Stormwater Retrofit Guidance Manual

PHILADELPHIA WATER
EST. 1801

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Introduction

chapter 1.0

1.0 INTRODUCTION

PURPOSE

The Retrofit Manual is intended to provide property owners with sufficient information to evaluate retrofitting their properties with Stormwater Management Practices (SMPs) in order to better manage stormwater runoff and potentially receive credit towards their stormwater fees. Any property is eligible to pursue and install retrofits; however, only non-residential, condominium, and multi-family properties with more than 4 units are eligible to receive stormwater credits.

A Stormwater Retrofit is defined as the voluntary rehabilitation and/or installation of SMPs on a property to better manage stormwater runoff[1] .

THE PROBLEM

Urbanization has altered the natural landscape and affected the hydrologic cycle. Where the natural hydrologic cycle maintains a balance of water circulation through evaporation, precipitation, infiltration/groundwater recharge, and absorption and transpiration by plants, urbanization has resulted in an altered hydrologic cycle through construction of impervious surfaces such as buildings, roads, and parking lots. The amount of groundwater recharge has been reduced while the volume and rate of runoff has been increased. For decades the philosophy of urban stormwater management was to collect stormwater runoff as quickly as possible, remove it from the surface, and either discharge it directly to a waterway or transport it for treatment and discharge to the rivers. Figure 1 demonstrated the difference in stormwater runoff from natural environments and urban environments. Urban environments with higher amounts of impervious surface create more runoff.

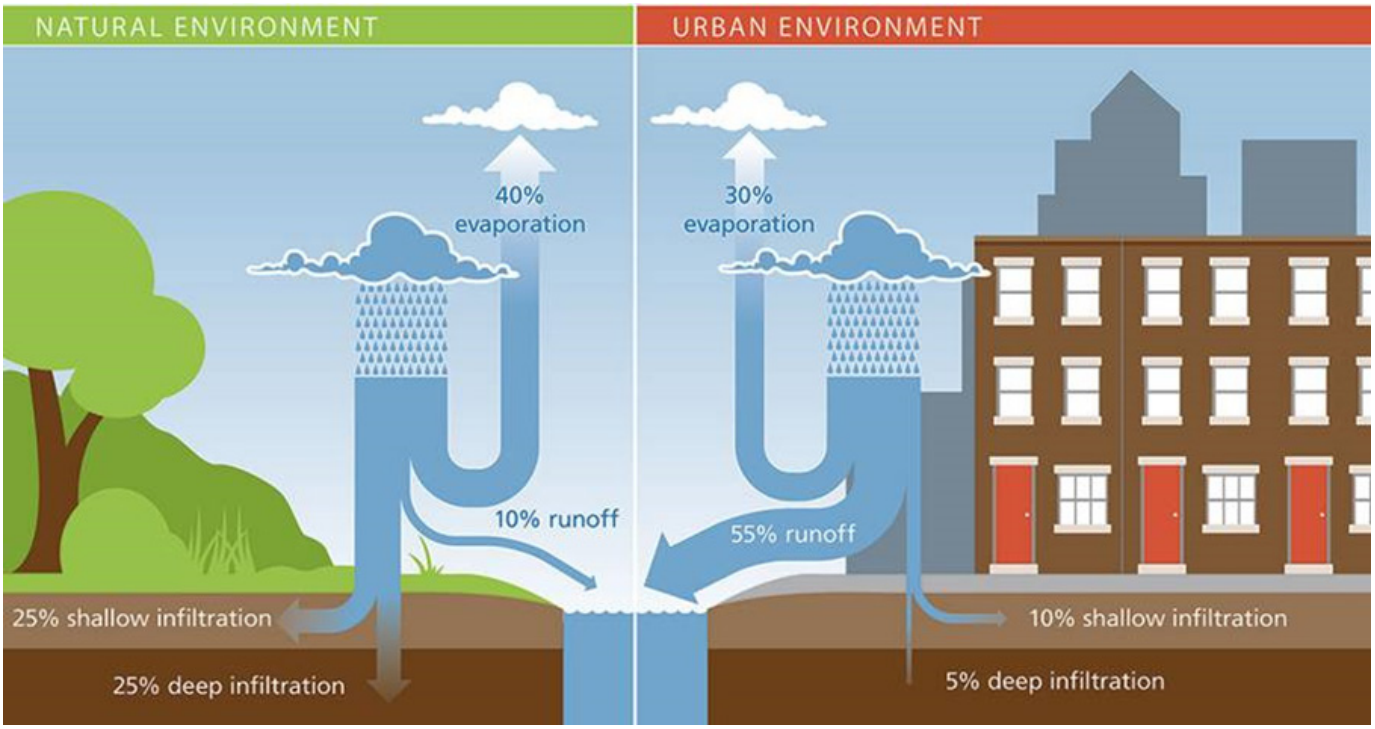


Figure 1: Stormwater Runoff from Natural and Urban Environments.

1 PWD Regulations §600.1.w Stormwater Definitions – Stormwater Retrofit

Within the City of Philadelphia there are over 69 square miles or 44,736 acres of impervious cover. Much of this existing impervious surface contributes excess stormwater runoff to the PWD sewer system and natural waterways.

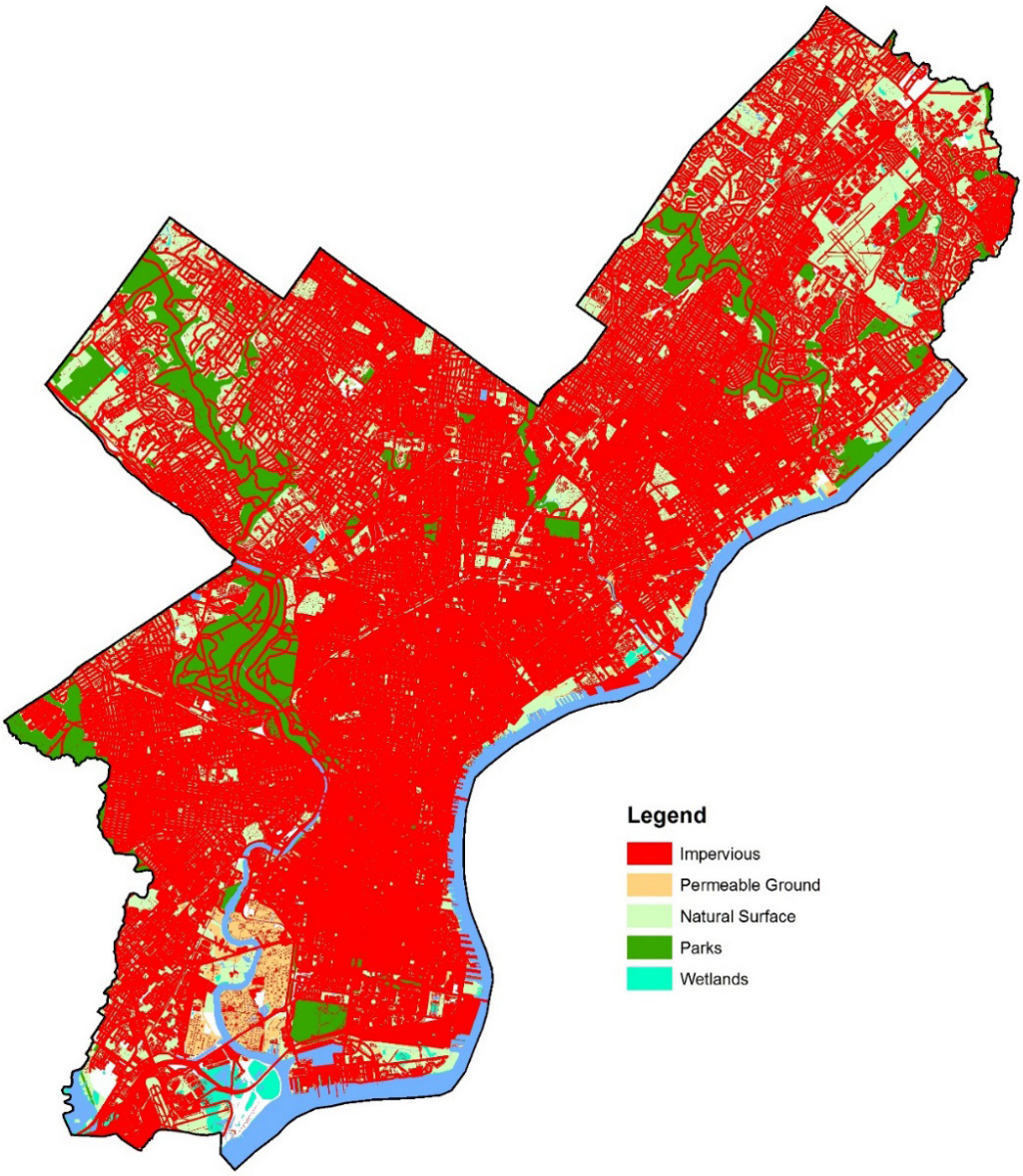


Figure 2: Philadelphia Impervious Area Distribution.

THE SOLUTION

Stormwater Management Practices (SMPs) can easily be integrated into existing landscapes to intercept runoff and provide retrofit opportunities for property owners. SMPs include a range of soil-water-plant systems and subsurface systems that manage stormwater runoff. The SMPs intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some cases, release a portion of the captured stormwater slowly back into the sewer collection system. SMPs treat stormwater runoff as a resource to be incorporated into the urban environment instead of as a waste product requiring removal and treatment. The SMPs covered by this manual are provided in Table 1.

Table 1: Retrofit Stormwater Management Practices

STORMWATER MANAGEMENT PRACTICES (SMPS)	
• Bioretention: Shallow, vegetated depressions used to promote absorption and infiltration of stormwater runoff. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by the plants and trees.	• Planter Box: A vegetated, contained system used to retain stormwater runoff. Stormwater flows into the Planter Box, ponds on the surface, is retained by the soil bed, and is used by the plants and trees. Example provided in Figure 3.
• Swale/Bioswale: An open channel, vegetated with a combination of grasses and other herbaceous plants, shrubs, and trees.	• Tree Trench: A system that provides opportunity for stormwater management within the same surface footprint as previously landscaped areas.
• Porous Pavement: A surface that provides similar load bearing support to that of conventional pavement but allows stormwater to drain directly through the surface.	• Green Roof: A green roof system is composed of multiple layers, including waterproofing, a drainage layer, engineered planting media, and specially selected plants.
• Subsurface Infiltration: Systems that are typically stone filled trenches beneath landscaped or paved areas.	• Cistern: A storage device designed to intercept and store runoff from rooftops typically used for water reuse purposes.
• Dry Extended Detention: Basins whose outlets have been designed to detain stormwater runoff for a minimum amount of time.	

Figure 3: Example of a Bioretention System Which Can Be Used as a Retrofit SMP

There are multiple reasons beyond receiving a stormwater credit that PWD customers may choose to retrofit a property. Some of these reasons include:

- To aid in Philadelphia's commitment to meeting the Greened Acres requirements set forth as part of the Green City, Clean Waters Plan. (http://www.phillywatersheds.org)
- To improve drainage conditions on a property.
- To take advantage of the Triple Bottom Line investment offered by green infrastructure, which adds important environmental and social benefits to the community in addition to the financial incentives, credits, and return on investment realized by managing a parcel's stormwater. Some of these specific benefits are provided below (USEPA 2007):
    - Cleaner Water
    - Enhanced Water Supplies
    - Cleaner Air
    - Reduced Urban Temperatures
    - Increased Energy Efficiency
    - Community Benefits
    - Cost Savings
    - Leadership in Energy and Environmental Design (LEED) Credits

In general, many SMPs provide the ancillary benefits listed above. Figure 4 presents the ways in which several SMPs can be integrated seamlessly into the built environment, thus taking advantage of the full range of benefits that green infrastructure has to offer.

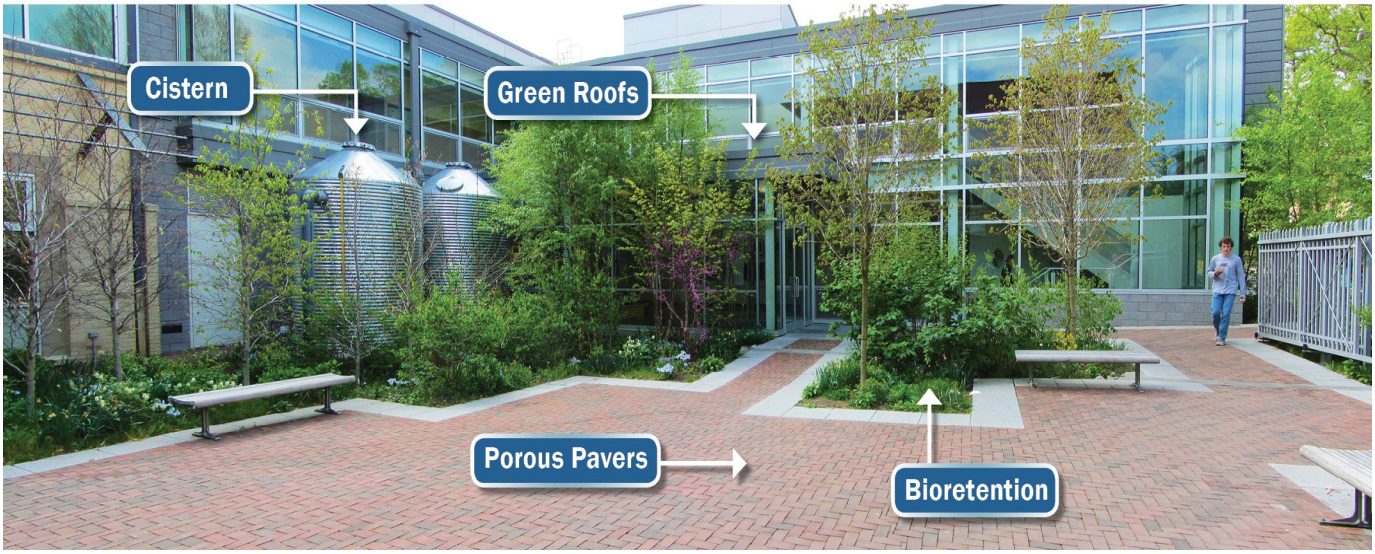


Figure 4: Retrofit Design Utilizing Several SMPs to Create an Aesthetic yet Functional Environment.

The Retrofit Manual

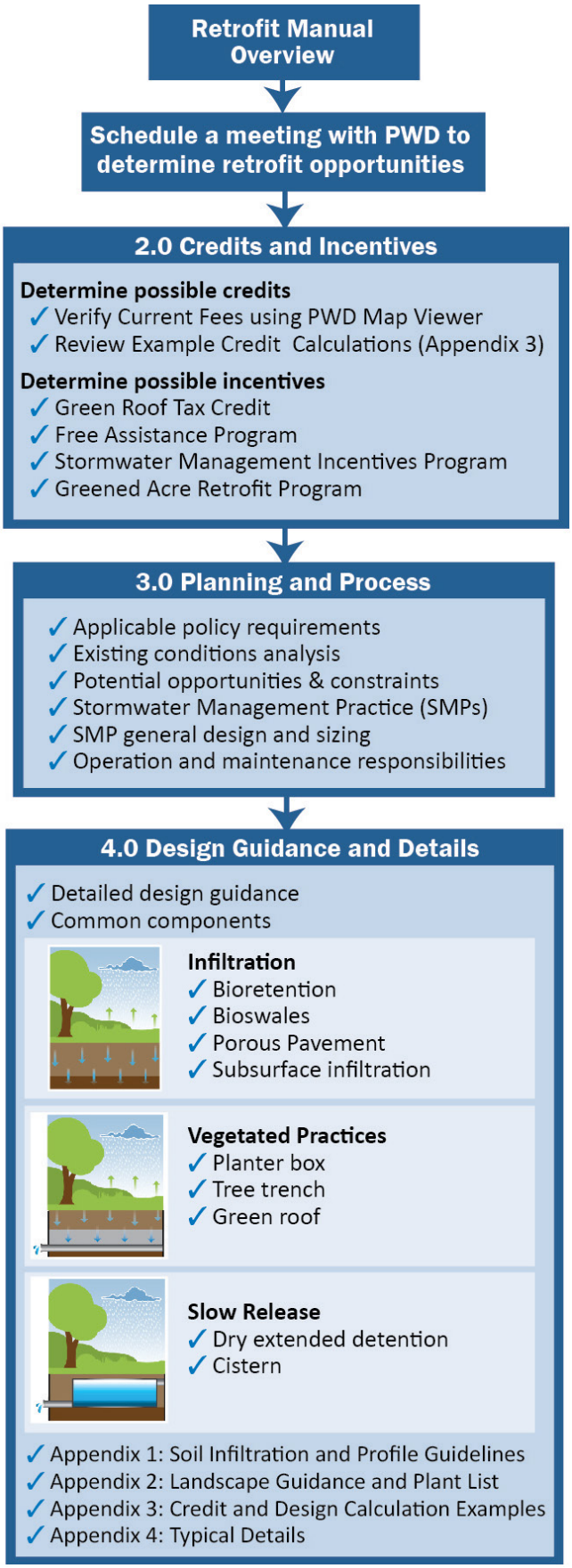
The Retrofit Manual is organized so that the general user may evaluate whether or not to install a stormwater retrofit on their property. The manual is designed to help the user determine what credits and incentives might be available, which SMP retrofit is best for their property, which guidelines and standards must be met, and to understand the general operation and maintenance needs.

