
Nutrients	●	Metal	●		
Organics	●	Bacteria	●		

○ Low ◒ Moderate ● High ⊛ Requires Pre-Treatment

Benefits

- Improves water quality by removing sediment, nutrients, organic matter, and trace metals.
- Reduces runoff volume and attenuates peak flows.
- Improves urban hydrology and facilitates groundwater recharge.
- Creates habitat and increases biodiversity in the city.
- Can provide open space, aesthetic, and recreational amenities.
- Can function as regional facility managing large volumes of water.
- Low construction and maintenance costs.

Limitations

- Must have minimum soil infiltration rate of 0.5 inches per hour, not appropriate for Hydrologic Soil Groups C and D (impermeable soils).
- If native soil infiltration rates exceed 5 inches per hour, runoff should be fully treated prior to infiltration to protect groundwater quality.
- 4- to 10-foot minimum vertical separation from basin bottom to seasonally-high groundwater is required, depending on location (see *Appendix C: Criteria for Infiltration-based BMPs* for more detailed information on this requirement).
- Depth to bedrock must be over 4 feet from the basin bottom.
- Not suitable on fill sites, steep slopes, contaminated groundwater or soils, industrial sites, or sites where spills are likely to occur.
- Site must have no risk of land slippage if soils are heavily saturated.
- Must be sited with sufficient distance from existing foundations, roads, subsurface infrastructure, drinking water wells, septic tanks, and drain fields (see “Setbacks” in Siting section).

An infiltration basin in Waterworks Gardens at the King County East Division Reclamation Plant, Renton, WA, is part of an environmental art park that treats stormwater. Runoff flows through stormwater treatment ponds, and the wetlands form an earth/water sculpture that funnels, captures and releases water. *Photo: Rosey Jencks*

Siting

Because of their large size relative to many other BMP types, infiltration basins in San Francisco are best suited for projects on large sites, such as parks and open spaces, industrial parcels, and multi-parcel projects. Other siting considerations for infiltration basins are essentially the same as those for infiltration trenches, with the exception of larger drainage area limitations.

Drainage area: Infiltration basins are best suited to drainage areas that are less than 10 acres. To reduce sediment loading and potential for clogging, infiltration basins are likely to perform better if designed exclusively for treatment requirements, rather than as dual stormwater treatment and volume-control facilities.

Soils and infiltration rate: Infiltration basins can be implemented where the native soil infiltration rates of native soils are 0.5 inches per hour or greater. However, if field-tested infiltration rates are greater than 5 inches per hour, runoff should be fully treated (e.g., with one or more upstream BMPs or by including 18 inches of sand meeting ASTM C33 beneath the facility) prior to infiltration to protect groundwater quality. Infiltration rates can be determined through geotechnical investigations. Geotechnical reports must be used to determine how stormwater runoff will move in the soil (horizontally and vertically), and whether there are any geological conditions that could inhibit the movement of water. As a general rule, soils should not have more than 30 percent clay content or 40 percent clay and silt combined. If they do, it may be necessary to choose a different BMP that does not rely on infiltration.

Setbacks: A discussion of setbacks and a table showing standard and conditional setback requirements are provided in *Appendix C: Criteria for Infiltration-based BMPs*

Groundwater protection: There should be a minimum vertical separation of 4 or 10 feet, depending on location, from the facility bottom to the seasonally-high groundwater elevations to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* for more information on this requirement) and depth to bedrock should be at least 4 feet from the facility bottom. If hazardous materials and other harmful substances are stored or used within the contributing drainage area, an infiltration basin should not be used unless these materials can be effectively prevented from entering stormwater draining to the basin. If this cannot be accomplished, other BMPs that do not allow interaction with the groundwater should be considered.

Design Considerations

Dimensions: Infiltration basins are generally between 1 and 3 feet deep with earthen side slopes no steeper than 3:1 (horizontal:vertical) to provide bank stability and allow for maintenance access. The bottom of the basin should be graded as flat as possible to provide uniform ponding and infiltration across the basin bottom.

Vegetation: A key feature of an infiltration basin is its vegetation. Deep-rooted plants on the basin bottom reduce the risk of clogging by increasing the infiltration capacity. Dense vegetation also impedes soil erosion and scouring of the basin floor. Vegetation on the basin bottom and sides must be capable of surviving up to 48 hours under water, with a design drawdown of 24 hours or less being preferred. Native vegetation is preferred. See *Appendix D: Vegetation Palette for Bioretention BMPs* for a list of recommended vegetation.

Pretreatment: Pretreatment measures should be used to prevent clogging of the basin bottom if runoff is expected to contain heavy sediment loads or oils and greases. Conveyance swales and sediment forebays provide effective pretreatment, especially if implemented as a treatment train. The upstream drainage should be completely stabilized before the basin is constructed and construction techniques should minimize sedimentation and compaction of the basin bottom.

Online versus offline configuration: Infiltration basins can be constructed such that they operate offline (high flows bypass the basin) or online (all flows are directed to the infiltration basin). When basins are constructed online, an overflow structure must be included in the design to convey flows exceeding the basin capacity to the collection system.

Access: Infiltration basin design should emphasize accessibility and ease of maintenance. Where possible the basin should have a drain with a shutoff valve, which allows the basin to be drained and accessed for maintenance in the event that clogging or soil saturation occurs.

An infiltration basin at the Saint Francis Court Apartments in South Fairmount, Cincinnati is used to reduce the volume of stormwater that enters the sewer system. Photo: Gary Landers

Maintenance ensures continued performance throughout the life of the installation. *Photo: Ken Kortkamp*

Sizing: Because infiltration basins are typically used at sites that exceed the site area limitations of the BMP Sizing Calculators (subwatersheds less than 2 acres and sites less than 5 acres), the project proponent should use modeling or other approved methods indicated the SFPUC Accepted Hydrologic Calculation Methods supplement (available at www.sfwater.org/smr) for sizing. Infiltration basins should be designed with a drawdown time of 48 hours or less.

Inspection and Maintenance

Proper soil conditions, sufficient pretreatment measures, and well-designed inspection and maintenance programs are the key to implementing successful and long-lasting infiltration basins. As described above, maintenance reduction features should be incorporated into infiltration basins and, as with all BMPs, infiltration basins should have a direct access path for maintenance activities. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Infiltration Basins	
Activity	*Schedule*
Check for ponding 24-48 hours after the end of a wet weather event. Failure to percolate within this time period indicates clogging. Dead or dying grass is another indication of inadequate percolation.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Post-construction and semi-annually (beginning and end of rainy season)
Check for erosion and presence of burrows or other damage to side slopes and around invert.	Post-construction and semi-annually (beginning and end of rainy season)
Check for signs of petroleum hydrocarbon contamination.	Post-construction and semi-annually (beginning and end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Infiltration Basins	
Activity	*Schedule*
Maintain vegetation, provide weed control, and remove litter.	At least semi-annually
Remove sediment and oil / grease from pretreatment devices and overflow structures.	At least semi-annually
Till or aerate basin bottom when drain time exceeds 48 hours.	As needed
Prune vegetation obstructing line of site at roadway or intersection.	Quarterly
Stabilize eroded banks with erosion control mat or mulch and revegetate.	As needed
If petroleum hydrocarbon contamination identified, implement appropriate source control and pretreatment measures.	As needed
If clogging occurs, remove accumulated sediment and till or aerate bottom of basin. Avoid soil compaction during the process.	As needed
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed
Remove sediment from forebay when depth exceeds 6 inches or 50 percent of storage capacity.	As needed (expected frequency every 3 to 5 years)
Remove sediment when the pond volume has been reduced by 10 percent. This can be measured with a barrel thief or on a sediment gauge installed near the basin outlet.	As needed (expected frequency every 10 to 20 years)
Rehabilitate basin to original storage capacity and 24-48-hour drain time by excavating basin bottom to expose clean soil (typically 2 inches), aerating, replanting, and remulching.	Upon failure

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Detention Pond

Also known as: detention basin, dry pond, dry detention basin, extended detention basin

Inlet 1

Forebay (pretreatment and energy dissipation) 2

Design volume level 3

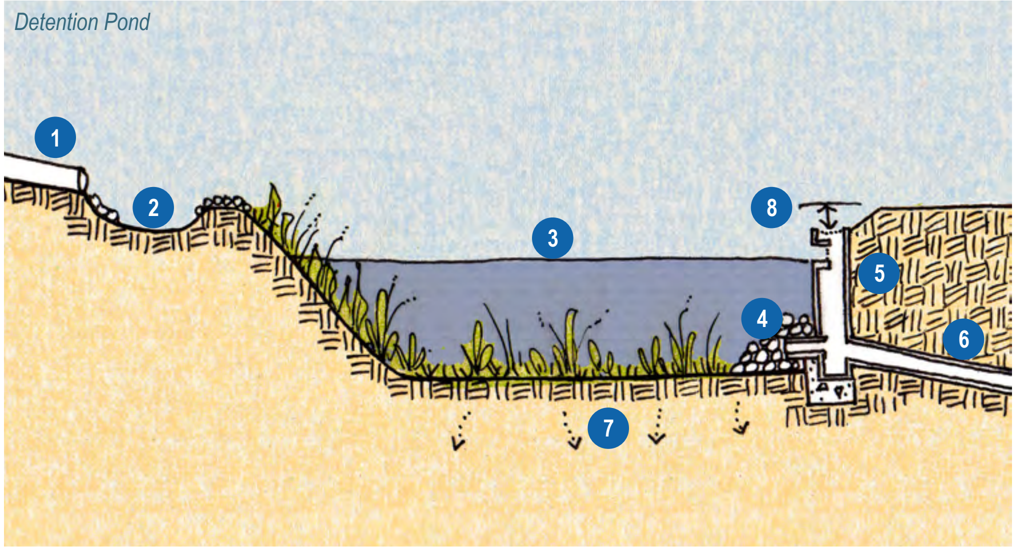
Primary outlet with sediment filter 4

Overflow structure with screened inlets 5

Outlet to collection system, catch basin, or receiving water 6

Infiltration where feasible 7

Minimum 1 foot freeboard 8



Description

Detention ponds are temporary holding areas for stormwater that store peak flows and slowly release them, lessening the demand on the sewer system during storm events and reducing flooding. Generally, detention ponds are designed to fill and empty within 48 hours of a storm event thereby reducing peak flows and runoff volumes. If designed with vegetation, ponds can also create wildlife habitat and improve air quality. They can also be used to provide flood control by including additional flood detention storage. Detention ponds are also known as "dry detention ponds" because unlike wet ponds, which are designed to have a permanent pool of water, they drain completely between storms.

In order to meet the definition of an "extended detention pond", the drawdown time for detention ponds should be 48 hours, with no more than 50 percent of the total volume draining in the first 16 hours. These drawdown requirements provide water quality benefits by allowing sediment particles to settle to the bottom of the pond. Another detention pond variation is the multi-purpose detention pond, which is only filled with water during storm events and can act as an open space such as a play area, dog park, or athletic field during dry weather. However, detention ponds – extended or otherwise – no longer meet the separate sewer areas performance requirements (see Siting section for more information).

Benefits

- Attenuates peak flows and may reduce runoff volume.
- Improves water quality by removing particulate matter and sediment.
- Removes trash and debris.
- Reduces flooding.
- Low construction and maintenance costs.
- Good for sites where infiltration is not an option.
- Creates habitat, increase biodiversity, and provides open space if designed as a multi-purpose detention pond.

Pollutant Removal	Volume Reduction	Peak Flow Reduction
◒	◒	●

Target Pollutants

Sediment ◒ ⊛	Trash ○ ⊛	Oil/Grease ◒
Nutrients ○	Metal ◒	
Organics ◒	Bacteria ◒	

○ Low ◒ Moderate ● High ⊛ Requires Pre-Treatment

Limitations

- Ineffective at removing soluble pollutants.
- 5-acre minimum drainage area (see Siting section for more details).
- Site must have no risk of land slippage if soils are heavily saturated.

A dry detention pond in the Algeurao Mem-Martins, located outside of Lisbon, Portugal, provides flood control during the short, wet season and serves as a neighborhood park with picnic tables, frequented by children riding bicycles and skateboards, during the rest of the year. Photo: Rosey Jencks

Detention ponds can take on a formal arrangement in a courtyard space such as this one. Photo: Rosey Jencks

A dry detention pond sited within a Children's play space in Augustenborg, Malmö/Sweden tests different methods of reducing and detaining peak stormwater flows while enhancing the neighborhood. Photo: Sharon Danks

Siting

Because of their large size relative to many other BMP types, detention ponds in San Francisco are best suited for projects on large sites, such as parks and open spaces, industrial parcels, and multi-parcel projects.

Detention Ponds may be used to meet peak flow reduction requirements in the combined sewer area. However, they may not be used for compliance with the separate sewer area performance requirements.

Drainage area and slope: Detention ponds should be used at sites with a minimum drainage area of 5 acres. It is generally more cost-effective to control larger drainage areas due to the economies of scale in pond construction. However, they can be used at smaller sites provided that the minimum outlet orifice diameter is at least 1 inch. The slope downstream of all types of detention ponds should not exceed 15 percent. The local slope in the immediate pond area should be relatively flat, however, in order to maintain reasonably flat side slopes.

Soils and infiltration rate: Detention ponds can be used on almost all soil types. In areas with rapidly infiltrating soils (over 5 inches per hour) such as coarse sands, runoff should be fully treated prior to infiltration. This can be achieved with upstream BMPs, a pretreatment system, or by including an 18-inch layer of sand meeting ASTM C33 at the base of the facility.

Setbacks: Unlined detention ponds must comply with setback requirements outlined in *Appendix C: Criteria for Infiltration-based BMPs.*

Groundwater protection: The base of the pond should not intersect the groundwater table to avoid creating a permanent pool where mosquitoes could breed. If infiltration is occurring, there should be a minimum vertical separation of 4 or 10 feet, depending on location, from the facility bottom to the seasonally-high groundwater elevations to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* for more information on this requirement) and depth to bedrock should be at least 4 feet from the facility bottom. If hazardous materials and other harmful substances are stored or used within the contributing drainage area, the detention pond should be lined unless these materials can be effectively prevented from draining to the pond.

Design Considerations

Dimensions: Detention ponds generally consist of a depressed area of land, or an area that is surrounded by earthen berms, where stormwater is stored during storm events. No minimum or maximum slope requirements for the pond bottom have been set; however, the slope should be flat enough in the direction of flow to maintain a low flow velocity, but with enough elevation drop to avoid stagnant water and ensure that flow can move through the system. A rock-lined channel from inlet to outlet, called a "pilot or low-flow channel," should be included to convey low flows through the pond. Detention ponds with earthen walls should have side slopes of 3:1 (horizontal:vertical) or gentler to minimize erosion and safety concerns and facilitate mowing. Detention ponds can also be hardscape architectural elements, in which case vertical walls are acceptable. Pond depths of 2 to 5 feet are considered optimal.

Vegetation: Vegetation within the detention zone (up to the elevation of the design storm) appears to increase pollutant removal and decrease resuspension of accumulated sediment. Plants selected for this zone should be able to withstand both wet and dry periods. Woody plants should only be used in areas above the elevation of the design storm, as they may cause accumulation of debris or block the flow path, thereby increasing the potential for standing water. If sufficient space is available, a vegetated buffer around the pond can be used to slow overland runoff entering via the side slopes and can help prevent access to the pond if desired. Refer to *Appendix D: Vegetation Palette for Bioretention BMPs* for a list of vegetation options.

Pretreatment: Pond maintenance is reduced when runoff passes through a forebay or sedimentation basin that allows coarse sediment particles to settle before reaching the main pond. The forebay is typically 10 percent of the detention basin volume.

Inlet structures: An energy dissipation structure should be included at the pond inlet to prevent erosion and resuspension of accumulated sediment. Stilling basins should not be used for this purpose because they create a pool of standing water where mosquitoes can breed.

In urban commercial centers, detention ponds serve as a visual amenity and natural oasis. Photo: Rosey Jencks

Next to a workplace or school, a detention pond can provide a place for relaxation and repose. Photo: Rosey Jencks

A detention pond can support water-loving plants, even in an urban setting. Photo: Rosey Jencks

Outlet structures: A typical detention pond outlet system includes an orifice that regulates the drawdown time of the pond (a 48-hour maximum drawdown time is required). An overflow weir or riser should be set at the elevation of the design storm. Additionally, online ponds must include a separate emergency weir or spillway to safely pass runoff from large flood events. A trash rack should be used to prevent clogging of outlet structures. The outlet should include a valve that can stop outflows from the pond in case of a spill in the watershed; this valve can be the same valve that is used to regulate pond drawdown time. Any outfall pipes greater than 48 inches in diameter must be fenced for safety. Finally, if the pond discharges to a natural waterway, the pond outfall should be stabilized to prevent erosion.

Access: A ramp and perimeter access to the main pond and sediment forebay should be included in the design of detention ponds to facilitate access for inspection and maintenance.

Sizing: Because detention ponds are typically used at sites that exceed the site area limitations of the BMP Sizing Calculators (subwatersheds less than 2 acres and sites less than 5 acres), the project proponent should use modeling or other approved methods indicated the *SFPUC Accepted Hydrologic Calculation Methods* supplement (available at www.sfwater.org/smr) for sizing. Detention ponds are typically sized for a drawdown time of 48 hours, with less than 50 percent of the total volume draining in the first 16 hours. Any runoff that exceeds the storage capacity is discharged back into the collection system.

Inspection and Maintenance

Maintenance requirements for detention ponds consist mainly of periodic sediment removal, vegetation management, and vector abatement if needed. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Detention Ponds

Activity	*Schedule*
Inspect pond for standing water to confirm drawdown time of 24-48 hours after end of wet weather.	Semi-annually (beginning and end of rainy season)
Inspect for erosion of banks or bottom and for presence of burrows or other damage to embankments.	Semi-annually (beginning and end of rainy season)
Confirm that inlet and outlet structures are operational and free of debris.	Semi-annually (beginning and end of rainy season)
Monitor sediment accumulation in the main pond and forebay.	Annually (end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Detention Ponds	
Activity	*Schedule*
If standing water present more than 24-48 hours, adjust outflow devices or regrade pond bottom.	Semi-annually (beginning and end of rainy season)
Remove trash and debris, especially at inlet and outlet structures.	Semi-annually (beginning and end of rainy season)
Correct erosion or damage to banks and bottom.	Semi-annually (beginning and end of rainy season)
Repair inlet and outlet structures as needed.	Semi-annually (beginning and end of rainy season)
Mow to prevent establishment of woody vegetation in areas below the elevation of the design storm.	Semi-annually (beginning and end of rainy season)
Prune vegetation obstructing line of site at roadway or intersection.	Quarterly
Seed or sod to restore dead or damaged vegetation and provide weed control.	Semi-annually
Remove sediment from forebay when depth exceeds 6 inches or 50 percent of storage capacity.	As needed (expected frequency every 3-5 yrs)
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed
Remove sediment when the pond volume has been reduced by 10 percent. This can be measured with a barrel thief or on a sediment gauge installed near the basin outlet.	As needed (expected frequency every 10-25 yrs)

References and Resources

California Stormwater Quality Association. 2004. "TC-22 Extended Detention Basin." *California Best Management Practice Handbook - New Development and Redevelopment*.

San Francisco Public Utilities Commission. 2007. Urban Watershed Planning Charrette: "Low Impact Design Toolkit."

"State Water Resources Control Board Order Number 2013-0001-DWQ." 3 March 2015 <http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2013/wqo2013_0001dwq.pdf>

The Stormwater Manager's Resource Center. "Stormwater Management Fact Sheet: Dry Extended Detention Pond." 12 March 2015 <http://www.stormwatercenter.net>

Wet Pond

Also known as: stormwater pond, retention pond, wet extended detention pond

Inlet 1

Forebay (pretreatment and energy dissipation) 2

Aquatic bench 3

Design volume level 4

Live storage 5

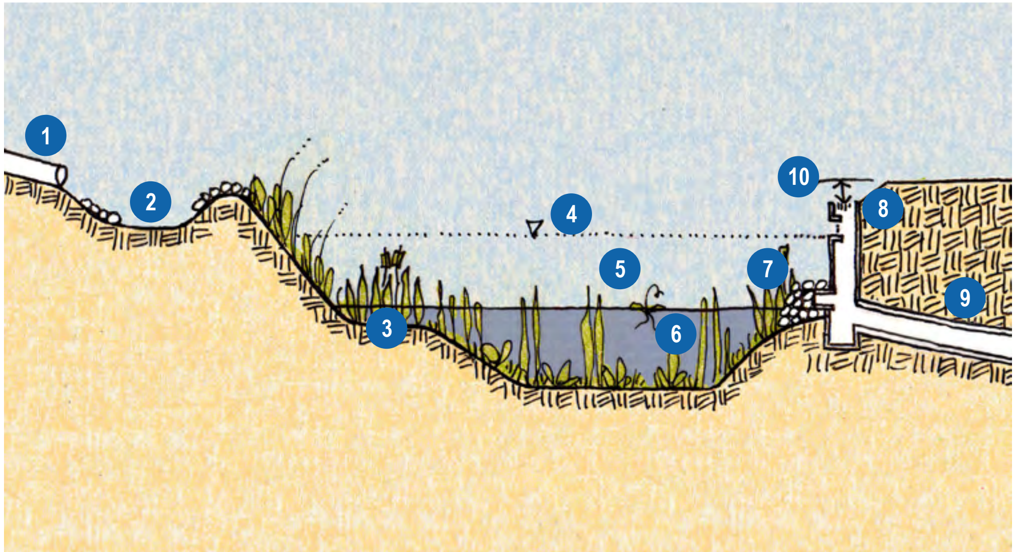
Permanent storage: 4 to 6 foot pool depth 6

Primary outlet with sediment filter 7

Overflow structure with screened inlets 8

Outlet to collection system, catch basin, or receiving water 9

Minimum 1 foot freeboard 10



Description

Wet ponds are constructed basins that have a permanent pool of water throughout the wet season, potentially extending throughout the year. The primary treatment mechanism is settling while stormwater runoff resides in the pool. When algae are present, algal uptake also aids stormwater treatment. Nutrient uptake also occurs through biological activity in the sediment and water. Wet ponds differ from constructed wetlands in that they are typically deeper, ranging from 4 to 6 feet, and have less vegetative cover. Wet ponds are among the most cost-effective and widely used large-scale stormwater treatment practices.

The typical configuration of a wet pond includes forebay storage, permanent storage, and live storage areas. The forebay is a small inlet pool that allows settling of coarse and medium grained sediment. Permanent storage refers to the permanent pool of water remaining in the wet pond between storm events and during dry weather. If intended as wildlife habitat or permanent water feature, supplemental water and the installation of an impermeable liner may be required to maintain the permanent pool during the dry season. Live storage refers to the remaining storage capacity in the wet pond that will vary based on stormwater inflows. The stormwater in the live storage area will generally drain from the pond 24 to 48 hours after the end of a storm event.

Benefits

- Attenuates peak flow and may reduce stormwater volume.
- Removes many stormwater pollutants via sedimentation and biological transformation.
- Can be an attractive and recreational public park amenity.
- Creates wildlife and wetland habitat.
- Suitable for sites with poor infiltration rates.
- Suitable for large drainage areas.

Pollutant Removal	Volume Reduction	Peak Flow Reduction
High	Moderate	High

Target Pollutants

Sediment	High, Requires Pre-Treatment
Nutrients	Moderate
Organics	High
Trash	Low, Requires Pre-Treatment
Metal	High
Bacteria	High
Oil/Grease	High

Low · Moderate · High · Requires Pre-Treatment

Limitations

- Requires relatively large land area and large drainage area (at least 5 acres), thus making it a good choice for master-planned and multi-parcel developments.
- Supplemental water required to maintain permanent pool may outweigh stormwater benefits.
- If seasonally dry, may appear dusty or unsightly.

Siting

Because of their large size relative to many other BMP types, wet ponds in San Francisco are best suited for projects on large sites, such as parks and open spaces, industrial parcels, and multi-parcel projects.

Wet Ponds may be used to meet peak flow reduction requirements in the combined sewer area. However, they may not be used for compliance with the separate sewer area performance requirements.