Note - This manual pertains only to stormwater retrofits.

The Retrofit Manual is organized as follows:

- Credits and Incentives
- Planning and Process
- Design Guidance and Details
- Soil Infiltration and Profile Guidelines
- Landscape Guidance and Plant Lists
- Credit and Design Example Calculations
- Typical Details

A Retrofit Manual Flow Chart is provided at right that outlines how to use the Retrofit Manual.



Credits and Incentives

chapter 2.0

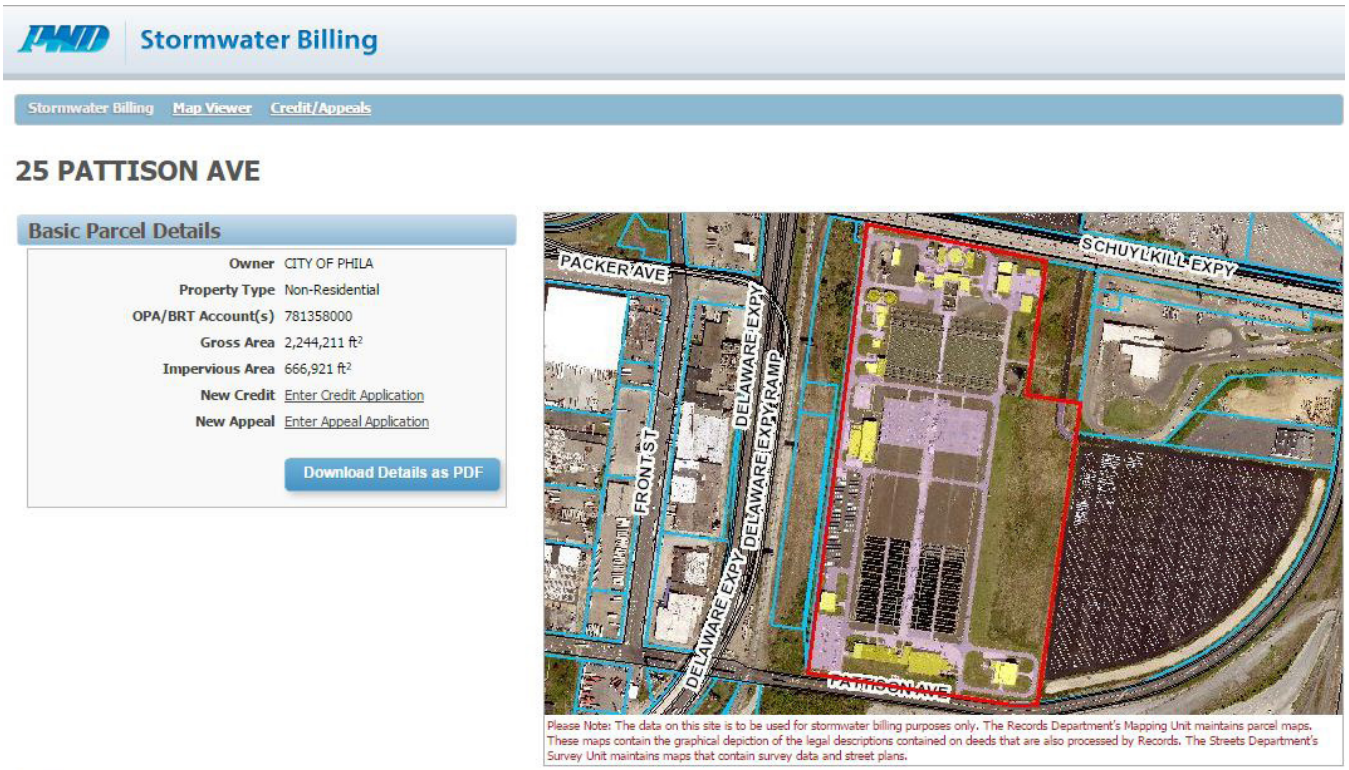
2.0 CREDITS AND INCENTIVES

PWD offers a variety of credits and incentives to encourage the installation of SMPs. PWD recommends that any property owner interested in a retrofit meet with them early on in the process to determine what credits and incentives may be available. PWD also offers a variety of programs that may aid the property owner in evaluating and ultimately constructing a retrofit.

Information regarding a property's current monthly stormwater charge can be obtained using PWD's Stormwater Map Viewer available at the following website:

http://www.phila.gov/water/swmap/

Examples of the map viewer and application from the website are shown below.



Charge Summary

This summary shows monthly stormwater charges phased in during FY 2011 to FY 2014 as the charge transitions from completely meter-based (FY 2010) to completely parcel area-based (FY 2014).

Rate Period (Show All):	Jul 1st, 2011 to Jun 30th, 2012	Jul 1st, 2012 to Dec 31st, 2012	Jan 1st, 2013 to Jun 30th, 2013	Jul 1st, 2013 to Jun 30th, 2014	Jul 1st, 2014 to Jun 30th, 2015
Account # 028-63340-00025-003					
Meter-Based Charge	$1,936.09	$968.04	$1,123.80	$0.00	$0.00
Parcel Area-Based Charge					
Gross Area Charge	$2,370.19	$2,370.19	$2,244.50	$2,513.84	$2,648.51
Impervious Area Charge	$5,561.45	$5,561.45	$5,337.33	$5,999.00	$6,331.16
Subtotal: Gross and Impervious	$7,931.64	$7,931.64	$7,581.83	$8,512.84	$8,979.67
Billing & Collection Charge	$2.65	$2.65	$1.98	$2.15	$2.19
Full Parcel Area-Based Charge	$7,934.29	$7,934.29	$7,583.81	$8,514.99	$8,981.86
Phase-in %	50%	75%	75%	100%	100%
Phased-in Parcel Area-Based Charge	$3,967.14	$5,950.72	$5,687.86	$8,514.99	$8,981.86
Total Stormwater Charge for Account 028-63340-00025-003	$5,903.23	$6,918.76	$6,811.66	$8,514.99	$8,981.86

Figure 5: Map Viewer Screen Shot to Determine Property Stormwater Utility Fee.

Figure 6: Map Viewer Screen Shot to Determine Property Stormwater Utility Fee Potential Credits.

CREDITS

The purpose of the Stormwater Credits Program is to provide non-residential, condominium, and multi-family residential customers the opportunity to reduce their monthly stormwater charge. Charges for stormwater-related services are based upon a property's area and characteristics. The two primary charges are calculated based on the measured amount of Gross Area (GA) and Impervious Area (IA) on a specific property. Stormwater credits can be earned as a result of the construction, operation, and maintenance of SMPs that reduce and/or manage stormwater runoff.

PWD currently offers the following 3 classes of credits:

- Impervious Area Stormwater Credit (IA Credit)
- Gross Area Stormwater Credit (GA Credit)
- National Pollutant Discharge Elimination System Industrial Permit Credit (NPDES Credit)

PWD also offers Impervious Area Reductions (IARs) for SMPs that act like pervious surfaces rather than impervious surfaces.

The Retrofit Manual focuses on the following stormwater management practices:

- IARs through the use of green roofs and porous pavement
- IA and GA Stormwater Credit through the use of SMPs that manage the first inch of runoff in one of the following ways:
    - Infiltration
    - Detention and Slow Release
    - Volume reduction and filtration

A detailed example of a credit calculation using the listed credits is provided in Appendix 3. As a general rule, up to 80% of the stormwater fee can be credited for a given area that is managed with a SMP.

The Retrofit Manual provides detailed guidance on the planning and design of SMPs to achieve the credits listed above.

INCENTIVES

Stormwater incentives offer customers a variety of tools that promote the design and construction of green stormwater infrastructure. By promoting the integration of SMPs, the incentives programs may also aid customers in reducing their monthly stormwater charge.

There are a variety of monetary and non-monetary incentives including tax incentives, free technical assistance, and grants. Below is a list and description of the incentives programs that are currently available.

TAX INCENTIVES

Green Roof Business Tax Credits

The Philadelphia City Council, which has been working to address the cost of stormwater management across the City, passed an ordinance in 2007 granting tax credits to businesses that install green roofs on their buildings. The credit can be claimed against an applicant's Business Privilege Tax for the year in which the green roof is completed. The credit is for 25% of the cost of installing the green roof, up to $100,000. This program is administered by the Philadelphia Department of Revenue. More information can be found here:

http://philadelphiaretail.com/pdf/GreenRoofTaxCredit.pdf

TECHNICAL ASSISTANCE

Concept Design Assistance Program

PWD provides free concept design assistance to property owners interested in obtaining stormwater credits. PWD staff works with property owners through site inspections to identify potential SMP installation opportunities and provide preliminary design recommendations. This program minimizes the up-front costs to customers for the preliminary evaluation and concept design of SMPs and also provides an evaluation of potential credits.

GRANTS

Stormwater Management Incentives Program (SMIP) and Greened Acre Retrofit Program (GARP)

PWD offers two types of grants for property owners to implement SMPs:

1. The Stormwater Management Incentives Program (SMIP) is administered by the Philadelphia Industrial Development Corporation (PIDC) and PWD. SMIP is a grant program that provides direct financial assistance to property owners for the design and construction of SMPs.
2. The Greened Acre Retrofit Program (GARP) is administered by PIDC and PWD. GARP provides funding to project aggregators or companies to construct stormwater retrofit projects on private property in the combined sewer area.

Grant applications are accepted throughout the year, provided available funding. The SMIP and GARP programs are further detailed in Table 2. More information can be found on PWD's website at:

http://www.phila.gov/water/wu/stormwater/Pages/Grants.aspx

Table 2: SMIP and GARP Details

	SMIP	GARP
Areas Eligible for Funding	Any property in City	Combined sewer area only
Recipient of Funds	Property Owner or Authorized Representative	Company/consultant on behalf of property owners
Who Records Operations & Maintenance Agreement	Property Owner	Property Owner(s)
Who Executes Economic Opportunity Plan	Property Owner	Company/consultant
Items Needed for Application	Concept plan, project budget, O&M summary	Concept plan, project budget, Agreements between property owners and company including Design-build contracts and O&M contracts
Maximum Grant Request	$100,000 per impervious acre	$90,000 per impervious acre
Minimum Project Size	None	10 acres

Planning and Process

chapter 3.0

3.0 PLANNING AND PROCESS

PRELIMINARY PLANNING AND DESIGN

Preliminary Planning to determine if a stormwater retrofit is feasible for your property consists of understanding the policy requirements, the basic physical requirements, and possible site constraints for SMPs, as well as the available financial considerations and restraints.

Property owners and/or their representatives are encouraged to meet with PWD early in the retrofit decision making process to help determine eligibility for Stormwater Management Incentives Program (SMIP) funding and other incentives (detailed in Chapter 2.0).

POLICY REQUIREMENTS

Retrofit policy requirements are different than those for new development and redevelopment projects. To provide a clear distinction between new development and redevelopment projects, which are subject to the Stormwater Regulations, and retrofit projects, which are not, PWD refers to the handling of all stormwater retrofit projects as a guidance process. PWD staff is available to provide guidance for eligible retrofits that are seeking credits.

Because a stormwater retrofit does not meet the definition of a development or redevelopment project per the Philadelphia Water Department Stormwater Regulations, retrofits are not required to meet all of the stormwater management requirements as defined in Chapter 6. If the developer is planning to manage impervious area outside of the limit of disturbance in excess of what is required, then the retrofit guidance would generally apply.

If an owner is retrofitting their property in the interest of getting stormwater credits, then the SMP must be designed in accordance with PWD Regulations Section 304.5(c)(1) and (2). The IA/GA managed credit is based on managing the first 1"of runoff.

http://www.phila.gov/water/pdf/pwdregch3.pdf

Table 3: Impervious Area (IA) Management Practice by discharge location

DISCHARGE LOCATION	COMBINED SEWER AREA	SEPARATE SEWER AREA
MANAGEMENT PRACTICE (SMP)		
Infiltrate first 1" of Runoff	●	●
Detain and slow-release the first 1" of runoff	●	
Route the first 1" of runoff through an approved volume reducing practice		●

Note: Infiltration practices are preferred and infiltration testing must be performed on retrofit sites to determine feasibility.

Figure 7 provides a map of Philadelphia's combined sewer area and separate sewer area. To determine your property's sewershed, use the following website:

http://phillywatersheds.org/what_were_doing/documents_and_data/live_data/csocast

Figure 7: Separate Sewer Area and Combined Sewer Area Location.

PRELIMINARY PLANNING PROCESS

A 3 step strategy is recommended for choosing the correct SMP or combination of SMPs for the retrofit. The three steps are:

STEP 1: Identify potential SMP retrofit locations based on existing conditions.

STEP 2: Consider potential SMPs and systems.

STEP 3: Select SMPs and size based on design considerations.

STEP 1: IDENTIFY POTENTIAL SMP RETROFIT LOCATIONS BASED ON EXISTING CONDITIONS

Successful retrofit projects start with a well thought out site layout that makes use of the site's existing opportunities and designs around the site's constraints. Utilizing the existing opportunities within the limitations of the site's existing constraints allows the property owner and designer to achieve maximum stormwater credits in the most cost effective manner.

For example, consider an old building surrounded by turf grass. If the building's roof is flat and can handle a significant increase in structural loading, the site may be perfect for a green roof retrofit. If the roof is steeply sloped or cannot handle additional weight without the risk of collapse, the installation of a green roof would require significant and costly modifications to the building. Instead, the surrounding grass could be converted to a rain garden which receives the runoff from the roof. While the total number of credits earned between the options may vary, the cost/benefit ratio will be higher for sites that work within the existing opportunities and constraints.

SITE OPPORTUNITIES

When identifying site opportunities for retrofit projects, there are several key features to look for, including:

- Downspout discharge locations. Downspouts that discharge directly to the sewer system or onto impervious surface offer opportunities to intercept and direct their discharge onto pervious areas or into proposed SMPs.
- Landscape islands. These islands are typically elevated landscaped areas surrounded by impervious surfaces and provide opportunities for transformation into areas that detain and infiltrate stormwater.
- Turf grass areas. These areas provide opportunities to convert the turf grass into an SMP without the removal of existing structures.
- Rooftops. Rooftops offer the opportunity to construct SMPs in highly developed areas with little ground to actually retrofit.
- Soils: Soils with a high infiltration rate but low organic content offer the opportunity for soil amendments and reuse as growing material in the proposed SMP.
- Pavement Conversion: Removing existing impervious pavement and replacing with a porous pavement stormwater management system and/or creating more green space can provide stormwater management benefits. Surface replacement with porous pavement or green space may result in minimal alteration if surface runoff patterns are appropriate.

SITE CONSTRAINTS

Existing site conditions, including constraints, affect the selection and design of SMPs during a retrofit project. Conditions that may affect the selection and location of SMPs include:

- Property boundaries/adjacent land uses. SMPs must be constructed on the subject property without encroachment or adverse impact to adjacent land uses.
- Existing utilities. Utilities will almost certainly be located near proposed SMPs within highly developed areas. The placement

of a SMP may limit future access to a buried utility that is within or below the SMP. If future replacement or repair is needed, the repair could involve disturbance of the SMP, adding to project costs and potentially damaging the SMP or system. For this reason, all SMPs and systems should be designed to avoid placement above or across utilities to the greatest extent possible. The designer should coordinate with PWD and the affected utility to define the specific project requirements. Installing SMPs with trees under overhead utilities should also be avoided to prevent future conflicts as the trees mature. The designer should request PA One Call information for all potential GSI locations before selecting potential SMP locations. PA One Call can be reached by dialing 811 or calling 1-800-242-1776.

- Existing building footprints. For retrofit projects, existing buildings will likely define the areas on the property available for proposed SMPs. Designers are encouraged to be creative and fit proposed SMPs into the existing landscape and parking areas surrounding building or on rooftops as available. Adequate separation from adjacent buildings or structures must be maintained to avoid potential basement flooding or damage to buildings when infiltration SMPs are planned.

- Existing drainage patterns. Retrofit projects are most cost effective when the only alteration to the property is the installation of the SMP. This means that the SMP should be placed in the existing drainage path in order to effectively intercept runoff. Diversion structures and conveyance piping may need to be installed if that is not feasible.

- Low infiltration rates and poor quality soils. Poorly draining soils are common constraints in retrofit projects. Construction activities can leave the soil compacted due to the weight of the construction equipment, and in many cases, the original topsoil has been removed to create a stable and flat foundation for development. In locations where the natural infiltration rate of the soil at the proposed bottom elevation of the SMP is less than 0.5 inches per hour (see Appendix 1 for infiltration testing requirements), additional design elements will be needed.