A wet pond serves as a focal point in this residential courtyard, providing air and water-quality benefits, as well as enhancing the aesthetic appeal of the courtyard. Photo: Rosey Jencks

Larger wet ponds may provide an opportunity for recreation. Photo: Rosey Jencks

Drainage area and slope: Though they only occupy 2 to 3 percent of their contributing drainage area, wet ponds require sufficient drainage to maintain a permanent pool, typically around 25 acres or more. Wet ponds can be used at sites with drainage areas as small as 5 acres provided that the permanent pool is maintained during the rainy season, either through use of a liner or addition of supplemental non-potable water if necessary. Wet ponds must be sited on a relatively flat area with less than 2 percent slope. While there is no minimum slope requirement, there must be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system by gravity. The slope downstream of wet ponds should not exceed 15 percent.

Soils and infiltration rate: Because they are not designed to reduce runoff by infiltration, wet ponds can be used in almost all soil types. In Mediterranean climates like San Francisco, wet ponds may either be allowed to evaporate in the dry season, or may be supplemented with an alternative source of water. Dry-weather water sources could be street and irrigation runoff, recycled water, groundwater, or other urban water applications.

Groundwater protection: Wet ponds may intersect the groundwater table, though this should be avoided in areas where either the stormwater or the groundwater could be contaminated.

Design Considerations

Vegetation: Though most of the pond is deeper than wetland plant rooting depth, wet ponds should incorporate an aquatic bench around their perimeter. The aquatic bench is a shallow shelf up to 18 inches deep that supports wetland vegetation. In addition to facilitating stormwater treatment via biofiltration, this feature also helps to stabilize the soil at the edge of the pond and enhances habitat and aesthetic value. Native species that can tolerate drought and inundation should be used wherever possible. Refer to *Appendix D: Vegetation Palette for Bioretention BMPs* for a list of vegetation options.

Pretreatment: A pretreatment forebay should be used to settle out coarse sediment before it reaches the main pool. Forebays are separate small ponds located between the inlet and the main pool that are typically about 10 percent of the live storage volume of the pond. This can greatly reduce regular maintenance costs. Accumulated sediment should be removed from the forebay when its depth exceeds 6 inches or 50 percent of the forebay storage capacity, typically every 3 to 5 years. A vegetated buffer should be created around the pond to protect the banks from erosion, and to provide some pollutant removal before runoff enters the pond by overland flow. This landscaping also provides aesthetic and habitat amenities for the community.

Drainage: Stormwater should be conveyed to and from wet ponds safely and in a manner that minimizes downstream erosion potential. The wet pond outfall should always be stabilized to prevent scour. An emergency spillway should be provided to safely convey large flood events into the collection system or a receiving water body. If discharging to streams, lakes, or the bay or ocean, designers should provide shade around the outflow channel to prevent warming that could adversely affect aquatic species.

Overflow: Wet ponds should be designed with a non-clogging outlet such as a weir outlet with a trash rack or a reverse slope pipe that is at least 3 inches in diameter. Because reverse slope pipes draw water from below the surface of the permanent pool, they are less likely to be clogged by floating debris. If the wet pond is online, meaning it receives continuous flow that cannot be diverted, principle and emergency spillways should provide at least 1 foot of freeboard.

Access: For ease of maintenance, wet ponds should incorporate direct access to both the forebay and the main pool. In addition, ponds should generally have a drain to draw down the pond or forebay to facilitate periodic sediment removal.

Sizing: Because they are typically used at sites that exceed the site area limitations of the BMP Sizing Calculators (subwatersheds less than 2 acres and sites less than 5 acres), the project proponent should use modeling or other approved methods indicated the *SFPUC Accepted Hydrologic Calculation Methods* supplement (available at www.sfwater.org/smr) for sizing.

Adding appropriate vegetation to ponds has multiple benefits. Photo: Becky Lithander

The High Point neighborhood in Seattle, WA is one of the largest developments in the nation to implement low impact design practices. Photo: Becky Lithander

To minimize short circuiting, wet ponds should always be designed with a length to width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as baffles or underwater berms. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater. Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system.

Inspection and Maintenance

In addition to incorporating features into the pond design to minimize maintenance, sediment should be removed approximately every 5 years. Aquatic vegetation should harvested and thinned and the surrounding vegetated buffer should be pruned, trimmed, or mowed annually. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement.*

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Wet Ponds

Activity	*Schedule*
Inspect for erosion damage, animal burrows, and structural integrity, especially of pond outlet.	Semi-annually (beginning and end of rainy season)
If petroleum hydrocarbon contamination identified, implement appropriate source control and pretreatment measures.	Semi-annually (beginning and end of rainy season)
Monitor for sediment accumulation in the forebay and main pond.	Semi-annually (beginning and end of rainy season)
Examine to ensure that inlet and outlet devices are operational and free of debris.	Semi-annually (beginning and end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

Typical Maintenance Activities for Wet Ponds

Activity	*Schedule*
Remove visible contaminants and debris and clean inlet and outlet structures.	Semi-annually (beginning and end of rainy season)
Remove accumulated trash and debris from forebay and edges of main pond.	Semi-annually (beginning and end of rainy season)
Provide weed control and mow or trim side slopes if vegetated.	Semi-annually (beginning and end of rainy season)
Repair undercut or eroded areas.	Semi-annually (beginning and end of rainy season)
Stock permanent pool with mosquitofish *(Gambusia spp.)*.	Semi-annually (beginning and end of rainy season)
Repair or replace damaged or detached impermeable liners, if applicable.	Semi-annually or as needed
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed
Remove sediment from forebay when depth exceeds 6 inches or 50 percent of storage capacity.	As needed (expected frequency every 3 to 5 years)
Replant vegetation as necessary.	As needed (expected frequency every 3 to 5 years)
Remove sediment when the pond becomes eutrophic. This can be measured with a barrel thief or on a sediment gauge installed near the basin outlet.	As needed (expected frequency every 25 to 50 years)

References and Resources

California Stormwater Quality Association. 2004. "TC-20: Wet Pond." *California Best Management Practice Handbook- Municipal.*

The Stormwater Manager's Resource Center. "Stormwater Management Fact Sheet: Wet Pond." 12 March 2015 <www.stormwatercenter.net>.

City of Seattle. 2014. *"5.8.6 Wet Ponds" Stormwater Code and Manual Vol. 3, pp. 5-207 – 5-211.* 12 March 2015 <http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2145427.pdf>

United States Environmental Protection Agency. "National Pollutant Discharge Elimination System Menu of Stormwater BMPs: Wet Ponds." 12 March 2015 <http://water.epa.gov/polwaste/npdes/swbmp/Wet-Ponds.cfm>.

Constructed Wetland

Also known as: stormwater wetland, treatment wetland, stormwater marsh

Inlet 1

Forebay (pretreatment and energy dissipation) 2

Irregular bottom surface 3

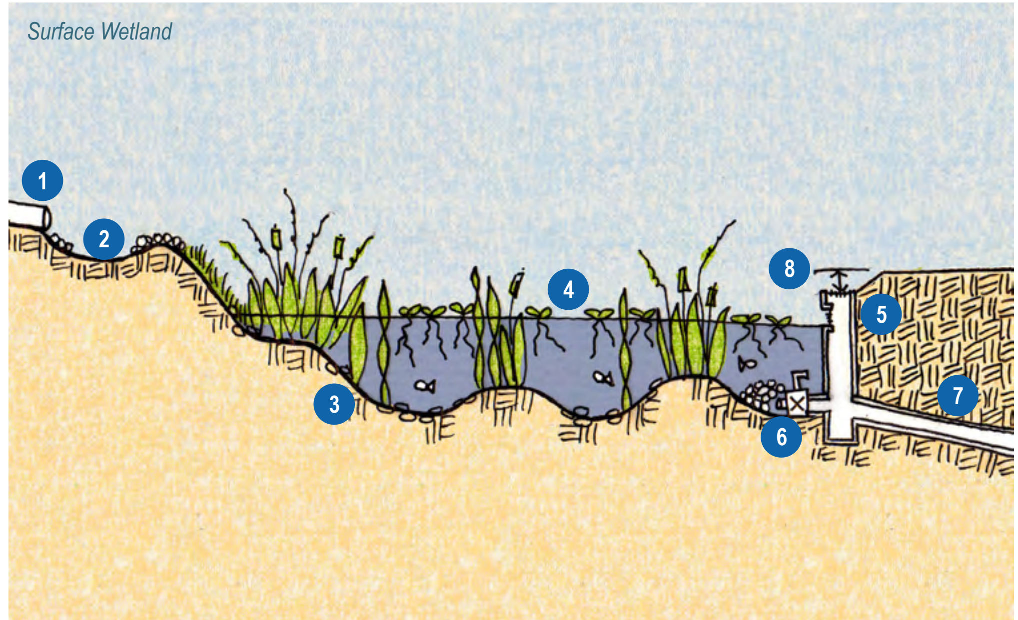
Open water surface 4

Overflow structure with screened inlets 5

Valve for drainage and maintenance 6

Outlet to collection system, catch basin, or receiving water 7

Minimum 1 foot freeboard 8



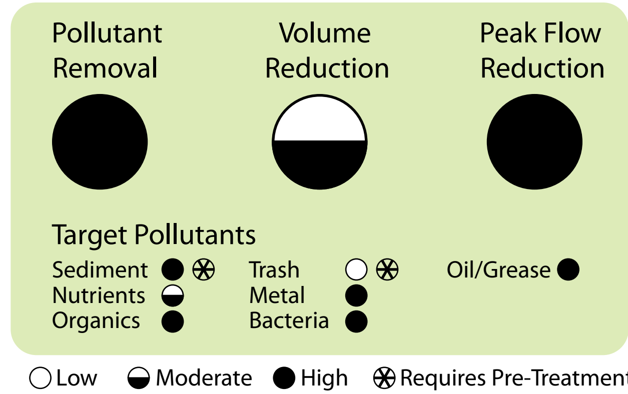
Description

Constructed wetlands are man-made wetlands designed to collect and purify stormwater through microbial transformation, plant uptake, settling, and adsorption. Water is stored in shallow, vegetated pools that are designed to support wetland plants. Constructed wetlands have some of the same ecological functions as natural wetlands and are beneficial for stormwater management and water quality improvement. Wetlands must be paired with other BMPs that remove sediment and litter from stormwater prior to its entry into the wetland.

There are two main types of constructed wetlands: surface and subsurface flow wetlands.

- Surface flow wetlands maintain a shallow and relatively constant depth of standing or slow-flowing water year-round, and contain both emergent vegetation and open water. Vegetated areas foster microbial communities that transform and remove stormwater pollutants, while open water areas aid in pathogen removal, hydraulic circulation, and mosquito abatement if the wetland is stocked with mosquitofish.
- Subsurface flow wetlands are sometimes called reed beds or vegetated rock filters. Water in these systems flows below the ground surface through a substrate such as rock, gravel, or sand that is planted with wetland vegetation. Compared to surface flow wetlands, subsurface flow wetlands generally require less land area and tend to have fewer mosquito management issues, but may be more expensive to construct and maintain.

Constructed wetlands have been shown to reduce total suspended solids, phosphorus, nitrogen, metals, and bacteria by 50 to 90 percent, depending on system design and influent water quality. Treatment occurs primarily in the root zone of wetland plants (for surface flow wetlands) or in the biofilm that grows on the substrate (for subsurface flow wetlands) via microbial transformation, sedimentation, and plant uptake.