- A high groundwater table. High groundwater may be a constraint on retrofit projects, especially those within mapped floodplains or lowland areas. If the groundwater table is high enough, it may saturate subsurface storage areas and dramatically lower infiltration rates, reducing the effectiveness of the SMPs. In extreme cases, underdrains may actually drain the high water table and greatly increase the load on the receiving sewer system. Another concern with high water tables is that pollutants from roofs, parking lots, and streets can easily enter the water table easily through receiving SMPs. In all of these cases, infiltration based SMPs may not be suitable for retrofit projects unless they are altered to work within the given site constraints.

- Hotspots. These areas can potentially contain contaminated soil or groundwater and may produce high levels of pollutants. Hotspots are generally inappropriate locations for infiltration based SMPs. It is also crucial to identify any hotspots or brownfields within close proximity to a proposed retrofit to ensure that no contaminated runoff enters the proposed SMP. See Appendix 1 for a detailed hotspot evaluation protocol.

- Maintenance concerns. Maintenance concerns are a common constraint for stormwater retrofits. All SMPs require inspections and some maintenance to continue to function as designed. Proposed SMPs should be in easily accessible areas to ensure that it is feasible to perform the routine inspection and maintenance activities. Additionally, each site is unique and generates different levels of debris and pollutants in the runoff. For example, urban areas may generate a lot of paper and trash, while wooded areas may generate tree branches and a large volume of leaves. The inlet and outlet structures of the proposed SMPs should be designed to handle anticipated debris loading. In highly polluted areas, hardy plant species may be needed to withstand the pollutant loads of the watershed.

The constraints discussed above are not an exhaustive list, as each site possesses its own challenges and requirements. The key is to become knowledgeable of the site's existing condition so that the most appropriate SMPs can be chosen. Design details related to specific constraints are covered in Chapter 4 Design Guidance and Details.

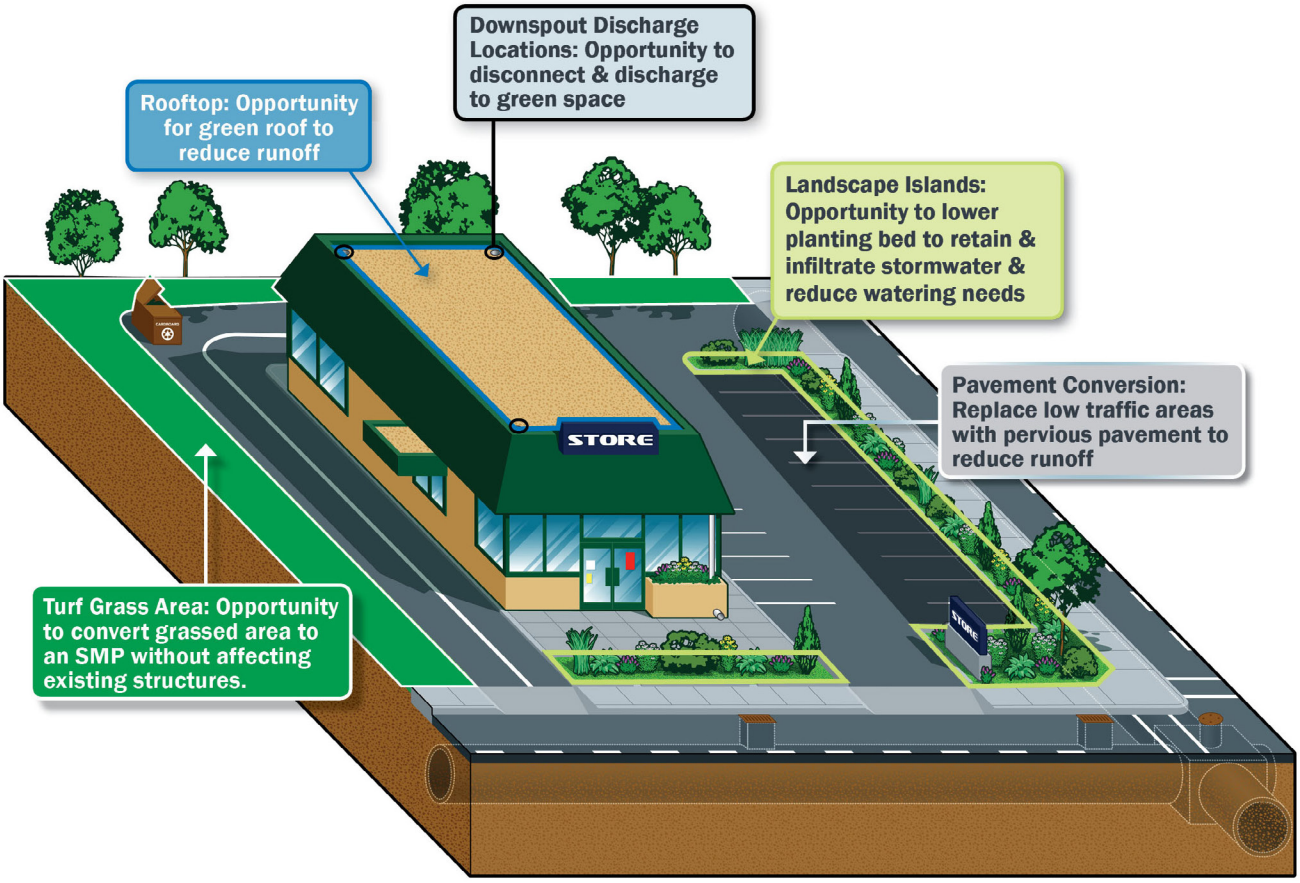


Figure 8: Site Opportunities

STEP 2: CONSIDER POTENTIAL SMPS AND SYSTEMS

HIERARCHY OF SMPS

SMPs that more effectively achieve triple bottom line goals are preferred. The following SMP hierarchy seeks to promote retrofits that:

- Reduce stormwater and pollutants entering the PWD collection system,
- Are likely to be maintained and have indicated longevity in previous installations,
- Are feasible to implement, in terms of both cost and site layout, and
- Provide vegetation to create a greener Philadelphia.

In order of preference, the hierarchy for SMPs is as follows:

- Infiltration Practices
- SMPs that direct stormwater through Volume Reducing Practices and then into Detention Practices
- Detention Only Practices (applicable in CSS area only)

When selecting a SMP it is important to determine how the SMP is intended to function and what potential credits can be achieved through the retrofit. Table 4 lists each of the SMPs and their potential to achieve Impervious Area Stormwater Credits and Impervious Area Reductions.

Table 4: SMP Applicability and Credit Potential

SMP	CREDIT APPLICABILITY			
	IMPERVIOUS AREA MANAGEMENT CREDIT*			IMPERVIOUS AREA REDUCTION
	INFILTRATE FIRST 1" OF RUNOFF	DETAIN AND SLOW RELEASE FIRST 1" OF RUNOFF	ROUTE THE FIRST 1" RUNOFF THROUGH AN APPROVED VOLUME-REDUCING PRACTICE	
Rain Garden/Bioretention/Infiltration	●	●	●	
Swale/Bioswale	●	●	●	
Porous Pavement				●
Subsurface Infiltration	●			
Flow Through Planter Boxes		●	●	
Tree Trenches	●	●	●	
Green Roof				●
Cisterns - Capture and Reuse		●		
Dry Extended Detention Basin		●		

* Impervious Area Management Credits receive a reduction in both Impervious Area (IA) charges and an equivalent reduction in the Gross Area (GA) charge associated with the retrofit project.

STEP 3: SELECT SMPS AND SIZE BASED ON DESIGN REQUIREMENTS

After determining the existing opportunities, the on-site constraints, and the potential SMPs that can meet the retrofit goals, the next step is to choose and size the SMPs that have been selected. The methodology for sizing and designing the system depends on the discharge location and the SMP utilized to manage impervious area. The methods to obtain credits are described in Table 3 and design guidance is further described in the following section.

SMP DESIGN OVERVIEW

SMPs must be designed to meet the following requirements in order to be eligible for stormwater credits. Detailed sizing requirements and guidance are provided in the following chapters. Note – infiltration testing is required on all retrofit sites in order to determine the feasibility of infiltration practices.

Infiltration Practices (Infiltration Feasible On-site, Combined and Separate Sewer Areas):

1. Provide static storage of the Water Quality Volume (Equation: 1) below lowest outlet from SMP.
2. Confirm that the SMP footprint meets the 10:1 loading ratio requirements.
3. Provide appropriate overflow for larger storm events.
4. Verify that the Water Quality Volume infiltrates and the system drains within the acceptable 72-hour period.

Volume Reducing Practices (Infiltration Not Feasible, Separate Sewer Area):

1. Verify that 100% of the Water Quality Volume (Equation: 1) is routed through a PWD-approved volume-reducing stormwater management practice.
2. Provide static storage of the Water Quality Volume and positive drainage via an underdrain or other outflow device.
3. Confirm the SMP meets the 10:1 loading ratio requirements.
4. Verify the system meets Channel Protection requirements per 600.5(b) of PWD's regulations by detaining runoff from a 1-yr 24-hr Natural Resources Conservation Service (NRCS) Type II design storm between 24 and 72 hours.
5. Provide appropriate overflow for larger storm events.
6. Verify that the system drains within the acceptable 72-hour period.

Detention and Slow Release Practices (Infiltration Not Feasible, Combined Sewer Area):

1. Confirm that the release rate for the Water Quality Volume (Equation: 1) is less than 0.05 cfs/acre (Equation: 2) based upon the contributing impervious area to the SMP retrofit by providing static storage of the Water Quality Volume in such a manner that the head acting on the selected outlet device does not exceed the maximum allowable head associated with the target slow release rate. This will require an adjustment to the SMP footprint area.
2. Provide appropriate overflow for larger storm events.
3. Verify that the system drains within the acceptable 72-hour period.

SMP SIZING REQUIREMENTS AND RECOMMENDATIONS

WATER QUALITY VOLUME

All SMPs must meet Water Quality Requirements as listed in Equation 1 (Eqn: 1). This equation requires that the SMP must capture and infiltrate the Water Quality Volume, which is equivalent to one (1) inch of runoff over a given impervious area. Equation 1 defines this volume as:

$$WQ_v = \left(\frac{P}{12}\right) * (IA) \quad Eqn: 1$$

Where:

WQ_v = Water Quality Volume (cubic feet)

P = 1.0 inch

IA = Impervious Area Managed (square feet)

The IA treated by the SMP is eligible for IA/GA Credits.

The Water Quality Volume must be infiltrated by the SMP at a rate of at least 0.5 inches per hour and no greater than 10 inches per hour (refer to Appendix 1 for infiltration guidelines).

RELEASE RATE FOR WATER QUALITY VOLUME

In areas where infiltration at the designated rates is impossible, an alternative water quality requirement must be met and is dependent on whether the SMP is installed in a combined or separate sewer area. In combined sewer areas, the SMP must detain and release the Water Quality Volume back into the combined sewer area at the following rate:

$$Q_{CSS} = 0.05 * \left(\frac{IA}{43{,}560}\right) \; Eqn: 2$$

Where:

Q_{CSS} = SMP discharge rate in CSO areas (cubic feet per second)

IA = Impervious Area Managed (square feet)

SIZING RECOMMENDATIONS FOR DETENTION

Sizing a detention system begins with determining the slow release rate requirement using Eqn: 2. Upon determination of the slow release rate requirement, the following method can be utilized to size a system:

- Select an appropriate orifice size to meet the release rate..
- Determine the maximum allowable head (depth) on the orifice that will meet the WQ slow release rate requirement using Eqn: 3.

$$H_{max} = \left(\frac{Q_{CSS}}{C_d * A}\right)^2 \Big/ (2 * g) \; Eqn: 3$$

..

Where:

H_{max} = Maximum allowable head on a chosen orifice to meet WQ discharge requirements (feet)

Q_{CSS} = SMP discharge rate in CSO areas (cfs) from Eqn: 2

C_d =Discharge Coefficient – Approximately 0.60 (for circular openings)

A = Orifice Area (square feet)

g = Gravity (32.2 ft/sec^2)

- Use Eqn: 4 to size the basin footprint to statically store the Water Quality Volume at the depth determined using Eqn: 3.

$$F = \frac{WQ_v}{H_{max}} \; Eqn: 4$$

Where:
F = Static Storage Footprint (square feet)
H_{max} = Maximum allowable head on a chosen orifice to meet WQ discharge requirements (feet)
- WQ_v = Water Quality Volume (cubic feet)

ADDITIONAL DESIGN AND SIZING GUIDANCE

All SMPs must be sized to statically store the Water Quality Volume. This volume may be stored above ground as ponded areas or below ground in soil and clean stone media layers. The storage available in the three layers is summarized below:

- Surface storage – maximum ponding depth of 2 feet
- Soil media – minimum depth of 1 foot, assumed 20% void space available for storage
- Clean Stone media – assumed 40% void space available for storage

Storage volumes are calculated by multiplying the square foot of SMP footprint by the depth of storage layer and by the percent void space where necessary. The Water Quality Volume Requirements may be met using a single storage layer or a combination of all three, depending on the opportunities and constraints of the site.

PWD recommends that SMPs be designed with a loading ratio of 10:1 or lower, meaning no more than 10 square feet of impervious area can drain to each square foot of SMP. PWD recognizes some projects may need leeway in this regard. In these instances, project designers should work directly with PWD to finalize the sizing of their SMPs.

The tables provide a simplified solution for sizing SMPs that ensures:

1. The SMP area meets the maximum 10:1 contributing drainage area to surface area loading ratio requirement; and
2. The SMP provides adequate storage for the WQV.

The tables allow the designer to select a combination of surface ponding, soil media storage, and stone storage to meet the design requirements as well as address site specific design concerns. Table 5 is for bioretention, bioswale, and planter SMPs without stone storage. Table 6 includes 12" of stone storage below the selected design cross section for those SMPs. Table 7 is for stone storage within subsurface infiltration basins or porous pavement systems. Cistern storage volumes are based on the geometry of the reservoir, and green roof storage should be determined in conjunction with the roof system supplier and designer.

For example, using the 10:1 loading ratio, a SMP with a contributing drainage area of 1000 square feet would need to have a minimum surface area of 100 square feet or greater to comply with the loading ratio requirement (item 1 above). In order to also provide sufficient static storage (item 2 above), the cross section of the SMP would need to include a minimum of 6" of surface ponding and a minimum of 24" of planting soil.

If site specific conditions dictate a shallow cross section due to utility conflicts, bedrock, or high water table, the surface area of the SMP can easily be increased and the depth decreased. As shown in the exhibit below, a SMP with 6" of surface ponding and 12" of planting soil requires an area of 119 square feet to comply with both items 1 and 2.

Table 5: Vegetated SMP Sizing Table (No Stone Storage)

VEGETATED SMP SIZING TABLE										
FOOTPRINT (SQUARE FEET) FOR WQ VOLUME										
BIORETENTION, BIOSWALES, PLANTERS - NO STONE STORAGE										
Surface Area		0" surface ponding				6" surface ponding		12" surface ponding		24" surface ponding
Impervious Area Managed (square feet)	Minimum Bottom Bed Area Required @ 10:1 loading ratio	Required Area @ 12" Soil Depth (square feet)	Required Area @ 18" Soil Depth (Square feet)	Required Area @ 24" Soil Depth (square feet)	Required Area @ 36" Soil Depth (squarefeet)	Required Area @ 12" Soil Depth (squarefeet)	Required Area @ 18" Soil Depth (Squarefeet)	RequiredArea @ 24" or Greater Soil Depth(square feet)	RequiredArea @ 12" or Greater Soil Depth(square feet)	Required Area @ 12" or Greater Soil Depth (squarefeet)
500	50	208	139	104	69	60	52	MINIMUM SURFACE BOTTOM AREA PER 10:1 LOADING RATIO APPLIES		
1000	100	417	278	208	139	119	104			
1500	150	625	417	313	208	179	156			
2000	200	833	556	417	278	238	208			
2500	250	1042	694	521	347	298	260			
3000	300	1250	833	625	417	357	313			
3500	350	1458	972	729	486	417	365			
4000	400	1667	1111	833	556	476	417			
4500	450	1875	1250	938	625	536	469			
5000	500	2083	1389	1042	694	595	521			
6000	600	2500	1667	1250	833	714	625			
7000	700	2917	1944	1458	972	833	729			
8000	800	3333	2222	1667	1111	952	833			
9000	900	3750	2500	1875	1250	1071	938			
10,000	1,000	4167	2778	2083	1389	1190	1042			
15,000	1,500	6250	4167	3125	2083	1786	1563			
20,000	2,000	8333	5556	4167	2778	2381	2083			
21,780	2,178	9075	6050	4538	3025	2593	2269	1/2 Acre		
43,560	4,356	18150	12100	9075	6050	5186	4538	1 Acre		
Note: Table assumes soil void ratio of 0.20										

Table 6: Vegetated SMP Sizing Table (Stone Storage)