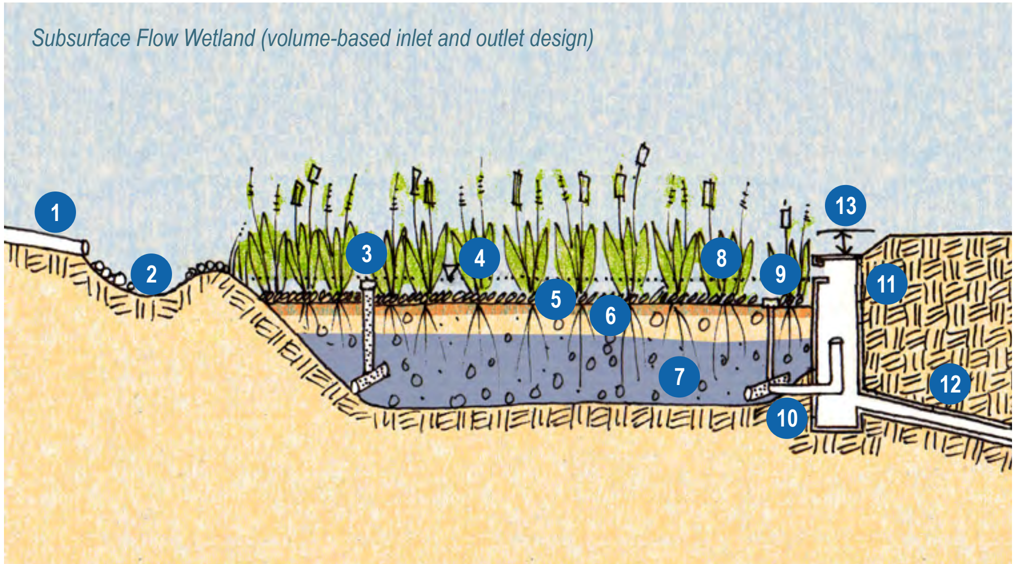
El Monte Sagrado - Living Resort and Spa in Taos, NM recycles almost all of its wastewater for landscape irrigation after treating the wastewater in a Tidal Wetland Living Machine. In addition, stormwater is captured and used to replenish ponds and waterfalls throughout the resort. Photo: Rosey Jencks

Benefits

- Effective at removing stormwater pollutants (sediment, nutrients, organic compounds, pathogens, heavy metals).
- Reduces stormwater peak flows, can reduce overall volume if runoff is stored and used.
- Attractive landscape feature and potential community park amenity.
- Provides valuable wetland habitat.
- Good in areas unsuitable for infiltration, including areas with a high groundwater table.
- Easily customizable to various sizes and dimensions, based on site, budget, and design intent.
- Can be designed to treat and store water for local non-potable use (e.g. for irrigation, toilet flushing, or fire protection) depending on site conditions and stormwater characteristics.

Limitations

- Requires a relatively large land area.
- May require a supplemental water source in the dry season.
- Water quality improvement may vary seasonally as plants senesce in winter.
- Vegetation may appear dormant in winter.



1 Inlet

2 Forebay (pretreatment and energy dissipation)

3 Perforated riser and inlet pipe (riser conveys ponded water to gravel layer)

4 Design volume level

5 Mulch

6 Low permeability wetland soil

7 Medium and coarse gravel

8 Wetland vegetation

9 Observation well and cleanout

10 Primary outlet (perforated pipe with adjustable standpipe to control water

11 Overflow structure with screened inlets

12 Outflow to collection system, catch basin, or receiving water

13 Minimum 1 foot freeboard

Constructed wetlands not only create a park-like settings, but they also remove contaminants from stormwater and provide flood control. *Photo: Programmed Property Services*

Siting

Because of their large size relative to many other BMP types, constructed wetlands in San Francisco are best suited for large sites, such as parks and open spaces, industrial parcels, and multi-parcel projects.

Drainage area and slope: Though they only occupy 3 to 5 percent of their contributing drainage area, surface wetlands require sufficient drainage to maintain a permanent pool, typically a minimum of 5 acres. Wetlands must be sited on a relatively flat area with less than 2 percent slope. While there is no minimum slope requirement, there must be enough elevation drop from inlet to outlet to ensure that water can flow through the system by gravity. The slope downstream of constructed wetlands should not exceed 15 percent.

Soils and dry season water supply: Because they are not designed to reduce runoff by infiltration, constructed wetlands can be used in almost all soil types. In Mediterranean climates like San Francisco, wetlands may either be allowed to evaporate in the dry season, or may be supplemented with an alternative source of influent water. Dry-weather alternative water sources could be greywater, street and irrigation runoff, or groundwater.

Groundwater protection: Wetlands may intersect the groundwater table, which will help support wetland vegetation. This should be avoided in areas where either the stormwater or the groundwater could be contaminated. In these areas, an impermeable liner can keep wetland flows and groundwater separated.

Design Considerations

Vegetation: The health of wetland vegetation is integral to the ability of stormwater wetlands to improve water quality. Wetlands should have zones of very shallow (less than 6 inches) standing water to facilitate emergent vegetation growth, and moderately shallow (6 to 18 inches) open water areas. Vegetated areas foster more microbial and plant treatment action, while open water areas can support mosquitofish (Gambusia spp.) to minimize mosquito breeding. Native emergent plants should be used wherever possible. Refer to *Appendix D: Vegetation Palette for Bioretention BMPs* for a list of vegetation options.

Pretreatment: Pretreatment, which occurs via settling of coarse sediment and debris in a wetland forebay, is key to the function of constructed wetlands. Other BMPs may also be used upstream of a constructed wetland to enhance treatment effectiveness. Conveyance swales or buffer strips may help filter stormwater before it enters a stormwater wetland; alternatively or additionally, sediment removal devices can trap sediment prior to treatment by a wetland. This can reduce maintenance needs in the wetland itself. See the Pretreatment section of this appendix for a description of selected pretreatment BMPs.

Drainage and Overflow: Inlet and outlet configurations for surface and subsurface flow wetlands can vary, and should be designed by the project engineer to reflect site constraints and design goals.

Sizing: Because they are typically used at sites that exceed the site area limitations of the BMP Sizing Calculators (subwatersheds less than 2 acres and sites less than 5 acres), the project proponent should use modeling or other approved methods indicated the *SFPUC Accepted Hydrologic Calculation Methods* supplement (available at www.sfwater.org/smr) for sizing. To enhance pollutant removal, stormwater wetlands should have varied microtopography along the wetland bottom to create as long a flow path as possible at lower flows and a length to width ratio of between 2:1 and 4:1. Stormwater wetlands commonly occupy 3 to 5 percent of the drainage area.

This project's constructed wetland treats the building's wastewater on-site while the pond and rain garden prevent stormwater runoff. *Photo: Albert Vecerka*

Inspection and Maintenance

Constructed wetlands should incorporate design features to make sediment cleanout of both the forebay and the main body of the wetland easier. Wetland design should provide direct maintenance access to the forebay, to allow sediment cleanout every 3 to 5 years. In addition, the main body of the wetland should have a drain so it can be drawn down for more infrequent dredging. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Constructed Wetlands

Activity	*Schedule*
Check inlets and outlets for signs of clogging or erosion.	Post-construction
Monitor vegetation to ensure successful root establishment.	Post-construction
Inspect for invasive vegetation and remove where possible.	Semi-annually (beginning and end of rainy season)
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)
Monitor for sediment accumulation in the forebay and main wetland.	Annually
Check for signs of erosion, animal burrows, or other damage.	Annually

Typical Maintenance Activities for Constructed Wetlands	
Activity	*Schedule*
Remove visible contaminants and debris and clean inlet and outlet structures.	Semi-annually (beginning and end of rainy season)
Provide weed control and trim vegetation as needed.	Semi-annually (beginning and end of rainy season)
Plant additional vegetation if at least 25 percent of the surface area has not established.	Annually or as needed
Harvest wetland plants that are "choking out" other beneficial plant species.	Annually or as needed
Repair undercut or eroded areas.	Annually or as needed
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed
Remove sediment from forebay when depth exceeds 6 inches or 50 percent of storage capacity.	As needed (Expected frequency every 3 to 5 years)
Regrade or raise wetland berms as sediment and root mass accumulate.	As needed (Expected frequency every 20 to 50 years)

References and Resources

California Stormwater Quality Association. 2004. "TC-21: Constructed Wetlands." *California Best Management Practice Handbook- Municipal.*

City of Seattle. 2014. *"5.8.8 Stormwater Treatment Wetlands" Stormwater Code and Manual Vol. 3, pp. 5-221 – 5-222.* 12 March 2015 <http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2145427.pdf>

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United States Environmental Protection Agency. 2000. "Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat." 17 July 2015. <http://water.epa.gov/type/wetlands/constructed/upload/guiding-principles.pdf>

An elevated walkway provides recreation at the Qunli Stormwater Wetland Park in Heilongjiang, China. Photo: Inhabitat

BMPs Appropriate as Pretreatment Devices and/or with Limitations

Conveyance Swale

Also known as: biofiltration swale, vegetated swale, grassy swale

Stormwater runoff 1

Maximum 5% channel slope 2

Check dams recommended for slopes over 5% 3

6-inch grass height recommended 4

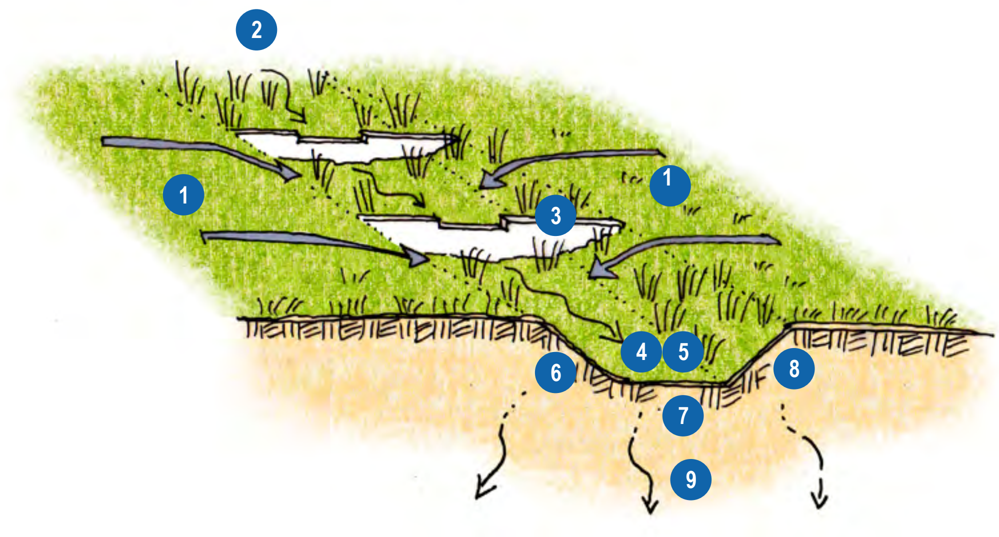
Maximum treatment depth 2/3 of grass height 5

Trapezoidal form 6

10-foot maximum channel bottom width 7

3:1 maximum channel bank slope 8

Infiltration where feasible 9

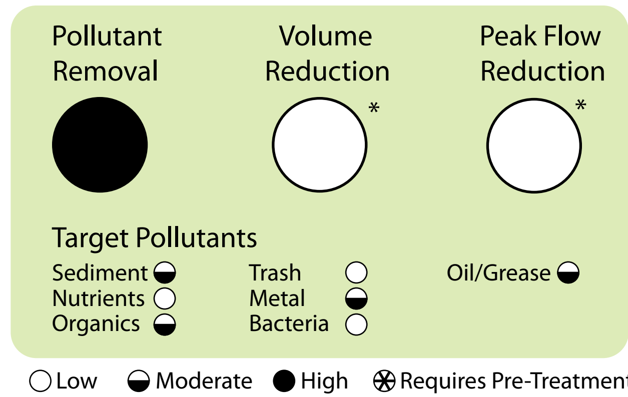


Description

A conveyance swale is a broad, shallow channel comprised of a soil medium and dense vegetation covering the bottom and side slopes. The vegetation in the channel provides filtration and solids removal and reduces flow velocities as the runoff is conveyed through the system. Depending on the capacity of the native soils, a variable amount of infiltration will also occur, which decreases runoff volume and provides additional filtering.

Conveyance swales can be designed as part of the stormwater conveyance system and, in appropriate locations, help minimize the need for curbs, gutters and storm drains. They are also well-suited to capture runoff from roads and parkways because of their linear nature. Conveyance swales provide effective pretreatment when paired with other BMPs, such as bioretention basins, wet ponds, infiltration basins, and treatment wetlands. However, these swales do not substantially reduce flow rates or volumes and thus do not contribute to meeting combined sewer performance requirements. Additionally, because of changes in San Francisco's 2013 NPDES Phase II Municipal Separate Storm Sewer System Permit, conveyance swales no longer meet the separate sewer area performance requirements. Conveyance swales are included as a pretreatment facility in the BMP Sizing Calculators.