VEGETATED SMP SIZING TABLE								
FOOTPRINT (SQUARE FEET) FOR WQ VOLUME								
BIORETENTION, BIOSWALES, PLANTERS - WITH 12" OF STONE STORAGE BELOW SOIL								
Surface Area		0" surface ponding				6" surface ponding	12" surface Ponding	24" surface Ponding
Impervious Area Managed (square feet)	Minimum Bottom Bed Area Required @ 10:1 loading ratio	Required Area @ 12" Soil Depth (square feet)	Required area @ 18" Soil Depth (Square feet)	Required area @ 24" Soil Depth (square feet)	Required area @ 36" Soil Depth (square feet)	Required area @ 12" or Greater Soil Depth (square feet)	Required area @ 12" or Greater Soil Depth (square feet)	Required area @ 12" or Greater Soil Depth (square feet)
500	50	69	60	52	MINIMUM SURFACE BOTTOM AREA PER 10:1 LOADING RATIO APPLIES			
1000	100	139	119	104				
1500	150	208	179	156				
2000	200	278	238	208				
2500	250	347	298	260				
3000	300	417	357	313				
3500	350	486	417	365				
4000	400	556	476	417				
4500	450	625	536	469				
5000	500	694	595	521				
6000	600	833	714	625				
7000	700	972	833	729				
8000	800	1111	952	833				
9000	900	1250	1071	938				
10,000	1,000	1389	1190	1042				
15,000	1,500	2083	1786	1563				
20,000	2,000	2778	2381	2083				
21,780	2,178	3025	2593	2269	1/2 Acre			
43,560	4,356	6050	5186	4538	1 Acre			
note: table assumes a soil void ratio of 0.20 and a stone void ratio of 0.40								

Table 7: Stone Storage

STONE STORAGE SMP SIZING TABLE					
FOOTPRINT (SQUARE FEET) FOR WQ VOLUME					
POROUS PAVEMENT, INFILTRATION TRENCHES, SUBSURFACE STONE GALLERIES					
Impervious Area Managed	Minimum Surface Bottom Area Required @ 10 to 1 loading ratio	Required area @ 12" stone depth (square feet)	Required area @ 18" stone depth (Square feet)	Required area @ 24" stone depth (square feet)	Required area @ 36" stone depth (square feet)
500	50	104	69	52	MINIMUM SURFACE BOTTOM AREA PER 10:1 LOADING RATIO APPLIES
1000	100	208	139	104	
1500	150	313	208	156	
2000	200	417	278	208	
2500	250	521	347	260	
3000	300	625	417	313	
3500	350	729	486	365	
4000	400	833	556	417	
4500	450	938	625	469	
5000	500	1042	694	521	
6000	600	1250	833	625	
7000	700	1458	972	729	
8000	800	1667	1111	833	
9000	900	1875	1250	938	
10,000	1,000	2083	1389	1042	
15,000	1,500	3125	2083	1563	
20,000	2,000	4167	2778	2083	
21,780	2,178	4538	3025	2269	1/2 Acre
43,560	4,356	9075	6050	4538	1 Acre
note: table assumes a stone void ratio of 0.40					

SMP SELECTION AND MODELING

After calculating storage and discharge requirements and comparing those to the available SMP footprint space, loading rates, and potential storage options, the designer is ready to finalize and size the SMP that best matches the site. More guidance on specific SMPs can be found in section 4.0.

For slow release systems, the final design and configuration of the proposed SMPs should be modeled and verified using HydroCAD or similarly acceptable software. Volume reducing practices can be routed to verify that the Channel Protection Requirement is met.

PLAN SUBMITTAL, REVIEW, AND APPROVAL PROCESS

All proposed stormwater retrofit projects must go through PWD's retrofit review and approval process to ensure the proposed project meets the requirements for stormwater credits. Figure 9 shows the general phases of the process. The requirements and phases of this process are specific only to voluntary stormwater retrofit projects and may vary based on site conditions or proposed SMPs. Note that an engineer licensed in the state of Pennsylvania is required to sign off on all projects.

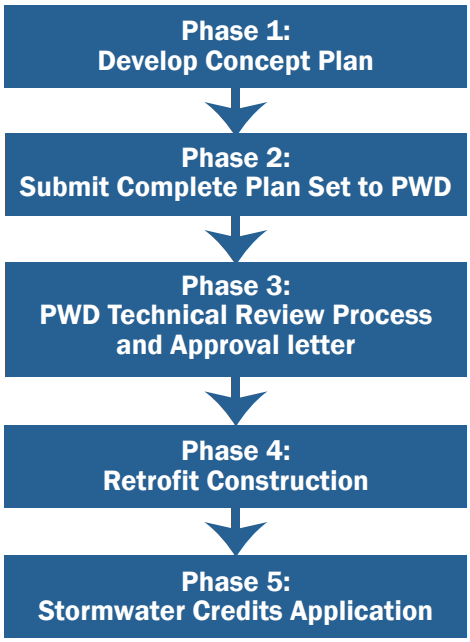


Figure 9: General Retrofit Workflow.

The property owner/engineer is encouraged to work directly with a credits reviewer at PWD. It is important to note that retrofit projects may be eligible for the free concept design assistance program. Contact PWD early in the process to fully utilize this assistance. The below provides general information needed for retrofit projects.

The first phase of the submittal and review process is the submission of a concept plan. A concept plan is required for all retrofit projects.

The general requirements for the Concept Plan include the following:

- Engineer Name, Date, and Project Title;
- Site address
- Name of Owner
- North Arrow, Legend and Graphical Scale
- Existing and Proposed Topography/Contours
- Parcel Boundary
- Existing Site Features and Conditions
- Proposed Site Improvements
- SMP Type(s) and Area (s)
- Drainage Area to each SMP
- Conveyance to each SMP
- Overflow from each SMP
- New Connections

The second phase of the submittal and review process is to submit a completed plan set for review. This completed plan set must be signed and sealed by a licensed engineer in the state of Pennsylvania. Furthermore, for projects in which the earth disturbance exceeds 5 acres, a NPDES permit must be obtained from the PADEP. General submittal requirements include:

- Erosion and Sediment Control (E&S) Plan,
- Proposed Site Plan,
- Existing Conditions Plan,
- Drainage Area Plan,
- Post Construction Stormwater Management Plan (PCSMP)
- Stormwater/Construction Details Plan
- Landscape Plan
- Geotechnical and/or Infiltration Report
- Operations & Maintenance Schedule

The E&S Plan must be kept on site for inspections at all times. This plan must show the limits of disturbance and the sequence of construction as well as any other standard requirements called out in the above Manual.

All projects, regardless of disturbance area, are required to provide an E&S plan for review. All E&S Plans must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines as specified in the following Manual:

PADEP, Bureau of Watershed Management, April 15 2000. Erosion and Sediment Pollutant Control Program Manual. Document 363-2134-008.

The Proposed Site Plan should include property lines, building footprints, and the proposed retrofit.

The Existing Conditions plan depicts the conditions of the site prior to disturbance. This plan should show all buildings, property lines, utilities, and sewers.

The Drainage Area Plan should show the drainage boundaries based on the post construction drainage areas. The drainage area that each SMP is managing should be delineated on the drainage area plan.

The Stormwater/Construction Details Plan must cover all of the engineering and design elements proposed throughout the submittal including pipe connections, E&S measures, and design components of the retrofit. A thorough and comprehensive list of details will help expedite the review process and help ensure proper installation of the retrofit. The designer is responsible for ensuring that the Stormwater/Construction Details Plan meets all of the requirements of the PADEP Erosion and Sediment Pollultant Control Manual.

The third phase is the Retrofit Approval Letter. This phase occurs after all agencies approve the design. For projects in which the earth disturbance exceeds 5 acres, a NPDES permit must be obtained from the PADEP. A pre-construction meeting is necessary before any construction begins.

The fourth phase of the submittal and review process is Retrofit Construction. During this phase, PWD will be performing inspections throughout construction on all projects. Projects that are required to do so must have a copy of the E&S Plan on-site at all times and must be in compliance with that plan. As-built plans are required for all projects and must be completed before the contractor has demobilized from the site.

The fifth and final phase of the process is the Credit Application. The applicant must complete Form B, Stormwater Credits Application, which must be signed by a registered professional. Along with Form B, the applicant must submit the as-built plan set. The as-built plans must still meet the accepted design standards. Changes to the submitted and approved plan set need to be pre-approved. There is an application fee of $150 to apply for stormwater credits (this fee is waived for PWD grant funded projects).

OPERATIONS AND MAINTENANCE PLAN

Routine inspection and maintenance is crucial to ensure the continued function of a SMP. A failing SMP increases stormwater loading on the sewer system, contributing to basement backups and combined sewer overflows into nearby rivers. It is the responsibility of the property owner to inspect and maintain their SMP.

Maintenance and inspections are a requirement to keep and renew credits for all retrofits. If the project is a grant funded retrofit, an Operation and Maintenance (O&M) Agreement needs to be signed and filed with Philadelphia Department of Records. PWD will provide the property owner with an O&M Plan and a Maintenance Log template with the final Retrofit Guidance letter. The Maintenance Log should be used to keep track of all maintenance and inspection activity and should be submitted with the credits and credits renewal applications.

Routine inspections should occur at least four (4) times per year. These inspections help identify maintenance action items and help prevent a minor issue from becoming a costly repair. Typical inspections look for clogs, erosion, unhealthy plants, and the loss of storage area. It is encouraged to perform other inspections throughout the year, especially during large rain events. A properly functioning SMP allows water to enter through a designed inlet, holds water in a designated place to allow for infiltration or reuse, and has a designed overflow for excess water during large storms. If flow into and through the system does not occur as designed, it is likely the sign of required maintenance.

Routine maintenance tasks often include trash and sediment removal to prevent clogging; establishment watering to help new plants survive; erosion repair including slope stabilization, planting, and minor re-grading; pruning during winter months; and weeding during the first two years to help the specifically chosen plants survive and become established. Table 9 identifies the basic SMP Maintenance Tasks.

Further information on specific SMP maintenance requirements can be found in Section 4 and example inspection and maintenance logs can be found in the City of Philadelphia's SMP Retrofit Operation and Maintenance Manual.

Table 9: Basic SMP Maintenance Tasks

	MAINTENANCE TASK	BASIC MAINTENANCE	TROUBLE SHOOTING
	Remove trash, sediment, & debris	Most trash, sediment, and debris can be removed easily using a shovel, rake, or shop vac. However, subsurface pipes or porous pavement that become clogged may need to be vacuumed with special equipment.	If trash or sediment are frequently building up within your SMP, you might need to consider where they are coming from. You may need to consult a professional to determine the best course of action.
	Water plants during first 2-3 years of establishment	During the months of June through September, water during any period of four or more consecutive days of dry weather.	If plants appear brown, dry, or wilted between watering or after full establishment, it may be necessary to increase the watering schedule.
	Repair eroded areas	Replace washed-out soil and stabilize the area with stone and/or additional plantings.	If erosion is persistent, consider stabilizing slopes using turf matting, or slowing the flow of stormwater using alternative engineered systems. You may need to consult a professional to determine the best course of action.
	Prune trees & shrubs	Dead, broken, or undesirable limbs should be pruned when the tree or shrub is dormant, usually in the months of January or February.	If growth of trees or shrubs creates a conflict with pedestrian areas or utilities, significant pruning of healthy limbs may be needed.
	Weed, mow, or cut excess vegetation	Aggressive vegetation is best controlled by hand or using mechanical tools. Avoid the use of pesticides, as these can wash through the system during rain.	If dense vegetation becomes an ongoing problem, either for aesthetic or clogging reasons, it may need to be replaced with a less aggressive variety. You may need to consult a landscape professional to select alternative species.
	Replant/reseed	Dead or missing plants can be replaced using nursery stock or a simple seed mix. New plants should be watered and kept clear of trash and debris to ensure establishment.	If bare areas persist despite replanting efforts, there may be a deeper problem. Erosion, contamination, or simply poor quality soil could all impact plant survival. If this is the case, consider stabilizing or replacing soil, redirecting water flow, amending soil, or alternate plant selection.
	Repair settled areas or soil voids	Stabilize and fill small soil voids with stone and/or soil using simple hand tools. If voids are located near pedestrian or vehicular travelways, mark the area using flags or cones until the problem can be addressed.	If large or recurring voids are present in your SMP you may need to consult a professional to determine the best course of action.
	Call a professional	You may encounter problems that you aren't able to solve yourself. If an issue is recurring or you can't find its source, you may need to enlist the services of a trained engineer, landscaper, or utility investigator.	

Design Guidance and Details

chapter 4.0

DESIGN GUIDANCE AND DETAILS

GENERAL DESIGN STANDARDS

General design standards are provided for Common Components and each SMP. Common Components consists of pretreatment systems, inlet and outlet controls, flow diversion structures and common materials. The common components will be used in several of the SMPs. The SMP chapters are organized to provide the following information and make design as seamless as possible:

General Background

- Location
- Design Guidance
- Vegetation and Materials
- Suggested Operation and Maintenance

In addition, each SMP has an accompanying typical detail that is provided in Appendix 4.

4.1 COMMON COMPONENTS

4.2 BIORETENTION

4.3 SWALES/BIOSWALES

4.4 POROUS PAVEMENT

4.5 SUBSURFACE INFILTRATION

4.6 FLOW THROUGH PLANTER BOXES

4.7 TREE TRENCHES

4.8 GREEN ROOFS

4.9 CISTERNS-CAPTURE AND REUSE

4.10 DRY EXTENDED DETENTION

Common Components

chapter 4.1

4.1 Common Components

There are several components common amongst most Stormwater Management Practices (SMPs). In many instances the materials utilized such as storage stone, geotextile separation fabric, underdrains, soil, mulch, plantings as well as pretreatment systems, energy dissipation elements and observation wells are similar for a wide variety of SMPs. The intent of this section is to provide a brief summary of the design standards and materials specifications associated with these common components. Standard details for pretreatement, cleanouts, observation wells, diversion structures, and outlet control structures are provided in Appendix 4 – Typical Details.

In general a SMP will have the following:

1. Inflow and Pretreatment System: An inflow system brings stormwater from hard surfaces into the SMP. It generally consist of inlets, piping, sloped ground, curb turnouts and/or open channels that allow the water to flow to the SMP. Pretreatment systems are intended to capture floatables, debris, grease, oils, silt, and sediment where they can easily be cleaned via regular maintenance, and before they can adversely impact the performance of an SMP – such as clogging the SMP and preventing infiltration.
2. Storage: Storage is the primary component. For all SMPs, runoff must be temporarily stored before it can either be infiltrated, released back into the local collection system (CSS or Separate Sewer) or discharged to a surface water body. The storage area may be a planted area with engineered soil, a cistern, or an underground vault. Storage areas include common components such as mulch, soil, stone, geotextile, and underdrains. Within the storage area it is also common to have observation wells to manage the performance and maintenance needs of the SMP.
3. Diversion Structures: Diversion structures can regulate the flow into an SMP, direct the desired runoff of volume to the SMP and divert larger storm events around the SMP. In the case of retrofits, diversion structures can be used to capture the first inch of runoff and convey it to the SMP; larger runoff of events such as those from flooding level events (i.e. the 100-yr storm) can be safely transported to the downstream conveyance system without overloading the retrofit SMP.
4. Outlet Control Structures: A control structure regulates the flow of water out of the storage area.
5. Outflow System: An outflow system allows water to flow from the storage area or control structure back to the city sewer and usually consist of piping or open channels.

Figure 4.1.1: Common Elements of an SMP.

The remainder of this section describes in detail:

- Inflow/Pretreatment
- Diversion Structures
- Materials
    - Geotextile fabric
    - Distribution Pipe
    - Storage Stone
    - Underdrains
    - Soil
    - Mulch
    - Vegetation
- Observation Well
- Inlet and Outlet Control Structures

INFLOW/PRETREATMENT

Inflow systems can be used to control flow into a system and help to minimize erosive forces which might damage the SMP. Pretreatment systems can be used to collect pollutants and enhance long-term performance of SMPs.

At SMP flow inlet locations, install controls to meet energy dissipation requirements and provide pretreatment.

- It is important to prevent coarse sediments, floatables and debris from entering subsurface infiltration systems, as they could contribute to clogging and failure of the system.

- It is also important to distribute concentrated flows and reduce runoff velocity before stormwater is introduced into the SMP

- The following are acceptable forms of pretreatment:
    - Roof leader sump, or an intermediate sump box
    - Roof gutter guard Filter Strips
    - Vegetated Swales
    - Forebays -Forebays should be sized to contain 10% of the overall volume of stormwater directed to the SMP.
    - Inlet sumps - Inlet sumps should be sized to have one cubic foot of storage for every 100 square feet of impervious are draining to it.
    - Inlet filter inserts

Roof leader sumps and gutter guards are often used in conjunction with cisterns or systems directly connected to subsurface infiltration. Filter strips, vegetated swales, forebays and inlet sumps most often serve SMPs with direct surface runoff such as bioretention, bioswales, and planters. Typical details for inflow and pretreatment are provided in Appendix 4. Additional guidance is provided in the Inlet and Outlet Control Section, later in this section.

DIVERSION STRUCTURES

Diversion structures can be used to capture and direct the first inch of runoff from contributing drainage areas to a SMP and allow larger storm events to bypass the SMP entirely, preventing the system from being overloaded. Typical diversion structures include:

- Downspout Diverters
- Flow Diverters
- In-line Weirs
- Orifices

Diversion structures sized to capture the first inch of runoff can be sized using the Rational method or by routing the NRCS Type II Design Storm.