In contrast, bioretention swales (see the Bioretention fact sheet), are designed as linear, sloped systems with bioretention media, which slow runoff and promote infiltration. Because bioretention swales are better suited to meet SMR performance requirements (in both combined and separate sewer areas), they are the only type of swale provided as a BMP option in the BMP Sizing Calculators.



* Moderate if designed as a dry swale (bioretention swale)

Benefits

- Improves water quality by removing sediment, particulate matter, and trace metals.
- Creates habitat and increases biodiversity in the city.
- Provides aesthetic amenities.
- Improves air quality.
- Low installation costs.
- Low maintenance requirements.

Limitations

- Limited volume reduction and peak flow attenuation.
- Conveyance swales, alone, will not meet separate sewer area performance requirements.
- Irrigation likely needed to establish plants and maintain them during the dry season.
- Impractical in areas with very flat or very steep topography or with erosive soils.
- Little removal of dissolved pollutants and bacteria.
- Vulnerable to erosion when flow velocities are high.
- Limited to relatively small drainage areas.

Swales at the Bay Natives nursery near Herons Head Park in San Francisco, CA. Photo: Rosey Jenks

Siting

Conveyance swales may be used to meet performance requirements in the combined sewer area. However, they typically provide limited volume and peak flow reduction benefits. In separate sewer areas, they may only be used as a pretreatment device; runoff discharged through conveyance swales requires further treatment by stormwater controls described in *Chapter 6: Separate Sewer Area Performance Requirements* to meet separate sewer area requirements.

Drainage area and slope: Conveyance swales are best suited for small drainage areas, but can be used to treat runoff from drainage areas with up to 5 acres of impervious surface. They are best used on sites with relatively flat slopes. Larger drainage areas and steeper slopes result in flow velocities that are too high to allow adequate treatment and may cause erosion of the swale bottom and side slopes.

Soils and infiltration rate: Conveyance swales are most effective on soils that allow infiltration. Care should be taken to avoid soil compaction. In some cases, however, swales can be installed on top of impermeable soils by excavating the native soil and replacing it with a layer of well-drained planting medium and an underdrain. Soils that consist mainly of gravels and coarse sands may also be problematic if they cannot support dense enough vegetation growth to adequately treat runoff. If there is a concern about soil or groundwater contamination or if the swale is located in an area with coarse soils, the swale may be lined.

Setbacks: If a conveyance swale is sited on infiltrative soils and receives run-on from adjacent areas, it must be designed in compliance with setback requirements outlined in *Appendix C: Criteria for Infiltration-based BMPs*.

Groundwater protection: There should be a minimum vertical separation of 4 or 10 feet, depending on location, from the bottom of the swale to the seasonally-high groundwater elevation to protect groundwater quality (see *Appendix C: Criteria for Infiltration-based BMPs* for more information about this requirement). This separation also helps prevent a moist swale bottom, which impacts the growth of grass and other plants not accustomed to long periods of root inundation, and can also lead to mosquito issues.

Design Considerations

Vegetation: A dense vegetative cover on the swale bottom and side slopes filters pollutants out of runoff and helps reduce flow velocities and protect the swale from erosion. Close-growing, no-mow grasses or ground covers are ideal, because increasing the surface area of the vegetation exposed to runoff improves the effectiveness of the swale. Native wildflower mixes and ground covers between plantings can also be used. Vegetation that can tolerate both wet and dry conditions as well as accumulations of sediment and debris are best-suited for swales. No runoff shall be allowed to flow in the swale until the vegetation is established. Irrigation will likely be required until vegetation is established.

Because conveyance swales rely on dense vegetation for pollutant removal and flow attenuation, proper sun exposure for selected plantings must be carefully considered. If grasses are used, the swale should receive a minimum of 6 hours of sunlight daily during the summer months throughout the length of the swale. Alternative vegetation should be considered if sun exposure is limited.

Flow: Typical flow depths under peak design storm conditions are less than 4 inches. Larger storms may produce greater flow depths, but the maximum velocity should be less than or equal to 3 feet per second to avoid erosion. A high-flow bypass should be used if velocities are anticipated to exceed this value. A dissipation structure, weir, or custom flow spreader should be used at the swale inlet to dissipate energy and spread runoff evenly across the swale bottom. If a swale discharges to a slope rather than to the collection system or to a confined channel, an energy dissipater should be used at the outlet.

Dimensions and sizing: Conveyance swales should generally have a trapezoidal shape with a flat bottom to promote even flow across the whole width of the swale. The bottom width is typically between 1 and 10 feet. The minimum allows for adequate planted area, while the maximum prevents the formation of small channels within the swale bottom. Side slopes are generally designed to be 3:1 (horizontal:vertical) or greater to minimize erosion and slow runoff entering the swale from the sides. However, if an architectural edge is desired and runoff does not enter from the swale sides, hardscaped vertical sides and a broad, flat bottom may be designed.

Stormwater runoff from a parking lot is directed to a vegetated swale via cobblestone inlets, managing stormwater while also enhancing public space. Photo: Krystal Zamora

Cornell University implemented swales to manage stormwater at their new Welcome Center, rather than use a conventional underground drainage system. *Photo: Cornell University*

The recommended longitudinal slope for swales is typically between 1 percent and 6 percent, with a slope around 2 percent being preferred. Limiting the longitudinal slope helps maintain a low flow velocity. Check dams should be installed in swales if the longitudinal slope exceeds 5 percent.

Inspection and Maintenance

If properly designed and regularly maintained, conveyance swales can last for the life of a project. The primary maintenance objective for conveyance swales is to maintain the hydraulic and treatment efficiency of the channel with a dense, healthy vegetative cover. During construction, it is important to stabilize the swale before the vegetation has been established, either with a temporary grass cover, or the use of natural or synthetic erosion control products. For further information about inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Conveyance Swale

Activity	*Schedule*
Check that the swale drains within the design drawdown time (typically 24-48 hours).	Post-construction and semi-annually (beginning and end of rainy season)
Inspect for erosion, damage to vegetation, channelization of flow, debris and litter, and sediment accumulation.	Semi-annually (beginning and end of rainy season)
Inspect level spreader for clogging and correct as necessary.	Annually
Inspect for signs of mosquito breeding.	Semi-annually (beginning and end of rainy season)

Conveyance Swale

Typical Maintenance Activities for Conveyance Swale	
Activity	*Schedule*
Regularly water during the first three months as vegetation establishes.	Post-construction
For grassed swales, mow grass to maintain a height of 3-4 inches. Remove litter prior to mowing.	As needed (frequently)
Replace dead vegetation and provide weed control, if necessary, to control invasive species.	As needed (frequently)
Remove litter, branches, visible contaminants, blockages, and other debris.	Semi-annually (beginning and end of rainy season)
Repair any erosion rills, gullies, or damaged areas within channel and replant bare areas as necessary.	Semi-annually (beginning and end of rainy season)
Remove sediment from head of swale if vegetation growth is inhibited or if the sediment is blocking the even spreading of water to the rest of the swale.	Annually
Plant alternative vegetation if original vegetation is not successfully established. Reseed and apply mulch to damaged areas.	Annually
Rototill or aerate the bioretention soil section if the swale does not drain within 24-48 hours after the end of a wet weather event.	As needed (infrequently)
Remove sediment build-up from the bottom of the swale once it has accumulated to 10percent of the original design volume.	As needed (infrequently)
Consult with a licensed professional pest control service if rodent or animal damage is observed.	Annually or as needed
Utilize Integrated Pest Management (IPM) strategies to safely and effectively minimize pest damage and hazard.	As needed

References and Resources

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City of Seattle. 2014. *“5.8.3 Biofiltration Swales” Stormwater Code and Manual Vol. 3*. 12 March 2015. <http://www.seattle.gov/dpd/codesrules/changestocode/stormwatercode/projectdocuments/default.htm>

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Portland Bureau of Environmental Services. 2014. “Stormwater Management Manual.”

United States Environmental Protection Agency. “National Pollutant Discharge Elimination System Menu of Best Management Practices Fact Sheets: Grassed Swales.” 12 March 2015. <http://water.epa.gov/polwaste/npdes/swbmp/Grassed-Swales.cfm>

United States Environmental Protection Agency. 1999. “Stormwater Technology Fact Sheet: Vegetated Swales (EPA 832-F-99-006).” <http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegswale.pdf>

Conveyance Swale

Vegetated Buffer Strip

Also known as: grassed filter strip, vegetated filter, infiltration planter strip

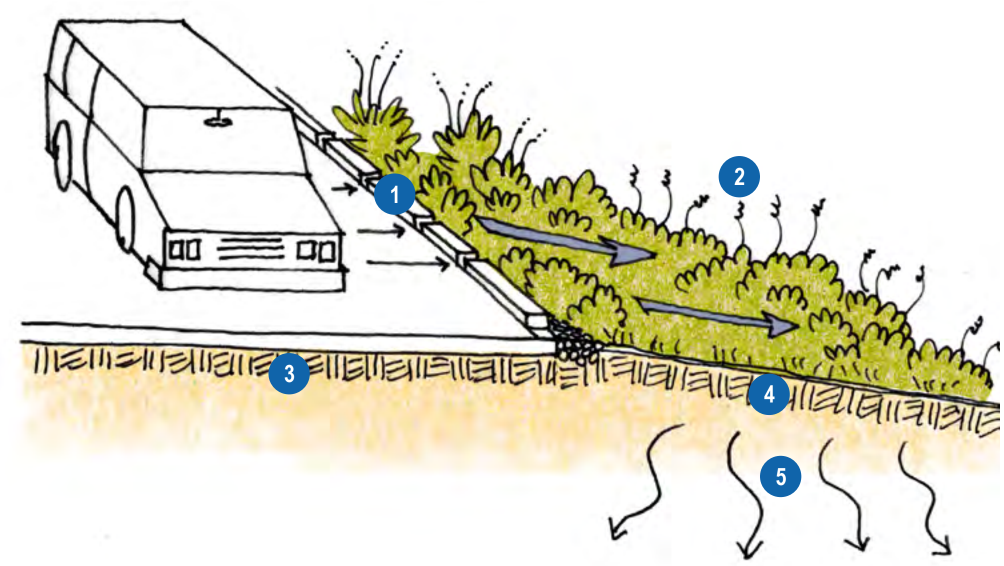
Optional curb cuts evenly disperse run-off inflow 1

Thick vegetation and 10% maximum slope 2

60-foot maximum road width 3

15-foot minimum buffer strip width (in the direction of flow) 4

Infiltration where feasible 5



Description

Vegetated buffer strips are sloping planted areas designed to treat and infiltrate sheet flow from adjacent impervious surfaces. They slope away from the impervious surface and are most often planted with no-mow grass species, though other uniformly distributed plant species may also be appropriate. Buffer strips function by slowing stormwater runoff and allowing sediment and other pollutants to settle. They ultimately discharge flows to the collection system or other BMPs. They are generally attractive features that tend to be viewed as landscape amenities rather than as stormwater infrastructure.

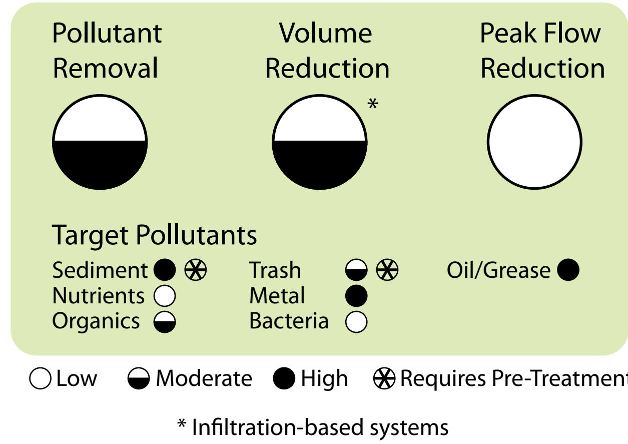
Benefits

- Improves water quality.
- Attenuates peak flows and may reduce stormwater volumes.
- Good for roadside shoulders and landscape buffers.
- Attractive landscape feature.

- Minimal maintenance required.
- Easy to customize to varying site conditions.