RATIONAL METHOD

Size splitters and overflow weirs for the appropriate flowrate, using the following parameters for the Rational method:

$$Q = CIA$$

Q= Flowrate (ft^3/s, cfs)

I = Rainfall Intensity of 2.5 inches/hr

A= Drainage Area (acre)

C = Rational Runoff Coefficient – the Rational method runoff coefficient (c) is a function of the soil type and drainage basin slope.

Choose appropriate runoff coefficients based on the Engineer's best judgment of land use type. Recommended assumptions to obtain conservative results using the Rational method include:

For pervious areas with rational coefficients less than 0.2, use a coefficient of 0.2.

Use a runoff coefficient value of 0.35 for pervious areas and a value of 0.95 for impervious areas.

ROUTING METHOD

Sizing a diversion structure by routing a hydrograph should utilize a 2.04 inch 24 hour NRCS Type II design storm and appropriate calculation methods or computer programs such as HydroCAD.

The use of diversion structures might be beneficial in bioretention, subsurface infiltration basin or water reuse SMPs when minimizing flow through the system may be desirable.

GEOTEXTILE FABRIC

Geotextile fabric is commonly used within SMP design to separate out drain layers or prevent soil from migrating into storage media and potentially clogging the available storage. In some instances such as hotspot locations, it may be desirable to line the SMP with an impermeable liner which prevents stormwater from migrating into the surrounding and underlying soil. They can help to ensure the long-term functionality and help in ongoing maintenance and upkeep of SMPs. The two basic types include woven and non-woven geotextiles as well as the aforementioned impermeable liners.

Non-Woven Geotextiles:

Non-woven geotextiles have excellent filtration and drainage characteristics and allow for separation of materials without trapping water.

- Geotextile separation fabric shall consist of needled non-woven polypropylene fibers and meet the following properties

Grab Tensile Strength (ASTM-D4632)	≥ 120 lbs
Mullen Burst Strength (ASTM-D3786)	≥ 225 psi
Flow Rate (ASTM-D4491)	≥ 95 gal/min/ft2
UV Resistance after 500 hrs (ASTM-D4355)	≥ 70%

Note: Heat-set or heat-calendared fabrics are not permitted

WOVEN GEOTEXTILES

Woven Geotextiles are most often used for load distribution and separation of dissimilar materials in roadway and retaining wall applications. Depending on the existing subsurface conditions and desired roadway strength, both woven and non-woven geotextile could be used in a permeable pavement application.

- Geotextile fabric used for permeable pavement applications should meet the manufacturers' requirements.

IMPERMEABLE LINERS

Impervious liners prevent water from infiltrating. There are four primary types: compacted till liners, clay liners, geomembrane liners and concrete liners.

- Regardless of material choice the permeability must be less than or equal to 10^{-7} cm/sec.
- The Stormwater Management Manual for Western Washington is recommended for more information on choosing and designing impervious liners.

DISTRIBUTION PIPE

Distribution pipe can be used to evenly spread runoff throughout subsurface SMPs to prevent the system from overloading one portion of the bed.

- Distribution pipe within the subsurface storage bed should be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches.
- High density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

STORAGE STONE

Stone can be utilized to provide additional storage of stormwater runoff within the cross-section of a SMP, when it is not possible to store the full WQV on the surface of the practice. This may be practical in constrained bioretention systems or planter box installations or when it is desirable to minimize surface storage.

Stone used to provide a storage reservoir shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 57.

- Stone shall be separated from soil medium by a non-woven geotextile or a pea gravel filter.

UNDERDRAINS

Underdrains can be used to collect runoff within SMPs when infiltration is not feasible or when a secondary outflow path is desirable in the event of failure. Consider an underdrain under the following conditions:

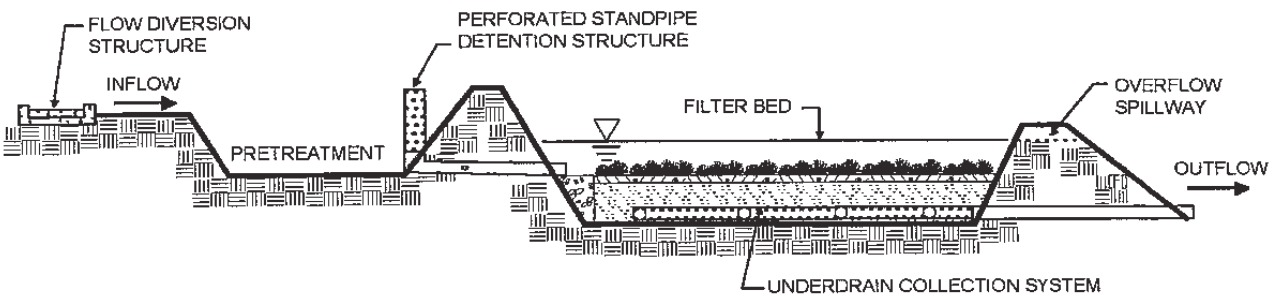
- In areas where infiltration is not feasible (See Appendix 1: Soil Infiltration Guidelines) or;
- In combination with other SMPs where the system as a whole meets storage and release criteria.

Pipe used for an underdrain shall be dual wall, continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

For retrofits designed to meet WQ slow release rate requirements, check that the outflow from the underdrain meets the release rate requirements for the contributing drainage area. If necessary, an orifice can be added within the underdrain system to further control outflow.

Underdrains are conduits, such as perforated pipes and/or gravel-filled trenches that intercept, collect and convey stormwater that has percolated through soil, a suitable aggregate, and/or geotextile. Perforated underdrains are an outlet control because they collect water and convey it to a system outlet. Underdrains may be used in combination with other techniques such as layering of porous media to regulate outflow. They can also be connected to an outlet structure that then controls the ponding elevation or release rate through weirs or orifices. The following criteria is suggested for the design of underdrains:

- A permeable filter fabric is placed between the gravel layer and surrounding soil to prevent sediment contamination.
- Clean out access must be provided for all underdrain systems.
- Underdrain pipes are spaced a maximum of 10 feet on center.



SOIL

Soils play an important role in both infiltration and volume reducing SMPs. Engineered soil is a mixture of different soil types that are combined together to produce a specified planting soil that is a fertile growing medium for vegetation in SMPs while providing infiltration characteristics suitable for stormwater management purposes. Testing shall be conducted within the bioretention area to determine appropriate amounts and types of soil additives. The soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

Planting soil should meet the following specifications:

- Have a permeability of at least 1.0 feet per day (0.5 inches per hour).
- Be free of stones, stumps, roots, brush, seeds from weeds or branches over 1 inch in diameter.
- Depending on the quality, existing soils can be adjusted to meet bioretention composition requirement by combining 20-30% existing/native soil with 20-30% compost and 50% sand.
- For engineered soils, the soil media should meet the following specifications:

  Texture of planting soil should conform to the classification within the USDA triangle for Sandy Loam or Loamy Sand. Planting soil should be a mixture of sand, silt, and clay particles as required to meet the classification. Ranges of particle size distribution, as determined by pipette method in compliance with ASTM F-1632:

  - Sand (0.05 to 2.0 mm) 50 - 85%
  - Silt (0.002 to 0.05mm) 40% maximum
  - Clay (less than 0.002mm) 10% maximum
  - Gravel (2.0 to 12.7 mm) 15% maximum

If existing site soils require amendments to meet the required specifications, an appropriate stockpile and mixing location should be provided. Amendments should be obtained from a reputable commercial source, tested and visually inspected to ensure consistent material is provided. Identified proportions of clay, sand and/or organic compost should be thoroughly mixed into the stockpile and tested until the results meet outlined requirements. Organic compost shall conform to the following minimum specifications:

- Organic compost shall be a commercially manufactured humus product that is dark, crumbly, fine textured decayed organic matter specifically manufactured for use as a soil amendment to promote vegetative growth. Organic amendments shall be well aged, and contain no visible admixture of refuse or other physical contaminate nor any material toxic to plant growth.
- Carbon/nitrogen ratio shall be between 12:1 and 25:1.
- Degree of maturity: composted organic matter shall be considered stable as determined by the Solvita compost maturity index. Compost must achieve a maturity index of 6 or better, indicating a curing active compost.
- Organic content shall be 40% minimum on a dry weight basis as determined by loss of ignition
- Particle size: 100% shall pass the ½ or smaller screen
- pH of the finished composted organic matter shall be near 7.0, and be within the range of 6.0 to 8.0
- Salinity: soluble salts shall be <4.0 mmhos/cm
- Ammonium content: Ammonium shall be less than 400 ppm on a dry weight basis

If any of the components of the soil have been treated with weed killer, confirm that appropriate time has passed based on manufacturer's recommendations prior to planting.

Planting soil should be placed be in layers of 12-18 inches, loosely compacted. It is important to follow the installation guidelines for the SMPs to ensure that the infiltrative capacity of the underlying soils is protected.

MULCH

Mulch helps prevent erosion and provides an environment suitable for beneficial soil organisms to thrive at the mulch/soil interface. For mulch, the following requirements apply:

- Grass clippings are not a suitable material for mulch.
- Any more than 3-4 inches of mulch can negatively impact growing conditions and cause excessive nutrients to leach into the SMP.
- Manure mulching and high-fertilizer hydroseeding are prohibited in a SMP area during and after construction.
- Organic mulch shall be aged, double-shredded hardwood bark mulch or composted leaf mulch.
- Mulch shall be free of weeds and shall be placed on bioretention surface to a depth of 2-3 inches.

Figure 4.1.5: Mulch is important for plant health.

VEGETATION

Plants play an important role in both infiltration and volume reducing SMPs. They provide volume reduction through water uptake and their roots keep soil loosened, providing deeper infiltration pathways.

Plants that are appropriate for soil, available water, light, and other site conditions should be selected. The intent is to establish a diverse, dense plant cover to reduce pollutants in stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and sun exposure. The proper selection and installation of plant materials is the key to a successful garden.

Plantings can be selected from the list of native species provided in Appendix 2.

Consider the following recommendations when selecting vegetation:

- Plants should have high salt tolerance if bioretention area receives runoff from ground level impervious surfaces (i.e. roads & parking lots).
- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
- Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens.
- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation

OBSERVATION WELL

Observation wells provide access for inspecting the system, as well as a means to dewater the system in the event of a failure. Observation wells should be installed for any SMP with subsurface storage.

An observation well should:

- Be located at the center of the SMP to monitor water drainage from the system;
- Include a lockable above ground cap, and;
- Provide adequate inspection and maintenance access to pump out water from the subsurface system, in the event of failure.

Appropriately sized PVC cleanouts can be used as observation wells.

Figure 4.1.6: Vegetation adds both a function and aesthetic value to SMPs.

Figure 4.1.7: Cleanout and observation wells are important to keep SMPs functioning properly.

Inlet and Outlet Controls

Figure 4.1.8: Outlet Riser

Inlet and outlet controls are the structures or landscape features that manage the flow into and out of a stormwater management facility. Flow splitters, level spreaders, curb openings, energy dissipaters, traditional inlets and curbless designs are all examples and elements of inlet controls. Outlet controls regulate the release of stormwater from a management facility. Examples of outlet controls include risers and orifices, underdrains, weirs, positive overflows and impervious liners. Outlet control structures limit flow to meet release rate requirements and bypass larger flows to prevent re-suspension of sediment, hydraulic overload or erosion of management practices.

Key elements:

- Inlet Controls:
  - Flow splitters divert a portion of flow generated by a storm event to a management facility, while allowing the remainder of the flow to bypass the facility.
  - Curbless roads, streets and parking lots allow stormwater to sheet flow into a SMP.
  - Curb openings allow water to flow through a curb that would otherwise block the flow.
  - Level spreaders spread out concentrated flow and release it as low-velocity, non-erosive diffuse flow.
  - Large-scale energy dissipaters slow down and spread flow from culverts and steeper slopes.
- Outlet Controls:
  - Risers and orifices release ponded water at a reduced rate, and control the storage capacity/peak water surface elevation of the SMP.
  - Positive overflows allow stormwater to safely flow out of an SMP.
  - Underdrains collect water that has filtered through a porous medium and convey it to an outlet.

INLET CONTROLS

FLOW SPLITTER

Flow splitting devices are used to direct a portion of the runoff produced from a contributing drainage area into a stormwater management facility, while excess flows from larger events bypass the facility. The bypass typically connects to another stormwater management facility or to the receiving drainage system, depending on the design and management requirements. This type of inlet control may also sometimes serve as the positive overflow for the SMP.

Flow splitters can be constructed by installing diversion weirs in stormwater control structures such as inlets and manholes. On a larger scale, they can be constructed using concrete baffles in manholes. Example designs for larger-scale flow splitters are shown in Figures 4.1.9 through 4.1.11. Smaller-scale designs operate using a similar concept.

DESIGN CRITERIA

There are two basic components involved in the design of flow splitters: the elevation of the bypass weir, which is based on the maximum ponding elevation in the SMP, and capacity of the pipe to and from the SMP, which controls the maximum flow the SMP can receive and discharge.

Bypass Elevation:

The elevation of the bypass baffle or weir dictates the maximum elevation of the water in the SMP. The bypass elevation can be selected by setting it equal to the design storage elevation in the SMP. Flow will only start to bypass the SMP once it exceeds the design storage level of the SMP. The water level in the SMP may exceed the design level for large infrequent storms that utilize the bypass, so the SMP should provide adequate freeboard to prevent overflow.

Pipe Capacity.:

The capacity of the influent and effluent pipes can also limit flow into and out of the SMP. Controlling flows in this fashion can help to minimize erosion and scour in the SMP and at the outlet structure. At a minimum, all new conveyance pipe must provide capacity for the peak runoff from the 10-year, 24-hour rainfall with a NRCS (Natural Resources Conservation Service) Type II distribution, without surcharging (as specified within §14.1603.1 Stormwater Controls of the Philadelphia Code). Adequate bypass capacity should be provided for conveyance of larger storms.

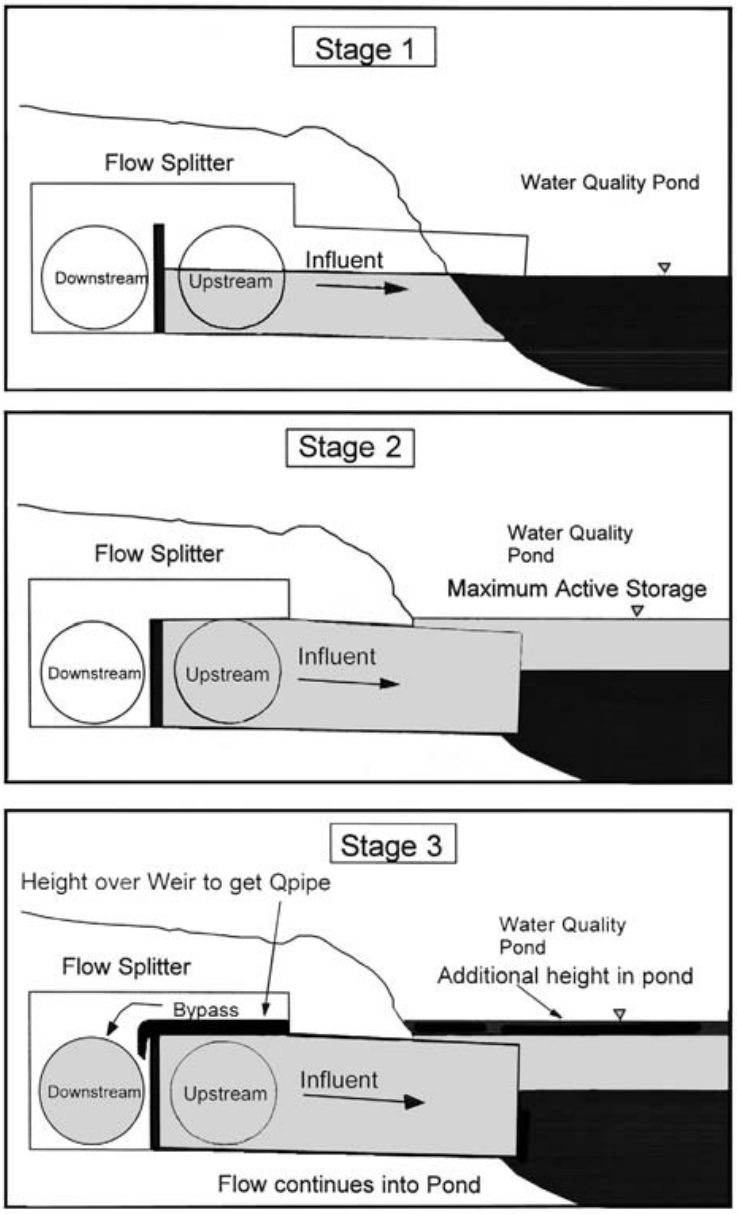
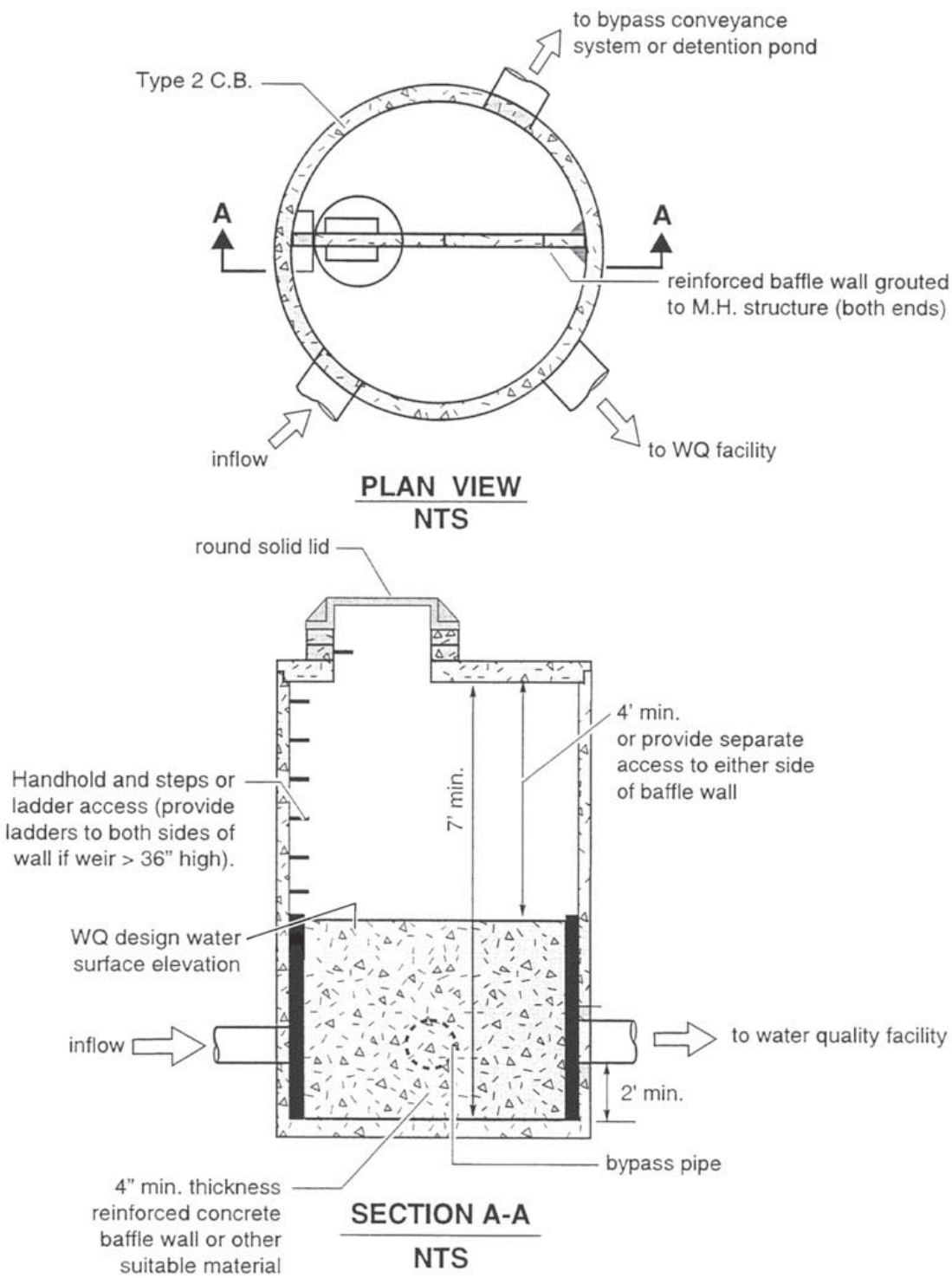
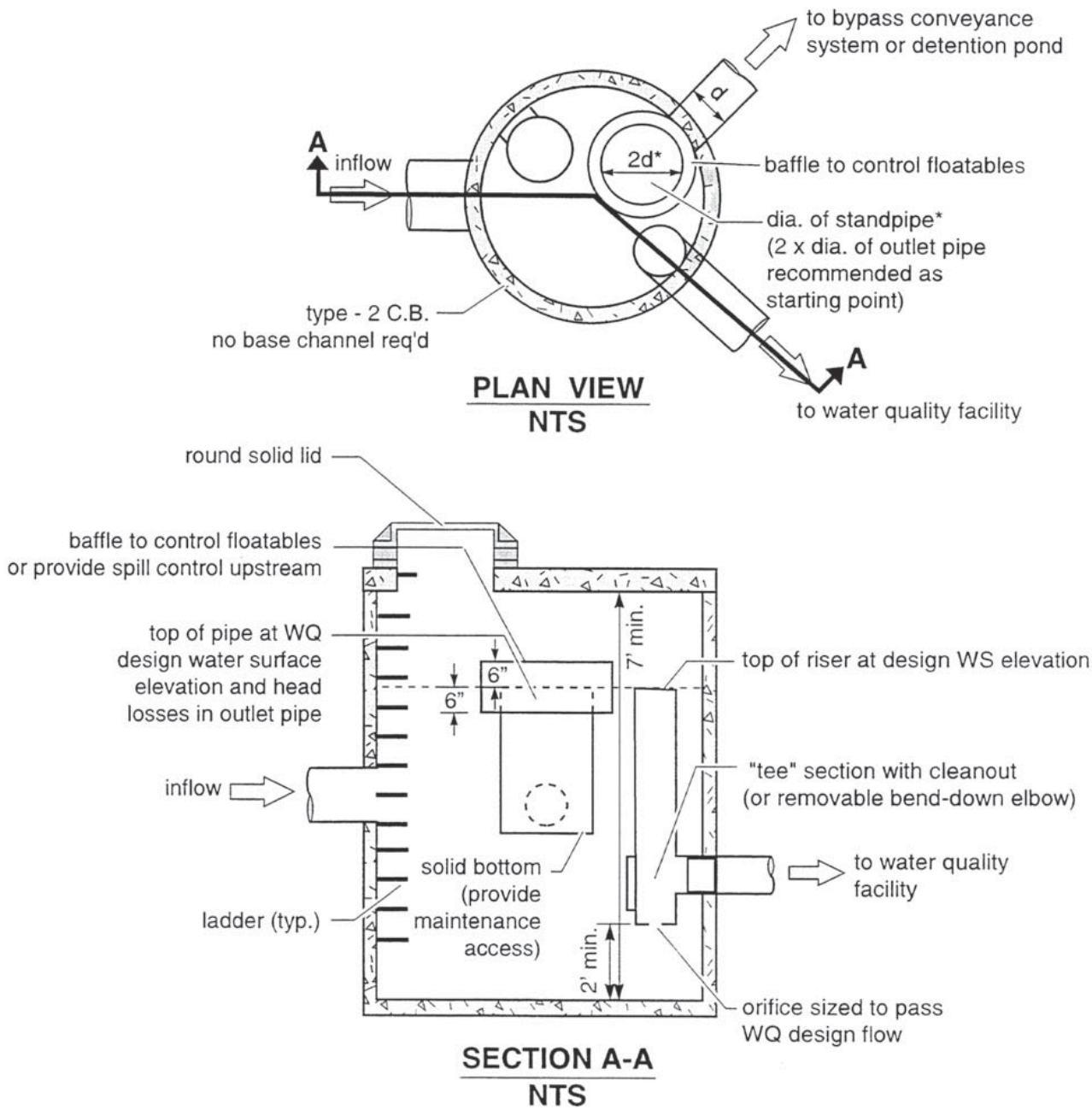


Figure 4.1.9: Flow Splitting Device



Note: The water quality discharge pipe may require an orifice plate be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimun headwater/diameter ratio of 2.0 on the outlet pipe.

Figure 4.1.10: Schematic of a Flow Splitter (1 of 2)



* **NOTE:** Diameter (d) of standpipe should be large enough to minimize head above WQ design WS and to keep WQ design flows from increasing more than 10% during 100-year flows.

Figure 4.1.11: Schematic of a Flow Splitter (2 of 2)

CURBLESS DESIGN

Curbless designs allow stormwater to flow directly from the impervious source to the SMP. This type of design discourages concentration of flow and reduces the energy of stormwater entering a management facility. Curbless designs are often used with bioretention islands or roadside swales.

CURB OPENINGS

Curb openings provide an alternative inlet control when a curbless design is not possible. Bioretention and landscaped islands in curbed parking lots or roadways often use curb openings as inlet controls.

If flow is to be introduced through curb openings, the pavement edge should be slightly higher than the elevation of the vegetated areas. Curb openings should be at least 12 – 18 inches wide to prevent clogging (CA Stormwater Manual). Small rock or stone should be used at the inlet of the curb openings to provide erosion protection.

Figure 4.1.13: Flow enters the bioretention system via a curb opening inlet

Figure 4.1.14: Curb openings allow flow to enter the bioretention system in the choker

Figure 4.1.15: Curb openings in a parking lot allow flow to enter a bioretention island

LEVEL SPREADERS

Level spreaders are inlet controls that are designed to uniformly distribute concentrated flow over a large area. There are many types of level spreaders that can be selected based on the peak rate of inflow, the duration of use and site conditions. Level spreaders help reduce concentrated flow, thereby reducing erosion and increasing the design life of many stormwater facilities.

All level spreader designs follow the same principles:

- Concentrated flow enters the spreader at a single point such as a pipe, swale or curb opening.
- The flow is slowed and energy is dissipated.
- The flow is distributed throughout a long linear shallow trench or behind a low berm.
- Water then flows over the berm or edge of trench uniformly along the entire length.

The following considerations are important when designing and constructing level spreaders:

- It is critical that the edge over which flow is distributed is exactly level. If there are small variations in height on the downstream lip, small rivulets will form. Experience suggests that variations of more than 0.25 inches can cause water to re-concentrate and potentially cause erosion downstream of the level spreader. The site selected for the installation of a level spreader must be nearly level before construction. Changes in ground elevation greater than 4 inches across the entire length of the level spreader can begin to make level construction difficult.
- The downslope side of the level spreader should be clear of debris. After construction, debris such as soil, wood and other organic matter might accumulate immediately downstream of the level spreader. This effectively blocks water as it flows out of the level spreader, forcing it to re-concentrate.

- The downslope side of the level spreader should be fully stabilized before the level spreader is installed. If a level spreader is installed above a disturbed area without sufficient vegetative cover or other ground cover such as mulch or construction matting, erosion rills will quickly form. Even sheet flow can cause significant downstream erosion on disturbed areas.
- Do not construct level spreaders in newly deposited fill. Undisturbed earth is much more resistant to erosion than fill. Erosion is even likely to occur over a well-established young stand of grass planted on fill.
- Level spreaders should not be considered to be sediment removal facilities. Significant sediment deposition in the spreader can render it ineffective.

TYPES OF LEVEL SPREADERS

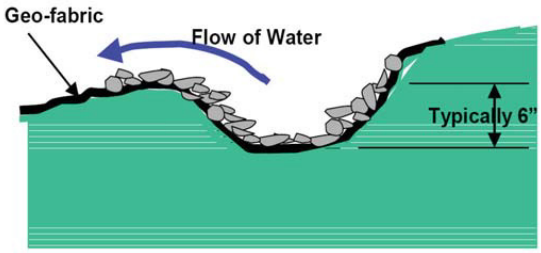


Figure 4.1.16: Cross-section of rock-lined channel

Rock-lined Channel. Rock-lined channels function as level spreaders when the lower (downslope) lip of the channel is level. The channel must be dug along an elevation contour, which helps make the downstream lip level. Rock-lined channel depths and widths are typically about 6 – 12 inches. The depth of the channel depends on the flow. Rock-lined channels do not serve as detention devices.

Concrete Troughs and Half Pipes. Concrete troughs 4 – 12 inches deep can be used as level spreaders. Half sections of pipe can also be used for the same function. The depths of the trough or pipe will depend on the flow. Concrete troughs are a more expensive level spreader alternative; however, they are easy to maintain and have a longer design life. If sediment or debris accumulates in the trough or pipe, it can be easily removed. Concrete level spreaders have design lives of up to 20 years, while other level spreader designs may be able to effectively function for a period of 5 – 10 years. Accordingly, long-term maintenance and replacement costs should be lower if installed properly.

Treated Lumber. Treated lumber is not recommended as a level spreading device due to issues with deformation and decomposition.

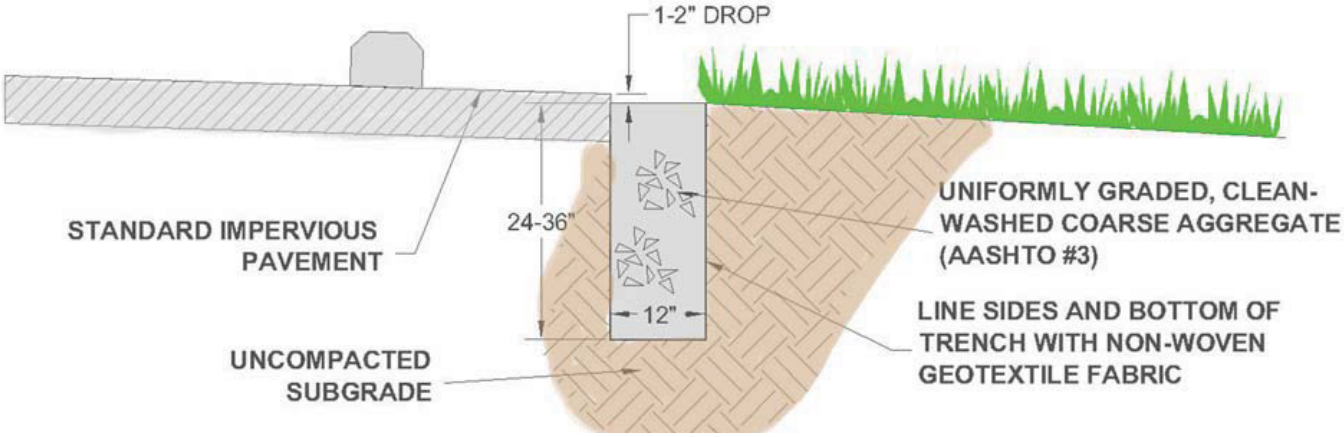


Figure 4.1.17: Filter strip with gravel trench level spreader

ENERGY DISSIPATERS

Energy dissipaters are large-scale engineered devices such as riprap aprons or concrete baffles designated to reduce the velocity, energy and turbulence of the flow. These structures can be employed when highly erosive velocities are encountered at the end of culverts or at the bottom of steep slopes where aesthetics are not a concern. A standard reference for design of these structures is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 14 (HEC-14).

RIPRAP APRONS

Riprap aprons are commonly used for energy dissipation due to their relatively low cost and ease of installation. A flat riprap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow. Riprap aprons should be sized for the 10-year storm event. Refer to sizing information in the PADEP *Erosion and Sediment Pollution Control Program Manual*.

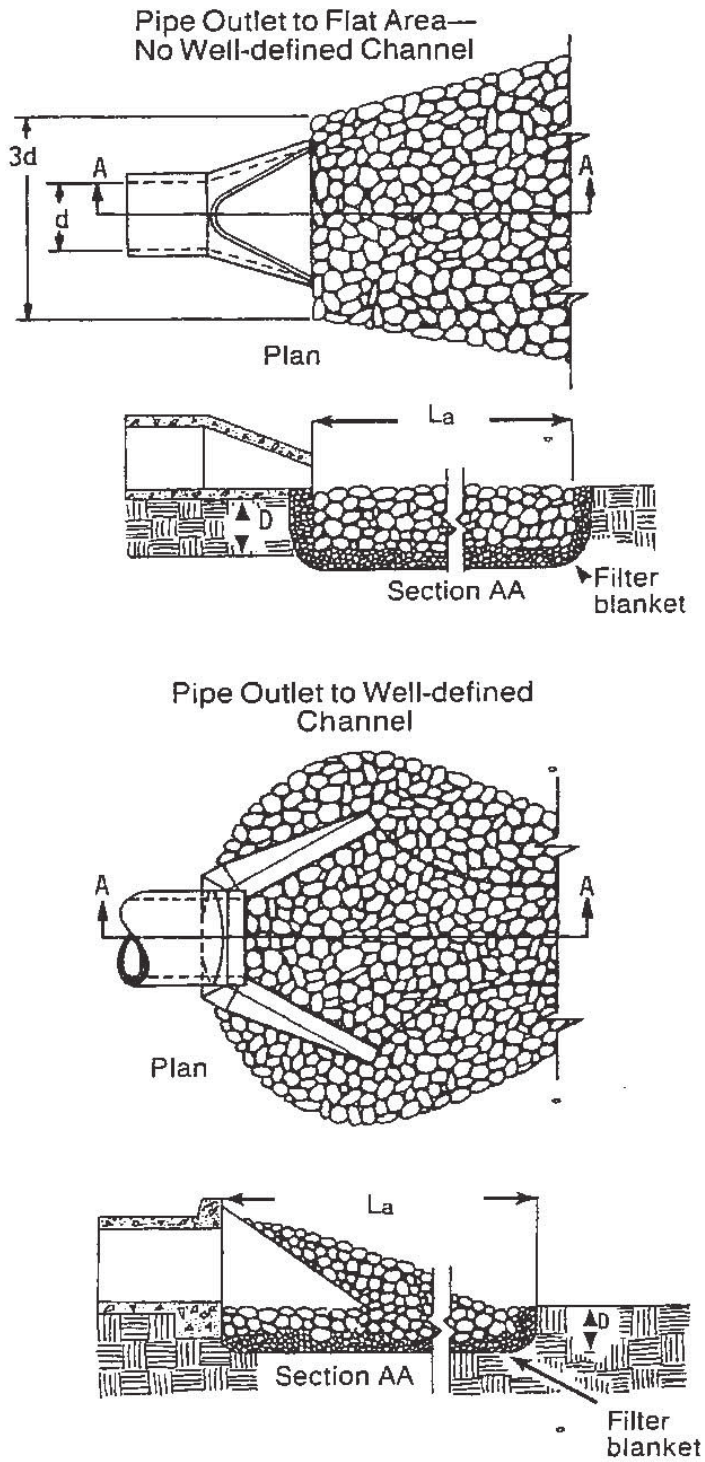
RIPRAP BASINS

A riprap outlet basin is a pre-shaped scour hole lined with riprap that functions as an energy dissipater.