Limitations

- Not appropriate for industrial or contaminated sites.
- Limited ability to treat large drainage areas.
- Limited stormwater volume reduction.
- May require irrigation in dry season, depending upon species.
- Persistent stormwater pollutants such as metals, oil, and grease may accumulate in sediments.

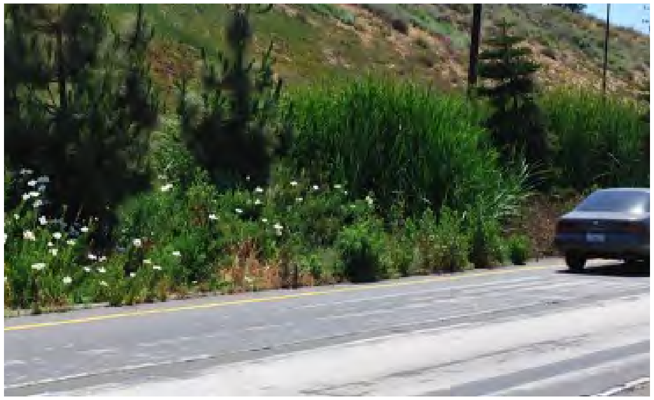


Siting

In separate sewer areas, vegetated buffer strips may be used as a pretreatment device; runoff discharged through buffer strips requires further treatment by stormwater controls described in *Chapter 6: Separate Sewer Area Performance Requirements* to meet separate sewer area requirements.

Drainage area and slope: Buffer strips are considered to be effective at treating contributing areas that are up to twice the width of the buffer strip, and no greater than 60 feet in width. The edge of the contributing area should be flat and even to ensure sheet flow onto the buffer strip and prevent erosion. The top of the buffer strip should be set 2 to 5 inches below the adjacent pavement so that vegetation and sediment accumulation at the edge of the strip do not prevent runoff from entering the buffer strip. Though once recommended, level spreaders such as berms, sawtooth concrete borders, or rock trenches are no longer encouraged, because they tend to erode, wash out, and require more maintenance.

Buffer strips should be sited on gentle slopes between 1 and 10 percent. Steeper slopes may trigger erosion during heavy rain events, thus eliminating water quality benefits. On slopes greater than 5 percent, fiber rolls, check dams, or other means should be used to slow flows and reduce erosion potential. If the buffer strip slope is less than 0.5



This vegetated buffer strip along the Imperial Highway in Los Angeles, CA slows stormwater runoff from the highway.
Photo: LA Stormwater Program

percent, or if the underlying soil has infiltration rates of less than 0.5 inches per hour, an underdrain system should be installed to facilitate drainage. The underdrain would be sited at the toe of the buffer strip and connected to the collection system or another BMP.

Soils and infiltration rate: Planting soil should be at least six inches deep. Native soil can be used if approved by the project landscape architect. The surface of the buffer strip should be graded flat prior to placement of vegetation. If infiltration is desired, the native soil should drain at a rate of at least 0.5 inches per hour. Low-slope buffer strips will be more effective at infiltrating runoff.

Design Considerations

Vegetation: The thicker and more uniform the plant cover, the greater the stormwater management benefits. In San Francisco's Mediterranean climate, native plants that can tolerate both inundation and drought should be used where possible, to minimize irrigation and fertilizer costs. Initial establishment of vegetation requires attentive care including appropriate watering, fertilization, and prevention of excessive flow across the facility until vegetation completely covers the area and is well established. Use of a permanent irrigation system may help provide the maximum water quality performance. Refer to *Appendix D: Vegetation Palette for Bioretention BMPs* for a list of vegetation options.

Sizing: Vegetated buffer strips are sized to be at least 15 feet wide (in the direction of flow) to provide water quality treatment. The upstream edge of the buffer strip should be contiguous to the roadway or other contributing area.

Inspection and Maintenance

The maintenance of vegetated buffer strips mainly consists of vegetation management. Recent research indicates that grass height and mowing frequency have little impact on pollutant removal; consequently, mowing may only be necessary once or twice a year for safety and aesthetics. Weed suppression must be done much more frequently than mowing; once a month is a typical weed suppression schedule. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*.

Vegetated Buffer Strip

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Vegetated Buffer Strips	
Activity	*Schedule*
After first rain event, inspect for standing water and erosion.	Post-construction
Inspect for standing water, trash accumulation, erosion, damage to vegetation, and sediment accumulation.	Annually

Typical Maintenance Activities for Vegetated Buffer Strips	
Activity	*Schedule*
Regularly water during first three months as vegetation establishes roots.	Post-construction
Control invasive weeds.	Monthly
Remove litter and mow or trim vegetation.	Annually or as needed
Replace or repair any damaged or non-functioning parts.	Annually or as needed

References and Resources

Alameda Countywide Clean Water Program. 2006. "Vegetated Buffer Strips." *C.3 Stormwater Technical Guidance, v1.0.*

California Stormwater Quality Association. 2004. "TC-31 Vegetated Buffer Strip." *California Best Management Practice Handbook- New and Redevelopment.*

LA Stormwater Program. 9 September 2015 <http://www.lastormwater.org/green-la/proposition-o/imperial-highway-sunken-median/>

Swirl Separator

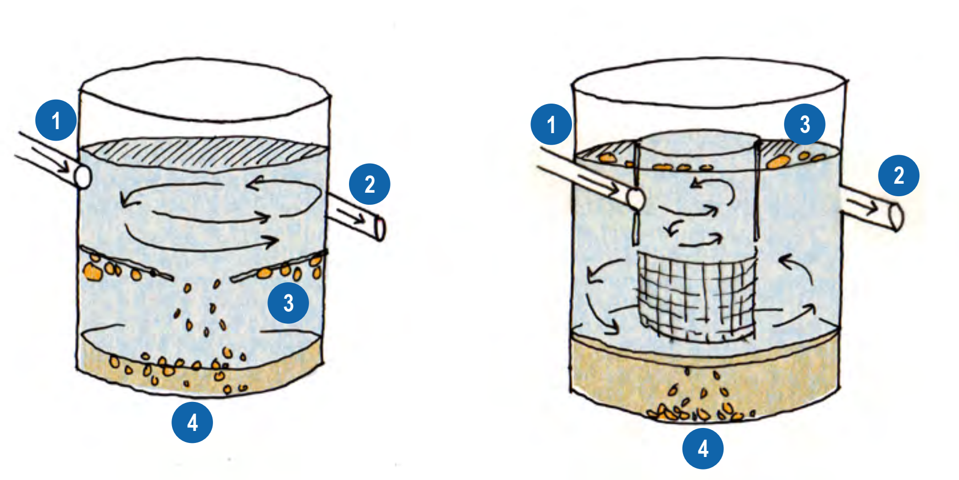
Also known as: vortex separator, hydrodynamic separator, swirl concentrator

Inlet 1

Outflow 2

Floatables 3

Settleables 4

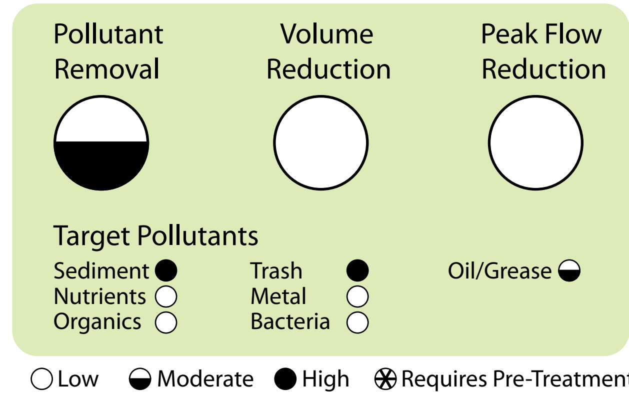


Description

Swirl separators are circular flow-through structures that use a vortex action to separate coarse sediment and floatables (trash, debris, and, in some instances, oil) from stormwater. Manufacturers have developed several proprietary versions of swirl separators for stormwater treatment, all of which function differently and include different internal components. In all devices, stormwater is piped into a round chamber tangential to the side walls, creating centrifugal forces that spin stormwater around the outside of the chamber. Swirl separators are not effective in removing soluble pollutants and smaller, less-settleable solids. They can provide effective pretreatment when paired with other BMPs.

Benefits

- Provides pretreatment by removing coarse sediment and floatables; some models remove oil and grease.
- Low space requirements.
- May provide more cost-effective pretreatment than a traditional wet or dry detention basin.
- Minimal mosquito control issues due to sealed top and inlet configuration.
- Low maintenance costs.



Limitations

- For use as a pretreatment device only; does not meet SMR performance requirements.
- Is not effective for removal of dissolved pollutants, fine sediments, and pollutants that adhere to fine sediment.
- Drainage area is limited by the capacity of the largest models.
- Relatively high capital and installation costs.
- No aesthetic value.
- No habitat value.

Thirteen subsurface swirl separators manage the first flush of stormwater at the Arizona Cardinals Football Stadium, a 120 acre site that is mostly impervious. *Photo: Civil and Structural Engineering Magazine*

Siting

Swirl separators are recommended only as pretreatment devices upstream of other BMPs. Since they are typically installed underground, soil depth and stability, site slopes, and groundwater depth may affect the applicability of swirl separators to different sites.

Design Considerations

Design variations in commercial units: Commercially available swirl separators vary in their geometry, radial baffle design, and internal circular chambers. Generally, a nonturbulent environment that allows particles to settle and floatables to rise, and protection against re-entrainment of settled particles, is considered an ideal condition for treatment. Depth of the unit, which can extend from 3 feet below the inlet pipe up to 25 feet in depth for large units, should also be considered. Consult with manufacturers to determine the best product for the specific site conditions and treatment needs.

Pretreatment: Swirl separators are most effective where pretreatment of coarse sediment and floatables is desired to reduce the treatment burden on downstream BMPs.

Sizing: Depending on the manufacturer, swirl separators can treat design flows from 0.75 to 300 cubic feet per second, with units ranging from 4 feet in diameter for the smallest precast units to 40 feet in diameter for large custom units that may extend up to 25 feet or more in depth.

Online versus offline configuration: Separators can be configured as online or offline devices. If configured as an offline facility, the device is designed to treat the full peak flow of the inlet pipe (hydraulic capacity equals treatment capacity). If the separator is an online facility, however, commercially available units typically have a peak flow through the inlet pipe about four times greater than the flow the device is designed to treat (hydraulic capacity equals four times treatment capacity). Flows that exceed the treatment capacity but not the hydraulic capacity can still pass through the device; however less pollutant removal is achieved. Designers should refer to the manufacturer's specifications to determine whether a product will be able to treat the desired flow.

Inspection and Maintenance

Because there are no moving parts, swirl separators are generally not considered to be maintenance intensive when compared with land-based BMPs such as swales and treatment ponds. However, without regular maintenance, these devices are prone to the following:

- Accumulated sediment reducing available treatment volume;
- Sediment resuspension during high-flow storm events;
- Accumulated floating material being released and discharged during high-flow events; and
- Accumulation of pollutants to the point where contents are characterized as hazardous for petroleum hydrocarbons or soluble metals.

The rate at which each system accumulates pollutants is site-specific, and most manufacturers recommend at least one inspection per month during the first year after installation. Vactor or vacuum trucks are typically used for maintenance, so unobstructed access to the treatment chambers is important to facilitate removal of accumulated pollutants. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*. Maintenance managers should adhere to the maintenance plan specified by the manufacturer of the chosen product.

Swirl separators remove grit and debris from stormwater runoff. Photo: Contech

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Swirl Separators	
Activity	*Schedule*
Determine long-term maintenance schedule by visual inspection of floatables and sediment accumulation and by measurement of sediment deposition rate using a probe or "dipstick."	Monthly during first year of operation
Check inlet and outlet pipes for obstructions.	Annually
Pump out unit and inspect for damage.	Annually
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

Typical Maintenance Activities for Swirl Separators	
Activity	*Schedule*
Remove accumulated sediment, debris, and floatables. Special disposal of floatables may be necessary if petroleum products are present.	Annually or as needed
For proprietary systems, refer to manufacturer's Operations and Maintenance documentation for additional inspection activities.	As needed

References and Resources

Barbaro, Henry L. and Clay Kurison, 2005. "Evaluating Hydrodynamic Separators." Road Ecology Center scholarship Repository, John Muir Institute of the Environment, University of California, Davis.