INLETS AND CATCH BASINS

Traditional inlets and catch basins may be used as an inflow device for stormwater facilities where curb and gutter design is desired or required. The disadvantage of traditional inlets is that the inverts of the outlet pipes are relatively deep, and excavation of stormwater facilities may need to be deeper than with curb openings or a curbless design. A standard reference for designing traditional drainage systems is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 22 (HEC-220).

All inlets must include a sump and trap or sump and hood for pretreatment of stormwater runoff. The sump depth must be 15 inches below the bottom of the trap or 12 inches below the bottom of the hood. Traps or hoods in combined sewer areas must be air-tight. Refer to the City of Philadelphia Plumbing Code Section P-1001.7 for guidance.



Notes

1. L_a is the length of the riprap apron.
2. D = 1.5 times the maximum stone diameter but not less than 6".
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6" above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.

Figure 4.1.18: Rip Rap Apron

MAINTENANCE CONCERNS FOR INLET CONTROLS

Table 4.1.1: Inlet Maintenance Guidelines

ACTIVITY	SCHEDULE
• Inletcontroldevicesshouldbeinspectedafterseveralstormstoensurethattheyarefunctioning properly and that there are no erosion problems developing. • Sourceofsedimentcontaminationshouldbeidentifiedandcontrolledwhennativesoilisexposed or erosion channels are present.	As needed
• Inspectedforsedimentanddebrisbuildup.Sedimentbuildupexceeding2inchesindepthorthat begins to constrict the flow path should be removed. • Clean out leaves, trash, debris, etc.	Every 3 Months
• Maintain records of all inspections and maintenance activity.	Ongoing

OUTLET CONTROLS

RISERS AND ORIFICES

An orifice is a circular or rectangular opening of a prescribed shape and size that allows a controlled rate of outflow when the orifice is submerged. When not submerged, the opening acts as a weir. The flow rate depends on the height of the water above the opening and the size and edge treatment of the orifice. A riser is a vertical structure with one or more orifices that provide the controlled release in combination. A standard reference for discharge through a submerged orifice is Brater and King's Handbook of Hydraulics (1996).

Control structures may consist of several orifices and weirs at difference elevations to meet stormwater management requirements. Multiple orifices may be necessary to meet the WQ slow release and Channel Protection performance requirements for a detention system. Orifices may be located at the same elevation if necessary to meet performance requirements. Note - for existing detention systems which are being retrofitted to meet stormwater credit requirements, the original Flood Control requirements will still apply.

Flow through multiple orifices, such as the perforated plate shown in Figure 4.1.19, can be computed by summing the flow through individual orifices. For multiple orifices of the same size and under the influence of the same effective head, the total flow can be determined by multiplying the discharge for a single orifice by the number of openings.

The site's Water Quality Volume must be statically stored through the use of the outlet control structure. Design of a control structure with multiple orifices is an iterative process. An orifice is designed and positioned to meet each control requirement independently (e.g., WQ slow release, Channel Protection and Flood Control). Calculations are then performed on the two orifices together, and the design is adjusted to meet all requirements concurrently without oversizing the basin. The Outlet Structures section of the Georgia Stormwater Management Manual at

www.georgiastormwater.com/

(current August 12, 2005) is recommended for detailed instructions on design of multi-stage outlet structures.

Small orifices are sometimes needed when a stormwater management system must meet low flow rate requirements. Control structures with small orifices must meet the following requirements:

- The orifice diameter should always be greater than the thickness of the orifice plate.
- The minimum recommended diameter for an orifice is typically 3 inches. For smaller orifices sizes, special consideration should be given to clogging and appropriate protection should be provided (see next section for more information). Contact PWD if an orifice smaller than 3-inches is needed for your retrofit project.

- Protection from clogging is required for any orifice utilized as part of the retrofits outlet control structure.
- Provide sufficient access for maintenance of the outlet structure.

PROTECTION FROM CLOGGING

Small orifices used for slow release applications can be susceptible to clogging, which prevents the structural control from performing its function, potentially causing adverse impacts. Design measures can be taken to prevent clogging. These measures are most effective when used in combination with periodic inspection and maintenance. These measures are summarized below; the Design Professional is encouraged to consult the original sources for more information.

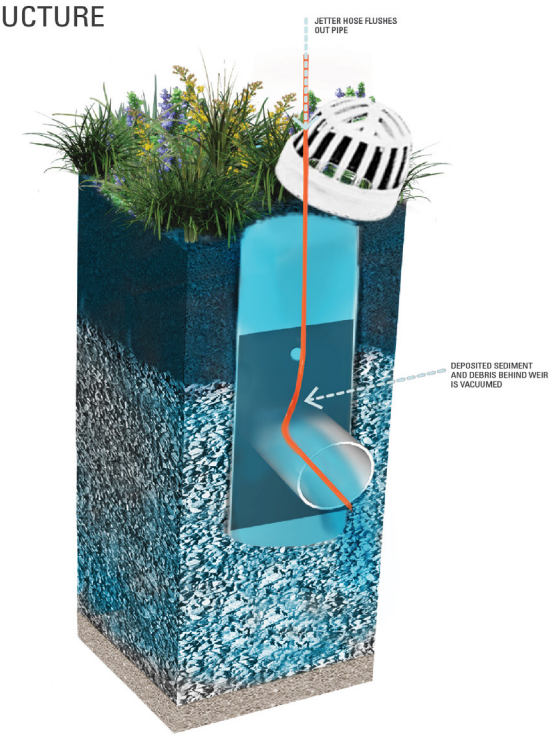
Since sediment will tend to accumulate around the lowest stage outlet, the inside of the outlet structure for a dry basin should be depressed below the ground level to minimize clogging due to sedimentation. Depressing the outlet bottom to a depth below the ground surface at least equal to the diameter to the outlet is recommended.

All outlet structures in combined sewer areas must include a sump and trap or sump and hood. The sump depth must be 15 inches below the bottom of the trap, or 12 inches below the bottom of the hood, and the traps or hoods must be air-tight. Refer to the City of Philadelphia Standards Details and Standard Specifications for Sewers booklet and the Philadelphia Plumbing Code Section P-1001.7 for guidance.

The Georgia Stormwater Management Manual recommends the following measures:

- The use of a reverse slope pipe attached to a riser for a stormwater pond or wetland with a permanent pool. The inlet is submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. See Figure 4.1.20 for an example.
- The use of a hooded outlet for a stormwater pond or wetland pool. See Figure 4.1.21 for an example.
- Internal orifice protection through the use of an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket. See Figure 4.1.22 for an example.
- Use of trash racks on larger outlets. See Figure 4.1.25 for an example.

CONTROL STRUCTURE



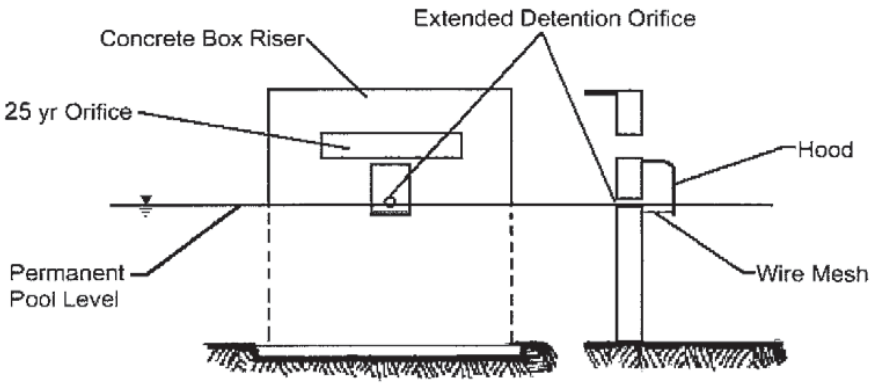


Figure 4.1.21: Hooded outlet orifice protection

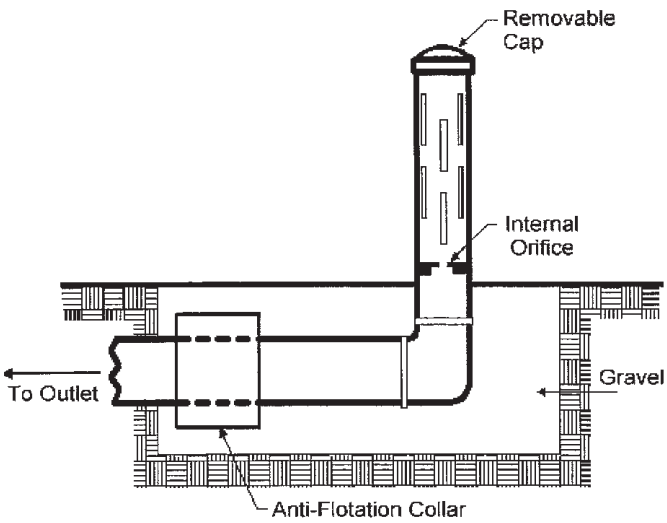


Figure 4.1.22: Internal control for orifice protection

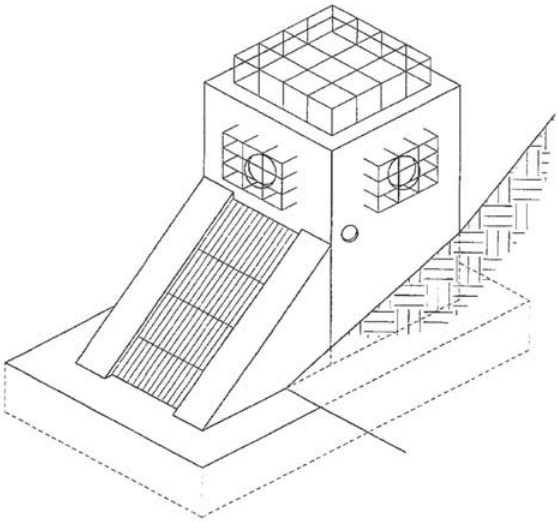


Figure 4.1.23: Trash racks

POSITIVE OVERFLOWS

A positive overflow permits stormwater to flow out of the SMP when the water level reaches a maximum design elevation in a subsurface feature or a maximum ponding depth in a surface feature. Flow through the positive overflow can either connect to another SMP or an approved point of discharge. A multi-stage outlet control may include a number of orifices for controlled flow and a positive overflow to quickly pass flow during extreme events. Overflow structures should be sized to safely convey larger storms from the SMP. If flow reaches the SMP via a flow splitter, this structure can provide the positive overflow.

Figure 4.1.24: Positive overflow

MAINTENANCE CONCERNS FOR OUTLET CONTROLS

Table 4.1.2: Outlet Maintenance Guidelines

ACTIVITY	SCHEDULE
Outlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion problems developing. Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed
Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. Clean out leaves, trash, debris, etc.	Every 3 Months
Maintain records of all inspections and maintenance activity.	Ongoing

Note:

Design of inlet and outlet controls are not limited to the examples shown within this text. Successful stormwater management plans will combine materials and designs specific to each site.

Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

Bioretention

chapter 4.2

4.2 Bioretention

Bioretention systems are ideal for retrofit projects as they can offer flexibility in sizing and placement. They can also be aesthetically pleasing and can be used to enhance the "greening" of more traditional turf grassed areas with increased plantings and vegetation. Bioretention systems are shallow, vegetated depressions used to promote absorption and infiltration of stormwater runoff. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by plants and trees in the system.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA MANAGED CREDIT
• Infiltration • Detention and Slow Release • Volume Reduction and Filtration
GROSS AREA STORMWATER CREDIT
• Management of first inch

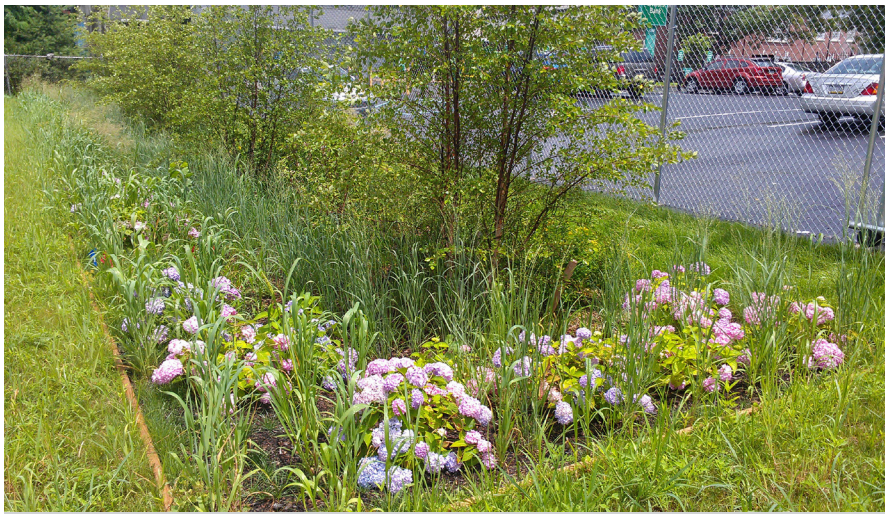


Figure 4.2.2: Bioretention can easily be integrated into parking lot areas. These areas provide an excellent retrofit opportunity.

Figure 4.2.1: Bioretention utilizes native plants that have seasonal interest, use less water, and attract birds and butterflies.

Figure 4.2.3: Typical Layout of a Bioretention System

LOCATION

When locating bioretention systems for retrofit projects:

- Investigate the subsurface soil and groundwater conditions at the proposed location.
    - Test the existing soil infiltration rate for the proposed bioretention area (Refer to Appendix 1 Soil Infiltration and Profile Guidelines).
    - If infiltration is not feasible, alternate locations or use of an underdrain should be considered.
    - In areas where infiltration is infeasible due to a hotspot, an impervious liner may need to be utilized (See Appendix 1 Soil Infiltration and Profile Guidelines).
- Locate bioretention systems at least 10ft away from building foundations. Otherwise provide appropriate waterproofing (i.e. impermeable liner).
- Confirm that existing runoff can be intercepted by the bioretention system.
- Maximize stormwater management by capturing the largest contributing drainage area possible.
- Expand the surface area of the bioretention system to the maximum extent possible given the site conditions. Surface storage can help reduce the need for additional soil and stone storage.
- Locate the bioretention system as close as possible to the source of runoff to limit the need for new stormwater conveyance piping.
- Avoid placing bioretention systems over or near underground utilities whenever possible.

DESIGN

Bioretention designs will vary depending on the individual site characteristics and the impervious area draining to the system. With appropriate soils, bioretention systems can be designed to infiltrate the water quality rainfall volume. The following chapters provide general design guidance intended to assist with bioretention system design development. The typical engineering details for bioretention systems can be found in Appendix 4 - Typical Details. An example of a bioretention retrofit is provided in Appendix 3 Credit and Design Calculation Examples - Example Site 2.

COMPONENTS OF A BIORETENTION SYSTEM

The primary components of a bioretention system are listed below.