California Stormwater Quality Association. 2004. "MP-51: Vortex Separator." *California Best Management Practice Handbook- New Development and Redevelopment*.

Civil and Structural Engineering Magazine. 1 September 2015 <http://cenews.com/article/4820/project-case-study-out-of-sight-stormwater-treatment>

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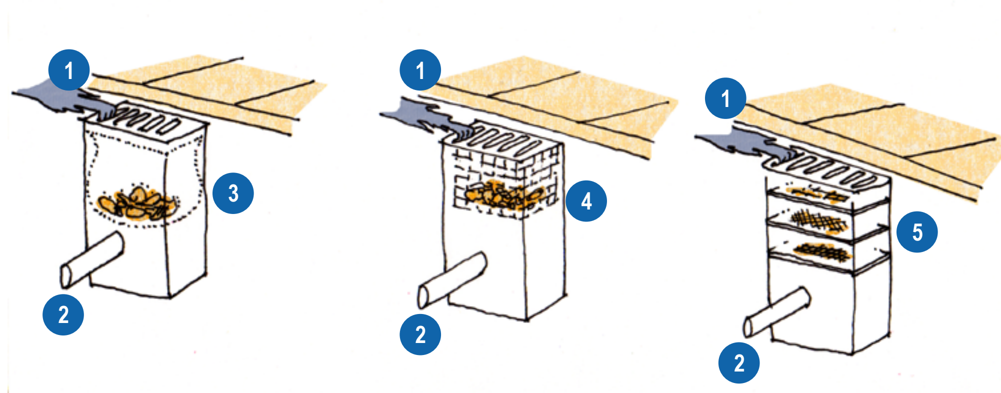
Drain Insert

Also known as: storm drain inlet protection, catch basin insert, baffle box, litter insert



Stormwater enters drain 1

Treated outflow to collection system 2

Debris is caught in polypropylene sack 3

Debris is caught in plastic or metal mesh 4

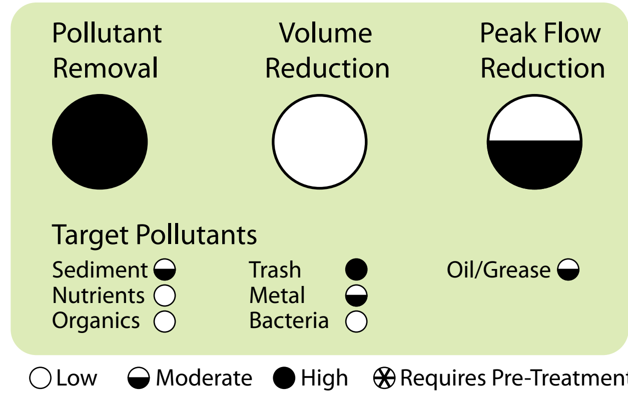
Debris is caught in various filter trays 5

Description

Drain inserts are manufactured filters, fabrics, or screens placed in a trench drain or catch basin to remove sediment and debris. Drain inserts are a flow-through separator technology, designed to provide pretreatment; they do not provide peak flow attenuation or volume reduction. There are three main types of drain inserts: socks, boxes, and trays. A sock insert refers to fabric, usually polypropylene, that attaches either to the inlet frame or to the grate. Socks are meant for vertical (drop) inlets. Boxes are constructed of plastic or wire mesh filled with filtration media. Trays are rows of filtration media held in place by trays or mesh grates. The trays may hold different types of media, including: polypropylene, porous polymer, treated cellulose, and activated carbon.

Benefits

- Low installation and maintenance costs.
- Can be implemented at many types of locations and at many scales.
- Easy retrofit tool.
- Requires no additional space beyond standard drainage system.
- Easy access for inspection and maintenance.
- Minimal risk of mosquito breeding because there is no standing water.
- Captures sediment, metals, and oil and grease.



Limitations

- For use as pretreatment device only; does not meet SMR performance requirements.
- Not suitable for large areas or areas with heavy sediment or litter loading.
- Requires more frequent maintenance than many other BMPs to avoid clogging.
- May require size modification to fit into drain inlets.
- If located on a road shoulder or median, maintenance may require traffic control.
- No aesthetic appeal.
- No habitat value.

Drain insert in a stomrwater catch basin. Photo: EnviroMet

Siting

Drain inserts are recommended only as pretreatment devices upstream of other BMPs. Drain inserts can be installed in nearly any storm drainage system because they require no additional space. Drain inserts are not suitable for large catchment areas or areas with heavy sediment or litter loading.

Design Considerations

Treatment: Pollutant removal varies by type of drain insert. Metal or plastic screens catch sediment, litter, and organic debris. Fabric inserts can trap oil and grease as well as sediment, litter, and debris. Filter inserts generally achieve the highest level of treatment and can target other pollutants that sorb to the solids, such as metals and nutrients. Skimmers and absorbent pads can increase hydrocarbon removal.

Overflow: Flows greater than the design event may bypass the drain insert through the catch basin's curb opening or may overflow from the insert into the catch basin. Clogged inserts can exacerbate flooding.

Installation and sizing: In general, drain inserts are designed to be installed beneath the inlet. They can attach to the inlet grate or to the catch basin frame. However, because most drain inlet products are proprietary technologies, sizing and installation should follow specifications provided by individual manufacturers.

Inspection and Maintenance

Drain insert maintenance is relatively simple, since filter media can be easily removed and replaced. Drain inserts should be inspected and maintained frequently to prevent clogging. During installation, ensure that stormwater enters the unit and does not leak around the perimeter. Leakage between the frame of the insert and the frame of the drain inlet can easily occur with vertical (drop) inlets. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*. Maintenance managers should adhere to the maintenance plan specified by the manufacturer of the chosen product.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Drain Inserts

Activity	*Schedule*
Ensure that stormwater directly enters drain insert without bypassing.	Post-construction
Inspect for clogging or water damage. Ensure that device is free of debris and operational.	Semi-annually
Monitor for sediment accumulation in, and upstream of, the insert.	Semi-annually

Typical Maintenance Activities for Drain Inserts

Activity	*Schedule*
Clean insert and remove debris from upstream side.	Semi-annually or as needed
Modify insert placement if stormwater begins to bypass the drain insert.	Semi-annually or as needed
Replace insert material, dispose of saturated insert properly - may require special disposal if it accumulates heavy metals, oil and grease, or trace organic compounds.	Every 1 to 3 years

References and Resources

California Stormwater Quality Association. 2004. "MP-52: Drain Inserts." *Stormwater Best Management Practice Handbook: New and Redevelopment*.

California Department of Transportation. 2010. "Drain Inlet Insert." Treatment BMP Technology Report (CTSW-RT-09-239.06), pp 33-44.

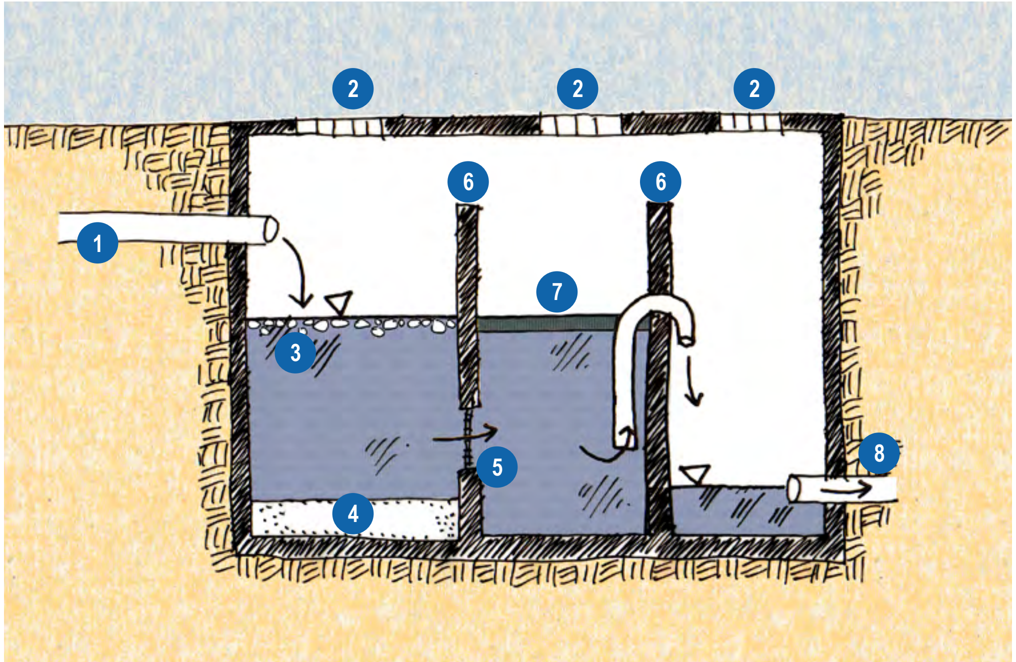
Dawg, Inc. 2015. "Dawgcatcher Drain Inserts." 13 March 2015 <http://www.dawginc.com/dawgcatcherandtrade-drain-inserts.html>.

United States Environmental Protection Agency. "National Pollutant Discharge Elimination System Menu of Best Management Practices Fact Sheets: Catch Basin Inserts." 13 March 2015 <http://water.epa.gov/polwaste/npdes/swbmp/Catch-Basin-Inserts.cfm>.

Water Quality Inlet

Also known as: trapping catch basin, oil/grit separator, or oil/water separator

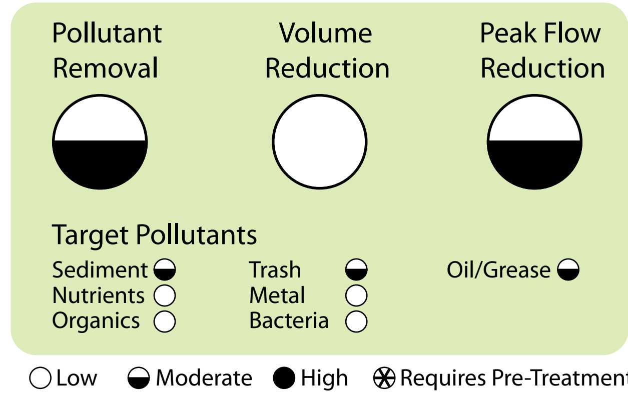
1. Inlet
2. Access manholes
3. Floatables
4. Settleables
5. Trash rack
6. Emergency overflow
7. Oil
8. Outflow



Description

Water quality inlets (WQIs) consist of one or more chambers that promote settling of coarse materials and separation of oil from stormwater. A WQI with a one-hour detention time can be expected to remove 20 to 40 percent of sediments, as well as some hydrocarbons. Some WQIs also contain screens to help retain larger or floating debris, and some of the newer designs include a coalescing unit that helps promote oil/water separation. These devices are effective for capturing suspended solids and hydrocarbon spills, but are not very effective at removing other pollutants found in stormwater runoff such as bacteria, nutrients, metals, and organics. They are best used as a pretreatment device upstream of other BMPs.

Most WQI designs include three vault chambers, with peak flow bypasses and baffles to improve retention of solids and floatables. In a three-chambered configuration, the first chamber captures larger solids, the middle chamber traps oil, grease, and other floatables, and the final chamber collects and discharges the treated runoff.



Benefits

- Effectively trap trash, debris, oil and grease, and other floatables.
- Can provide spill control for contaminated or heavily polluted runoff.

Limitations

- For use as pretreatment device only; does not meet SMR performance requirements.
- Periodic standing water can foster mosquito breeding.
- Limited removal of dissolved pollutants (e.g. nutrients, emulsified oil).
- Pollutants trapped by inlet can re-enter stormwater during subsequent storms.
- Requires frequent cleaning.
- Not effective for large drainage areas.
- No aesthetic value.
- No habitat value.

Siting

Water quality inlets are recommended only as pretreatment devices upstream of other BMPs. They are most effective for drainage areas of 1 acre or less. WQIs are often used in industrial applications such as airport runways, equipment wash down areas, and gas station parking lots. WQIs should be constructed near a storm drain network so that flow can be easily diverted to the inlet for treatment. Inlets can be situated at the ground surface or underground. WQIs should be sited such that vactor trucks can easily access and remove sediment and pollutants.

Design Considerations

WQIs can be configured to receive runoff from a drain inlet grate or from a subsurface storm drain pipe. The piped configuration essentially seals off the permanent pool from the surrounding environment, which reduces the potential for mosquito breeding. They are available as pre-manufactured or cast-in-place units, typically constructed with reinforced concrete. A WQI should be water-tight to prevent possible groundwater contamination.

Overflows and sizing: Typically, WQIs are offline, meaning only diverted flows enter the system as opposed to all stormwater flows. These offline units generally are sized to handle the first 0.5 to 1 inch of runoff from drainage areas, known as the "first flush." Upstream flow splitting structures divert runoff to the offline structure. If designed as an online device, the WQI should be sized for the entire hydraulic capacity of the inlet pipe and should include an internal bypass to redirect high flows around the sedimentation area. This helps prevent re-suspension of settled sediment. Outlet configurations should be sized to drain the design volume within the desired time.

Inspection and Maintenance

WQIs must be regularly inspected, and accumulated sediment, floatables, and hydrocarbons must be removed. A lack of regular clean-outs can lead to re-suspension of settled stormwater pollutants and washout of trapped floatables and hydrocarbons, rendering the WQI ineffective. Because WQIs can accumulate potentially toxic sediments (metals, hydrocarbons, and trace organic compounds adsorb to soil particles), proper disposal in a hazardous waste landfill by trained personnel may be required. For further information on inspection requirements, please see *Chapter 10: Inspection and Enforcement*. Maintenance managers should adhere to the maintenance plan specified by the manufacturer of the chosen product.

The tables below provide more information on typical post-construction inspection and maintenance activities.

Typical Inspection Activities for Water Quality Inlets	
Activity	*Schedule*
Inspect for clogging, erosion, and sediment build-up.	Post-construction
Ensure that system does not cause back-ups or flooding.	Post-construction
Determine long-term maintenance schedule by visual inspection of floatables and sediment accumulation and by measurement of sediment deposition rate using a probe or "dipstick."	Monthly during first year of operation
Keep a log of the amount of sediment collected and date removed.	As needed
Health inspectors should perform routine inspections to prevent mosquito breeding.	As needed

Typical Maintenance Activities for Water Quality Inlets	
Activity	*Schedule*
Remove surface debris and sediment from inlets to avoid clogging.	Semi-annually or as needed
At least twice during each wet season, settled sediment, floatables, and hydrocarbons should be removed by trained operators.	Semi-annually or as needed
Dispose of settled sediment properly - may require special disposal if contaminated with metals or trace organic compounds.	Semi-annually or as needed
Apply vector control treatment to open systems with standing water as needed.	Semi-annually or as needed

References and Resources

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Water Quality Inlet

Source pollutants impact receiving water bodies like Mission Bay in San Francisco. Photo: Brant Ward, The Chronicle

Source Control Resources

Everyday residential, commercial, and industrial activities generate pollutants such as trash, sediment, oil and grease, pesticides, and metals. In the presence of stormwater, these pollutants can become mobilized and transported to the stormwater conveyance system and into our waterways. The presence of pollutants in stormwater discharge can be reduced or eliminated by utilizing pollutant source control measures at the design stage of new and redevelopment projects. Source control BMPs prevent pollutant generation and discharge by controlling pollution at its source, or, at a minimum, limiting pollutant exposure to stormwater.

Both structural source control BMPs (specific design features) and operational source control BMPs (ongoing routines) must be implemented to address source control requirements. Typical structural source control BMPs include covering, berming, or hydraulically isolating potential pollutant source areas. Operational source control measures include routine pavement sweeping or regularly inspecting drains to prevent blockages or overflow. Source control requirements are meant to supplement, not supersede, other San Francisco codes and the feasibility of meeting these requirements may be evaluated on a case by case basis.

To comply with source control requirements, project proponents must identify potential pollutant source areas and implement the associated source control BMPs. The SFPUC has developed the *Source Control Checklist* (available online at www.sfwater.org/smr) as a guide for project proponents to identify potential pollutant sources based on project-specific operations/activities and choose appropriate source control BMPs. To document source control BMP implementation, project proponents must fill out the *Source Control Checklist* and include it in the Stormwater Control Plan (SCP) for submittal to the SFPUC or Port. See *Chapter 9: Stormwater Control Plan Requirements* and the *SCP Instructions* for more information. The *Source Control Checklist* is available for download with the *Technical Report Templates* are available online at www.sfwater.org/smr. Additional source control resources are listed at the end of this chapter.

Stormwater mixed with anything else is considered non-stormwater and any discharge to the stormwater conveyance system not composed entirely of stormwater is prohibited. As a part of the SFPUC's Pretreatment Program, certain commercial or industrial operations, such as restaurants, laundry facilities, or medical offices, may be required to complete an Industrial User Wastewater Discharge Permit. Likewise, wash down of facilities such as a parking garage or vehicle maintenance area may require a Batch Wastewater Discharge Permit. Visit the SFPUC's Wastewater Discharge Permit webpage (http://sfwater.org/index.aspx?page=498) for more information.

Waste yards produce high levels of stormwater pollutants.
Photo: Chesapeake Bay Stormwater Training Partnership

Pollutant Source Areas

A short description of each pollutant source area type is provided below along with a corresponding source control BMP example. Project proponents must identify pollutant source areas at their project site and implement associated source control BMPs, as outlined in the *Source Control Checklist* (available online at www.sfwater.org/smr).

Accidental spills or leaks

Unauthorized and unexpected discharge of waste materials into the stormwater conveyance system can have severe impacts on the system and can pose a hazard to human health and the environment. Appropriate precautionary measures should be in place to prevent accidental discharge of pollutants and to handle such an event should it occur. This may include, but is not limited to, maintaining equipment and storage receptacles, training staff on safe handling of waste materials, ensuring handling and storage of pollutants occurs in designated areas, and posting emergency contact numbers in the event of a spill.

Interior floor drains (separate sewer areas only)

Any indoor activities that produce a non-stormwater discharge must be plumbed to the sanitary sewer system. Steps must be taken to ensure there is no overflow that may accidentally discharge to the stormwater conveyance system. In some cases, a water treatment device may be necessary before discharge is permitted.

Parking/storage areas and maintenance

The short-term or long-term storage of vehicles, equipment, or other items will inevitably lead to the release of toxic and hazardous materials such as oil and grease, vehicle fluids, and general debris, which must not enter the stormwater conveyance system. Providing cover, hydraulically isolating the areas, and minimizing storage space are some strategies for preventing these materials from coming into contact with stormwater runoff. These areas must be connected to the sanitary sewer and may be required to connect to a water treatment device before discharge is permitted. A Batch Wastewater Discharge Permit may need to be completed prior to washing these areas.

Indoor and structural pest control

Unwelcome animals and insects can be a source of bacteria, viruses, and other biologically hazardous materials. Likewise, some pest control measures contribute toxic or hazardous materials that may be equally, if not more harmful should they come into contact with stormwater runoff. Integrated Pest Management is an ecological approach to suppressing pests in an economical and environmentally safe way with low-risk pest control techniques.

Landscape/outdoor pesticide use

Landscaped areas may contain pesticides, herbicides, fertilizers, or sediment, which have major implications on human health and plant and animal life, if they become a part of stormwater runoff. Well-designed planted areas incorporate pest-resistant plant species using appropriate landscaping methods, such that the need for chemical treatment is reduced or eliminated and the plants become well established, thus reducing soil erosion and maximizing infiltration.

Pools, spas, ponds, decorative fountains, and other water features

Recreational and decorative water features may contain nutrients, copper, chlorine, and other contaminants. Additionally, pH levels and high water temperatures may be of concern if discharged improperly. Overflow and drainage of such features should only be connected to the sanitary sewer in separate sewer areas and large volume discharges should comply with the City's Pretreatment Program.

Restaurants, grocery stores, and other food service operations

Fats, oils, and grease (FOG) that result from typical food preparation activities can pose major problems for both the stormwater and sanitary sewer systems alike. These pollutants harden inside pipes, constricting flow and clogging pipes, inevitably leading to overflow of the systems and producing a risk to human health and wildlife. All restaurants and other food service establishments that prepare food must install grease capturing equipment and be permitted in accordance with the City's FOG Control Program. Visit the SFPUC's Commercial Fats, Oils & Grease (FOG) Control webpage (http://sfwater.org/index.aspx?page=480) for more information.

Refuse areas

All refuse areas, no matter the location, can be the source of oils and greases, vehicle fluids, and any number of other hazardous materials that must be disposed of properly. There are a number of structural and operational strategies to ensure that these pollutants are contained and do not come in contact with stormwater.

Industrial processes

Any number of toxic compounds, oils and greases, metals, and other hazardous materials can result from commercial or industrial operations, including activities at dental and medical offices. All storage, treatment, and disposal of hazardous and medical waste materials must be in compliance with the City's Health Code and the Industrial User Wastewater Discharge Permit.

Outdoor storage of equipment or materials

If stormwater comes into contact with stored materials, pollutants can be leached and sediments can be transported out of the storage area. Likewise, pollutants such as oils, metals, and fuels can be washed away by stormwater in areas where machinery or equipment is improperly stored. Depending on site-specific activities, the site may need to comply with the City's Health Code as it relates to storage and handling of hazardous materials and a Batch Wastewater Discharge Permit may need to be completed prior to washing these areas.

Runoff from gardens and lawns can contain high concentrations of fertilizers, pesticides and other chemicals.
Photo: James Lee via Flickr

Loading docks are another source of stormwater pollutants.
Photo: Stormwaterjess

Vehicle and equipment cleaning

The washing of vehicles, tools, cooking equipment, and other equipment, by its definition is intended to remove pollutants. These hazardous materials, such as vehicle fluids, fuel, and battery acid, as well as the soaps and detergents used to remove them, must be disposed of properly and must not be discharged to the stormwater conveyance system. These areas may require secondary containment, canopy or other covering, and onsite treatment, as well as an Industrial User Wastewater Discharge Permit. Onsite water recycling is encouraged.

Vehicle and equipment repair and maintenance

Maintenance and repair activities typically involve the removal and replacement of fluids such as oils, fuels, coolants, and brake fluids, among others, which must be disposed of in accordance with the City's Health Code. These areas should be conducted indoors and may require secondary containment and onsite treatment, as well as an Industrial User Wastewater Discharge Permit. Additionally, a Batch Wastewater Discharge Permit may need to be obtained prior to washing these areas.

Fuel dispensing areas

Typical contamination at fueling stations is caused by leaks and spills of fuels, oils, and coolants, which are hazardous to human health as well as other animal and plant life. There are several key structural and operational strategies to be implemented to ensure that contamination of stormwater does not occur. Power washing of fuel dispensing areas may require completion of a Batch Wastewater Discharge Permit.

Loading docks

Loading and unloading of materials at designated locations will produce incidental spills of liquids and solids and will generate debris. Industrial materials, oils, metals, food products, as well as pollutants from delivery vehicles, are some of the contaminants of concern that must be handled and disposed of safely to ensure there is no contact with stormwater.

Fire sprinkler test water (separate sewer area only)

Water resulting from the testing of fire sprinkler systems is considered non-stormwater and must not be discharged to the stormwater conveyance system.

Drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources

Wastewater or runoff from cooling units, heating units, and other mechanical appliances can contain toxic chemicals, metals, solvents, and other hazardous materials that must not be drained to the stormwater conveyance system. Roof drainage can contain contaminants from paints, coating materials, and roofing materials and must also be handled as a non-stormwater discharge. Directing drain lines and roof drainage to vegetated areas is encouraged.

Unauthorized non-stormwater discharges

Once stormwater is mixed with any other constituent, it is considered non-stormwater and its discharge into the stormwater conveyance system is not permitted. Special precautionary measures must be taken to ensure that staff only discharges stormwater into the stormwater conveyance system and to discourage unsolicited or illegal discharges.

Building and grounds maintenance

A well-developed maintenance program with trained staff members will reduce or eliminate the buildup of debris and pollutant sources, will ensure the continued function of pollution source control measures, and will prevent unauthorized discharges into the stormwater conveyance system

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