- Flow entrance/inlet
- Surface storage (ponding area)
- Native plantings
- Mulch or organic compost surface layer
- Soil and filter media
- Sand bed or stone filter and underdrain, if necessary
- Stone storage for additional storage, if needed
- Observation Well
- Overflow outlet

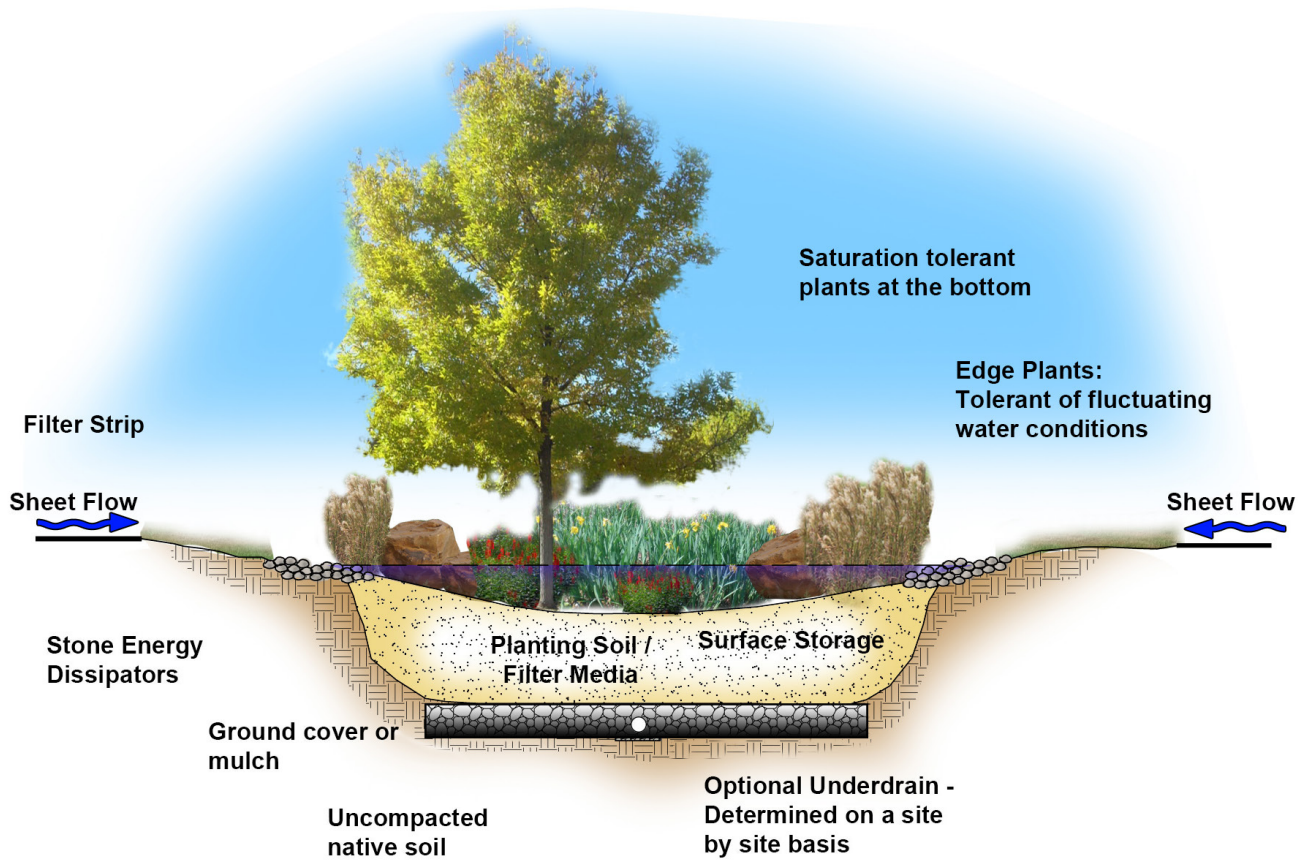


Figure 4.2.4: Components of a Bioretention System

DESIGN GUIDANCE

Design of bioretention systems is somewhat flexible, and the area, depth, and shape of the system can be varied to accommodate site conditions and constraints. An engineer shall provide assistance in the design process to assure the necessary volume, drainage time, and site constraints are met. Refer to design details located in Appendix 4 for detailed cross-sections.

General Design Guidance

In accordance with Appendix 1, suitability of infiltration and the saturated vertical infiltration rate shall be determined. If infiltration is not feasible, consider the following:

1. An alternate location for the bioretention area,
2. The use of soil amendments (See Section below on Vegetation and Materials), or
3. The use of an underdrain

- Loading Ratio: 10:1 contributing impervious drainage area to bioretention bottom bed area.
- Maximum Drain Down Time:
  - 72 Hours for entire storage volume (including surface, soil, and stone if used)
  - 24 – 48 hours recommended for surface storage
- Maximum Surface Ponding Depth: 2 feet.
- Side slopes: 3:1 recommended, 2:1 maximum.

Figure 4.2.5: Bioretention System during Dry Conditions

Inlet Control

Runoff can enter the bioretention system through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope in a diffuse manner.

Storage Calculations

Storage may be met by surface, soil and media storage or a combination thereof, as follows:

- Surface storage: Surface ponding below the overflow elevation;
- Soil media storage: Maximum of 20% of the void space within the soil media volume; and
- Stone storage: Maximum of 40% of the void space of the stone storage volume.

The following equation shall be used to determine the Water Volume Control storage requirement in cubic feet for managing 1.0 inch of runoff:

Water Volume Control (cubic feet) = (1/12) * (IA)

Where: IA = Impervious Area Managed (square feet)

Figure 4.2.6: Bioretention System during Wet Conditions

The table provided for bioretention soil storage and stone reservoir storage (See Section 3.1 Preliminary Planning and Design) can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

Figure 4.2.7: Bioretention System with Full-Sun Vegetation

Storage Stone (if used)

A washed stone layer may be added beneath the soil to increase storage and promote infiltration. For Storage Stone specifications see Section 4.1 Common Components.

Soil& Vegetation

Soil

Prepared soil may consist of amended native soils or imported soil. See Section 4.1, Common Components for more information regarding soil mixture requirements.

Vegetation

The design professional should consider ponding depth, drain down time, sunlight, salt tolerance, and other site specific conditions when selecting plants from the approved vegetation list in Appendix 2, Landscape Guidance and Plant List.

Adjust soil mixture, vegetation, and temporary or permanent stabilization measures to achieve maximum survivability.

Underdrains

When infiltration is not feasible or when a back-up system is desirable, an underdrain may be used. Underdrains should be designed in accordance with Section 4.1 Common Components.

If infiltration is not feasible, check that the applicable release rate requirements are met in accordance with Section 3.0 of this manual.

Observation Well

Observation wells provide access for inspecting the system, as well as a means to dewater the system in the event of a failure. For Observation Well guidance see Section 4.1 Common Components.

Outlet Controls

A bioretention system may have an outlet control to convey water to a storm sewer or receiving water body. Inlet and outlet controls shall be designed in accordance with Section 4.1 Common Components.

VEGETATION AND MATERIALS

Soil

Bioretention soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle. Refer to Section 4.1 Common Components for prepared soil specifications.

Mulch

Mulch helps prevent erosion and provides an environment suitable for beneficial soil organisms to thrive at the mulch/soil interface. Guidance for mulch specifications can be found in Section 4.1 Common Components.

Figure 4.2.8: Native Vegetation in a Bioretention System

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in species in Appendix 2, Landscape Guidance and Plant List.

- The following quantities per 100 square feet of bioretention area are suggested:
    - 1 large tree per 100 square feet of bioretention area.
    - 2-4 small trees or shrubs per 100 square feet of bioretention area.
    - 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers).
    - Groundcover plantings and wildflower plugs with centers 12-inches apart in a triangular pattern.
    - A native grass/wildflower seed mix can be used as an alternative to groundcover planting.
    - Seed mix shall be free of weed seeds.

Storage Stone (Optional)

- Stone used to provide additional storage should meet standards in Section 4.1 Common Components
- Stone shall be separated from soils by a non-woven geotextile or a pea gravel filter.

Non-Woven Geotextile

- Geotextile should meet standards as found in Section 4.1 Common Components.

Pipe (if needed)

- Pipe used for an underdrain should meet standards as found in Section 4.1 Common Components.

MAINTENANCE

Properly designed and installed bioretention systems require little maintenance. An overview of long term maintenance needs for bioretention systems are provided in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A bioretention system should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Figure 4.2.9: Routine Maintenance Performed after Storm

ACTIVITY	SCHEDULE
• Inspect trees and shrubs to evaluate health, replace or treat if necessary. • Inspect underdrain cleanout. • Verify drain down time of system. • Inspect for sediment buildup, erosion, vegetative conditions, etc. • Inspect inlets for debris. • Inspect soil and repair eroded areas. • Clear litter and debris from overflow and inlet areas.	Every 3 Months
• Maintain records of all inspections and maintenance activity.	Ongoing

SUGGESTED BIORETENTION MAINTENANCE ACTIVITIES

GENERAL DO'S AND DON'TS OF BIORETENTION SMP MAINTENANCE

DO:

- Check for signs of erosion, trash, or sediment build up, especially near inlets.
- Inspect for large stands of reeds or other invasive plant species, as these may require professional control.
- Remove any large sediment deposits that could take up volume in the bioretention system or damage plants.
- Water non-aquatic plants and trees during establishment, and if they look dry or brown.

DON'T:

- Use too much salt or sand around the bioretention system during winter months.
- Apply fertilizer. Consult a local nursery or PWD if plants are not thriving.
- Pile snow in bioretention area; this crushes plants.

Swale/Bioswale

chapter 4.3

4.3 Swale/Bioswale

A swale is an ideal retrofit option as swales can serve as a practical replacement for roadway median strips and parking lot curbs and gutters. A swale is a vegetated open channel with a combination of grasses and other herbaceous plants, shrubs, and trees. A swale functions as a conveyance and storage feature, and may provide infiltration and water quality treatment; these functions can be enhanced by adding check dams periodically along its length. As the number of check dams increases, a swale may resemble a series of bioinfiltration/bioretention basins while still being designed to convey peak flows.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA MANAGED CREDIT
• Infiltration • Detention and Slow Release • Volume Reduction and Filtration
GROSS AREA STORMWATER CREDIT
• Management of first inch

Figure 4.3.1: Typical Bioswale

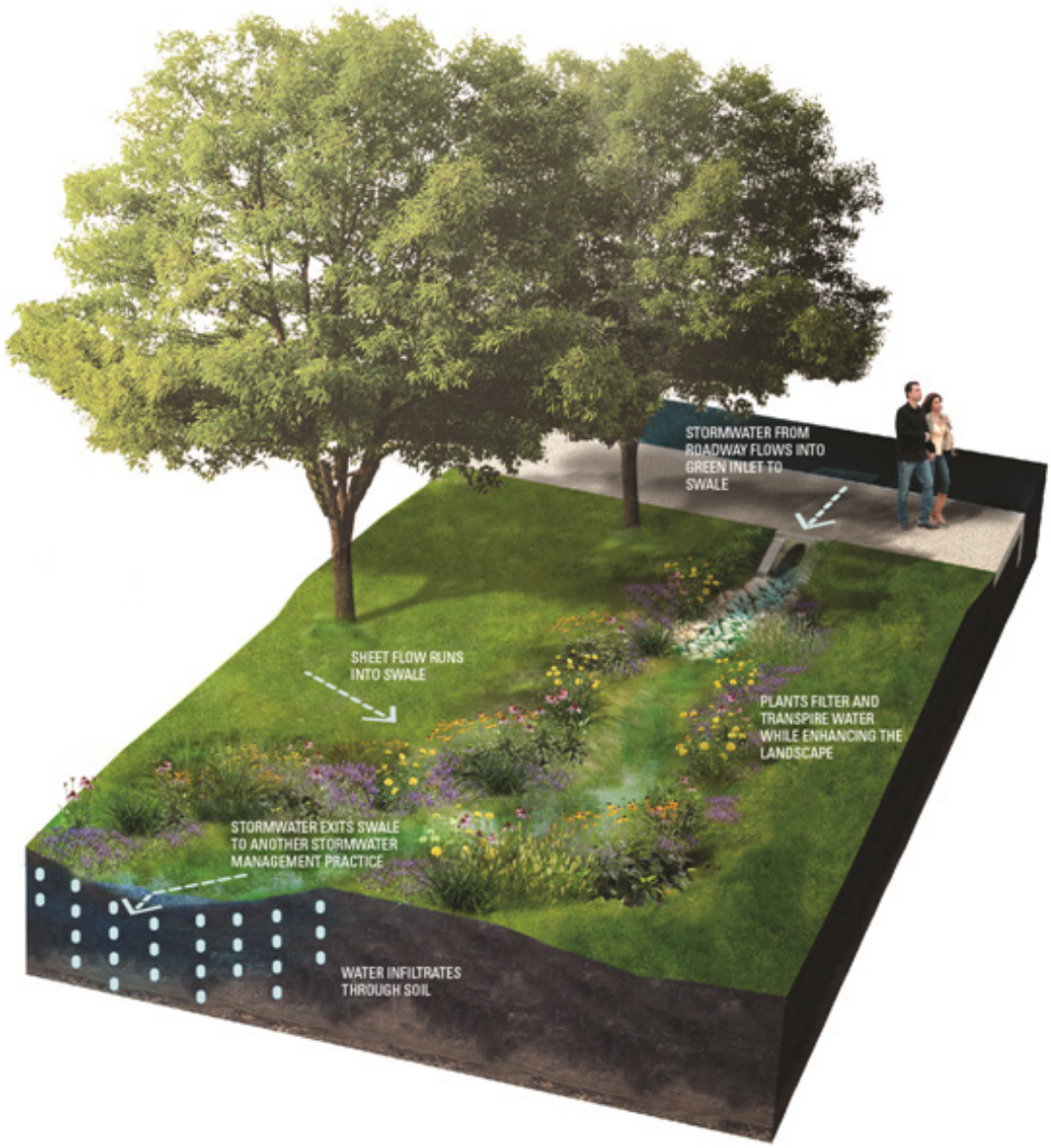


Figure 4.3.2: Typical Layout of a Swale

LOCATION

Swales are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, and residential developments. A swale can be more aesthetically pleasing than a concrete or rock-lined drainage system and is generally less expensive to construct and maintain. When locating swales for retrofit projects:

- Determine what portion of the drainage area the swale will manage.
- Consider the site's natural topography when siting the swale; if possible, locate the swale along contours and natural drainage pathways with slopes of 2-3%.
- Determine the location of underground utility lines and avoid conflicts.
- Investigate the feasibility of infiltration according to conditions in the area proposed for the swale. If infiltration is feasible, determine the saturated vertical infiltration rate. See Appendix 1 Soil Infiltration and Profile Guidelines.

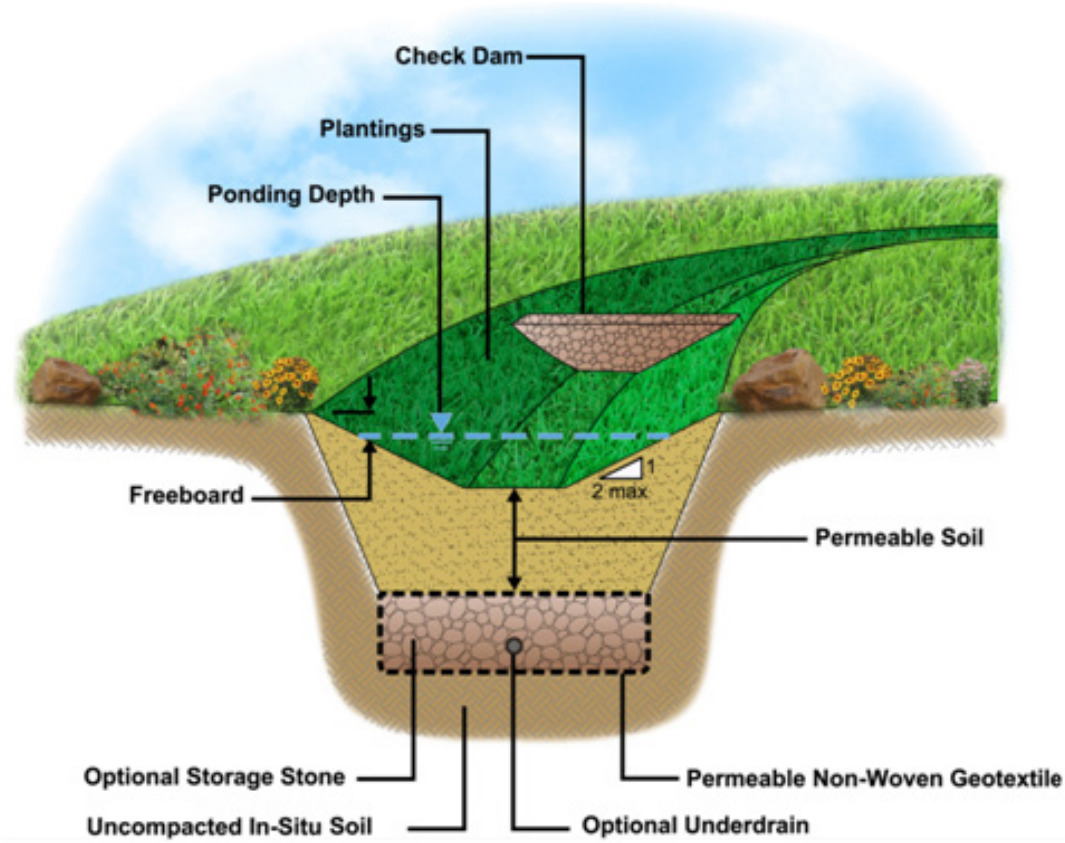


Figure 4.3.**3**: Components of a Bioswale

DESIGN

Swale designs will vary based on the slope and the contributing drainage area. The typical engineering details for swales and bioswales can be found in Appendix 4 Typical Details. An example of a swale retrofit is provided in Appendix 3 Credit and Design Calculation Examples– Example Site 2.

COMPONENTS OF A SWALE SYSTEM

- Inlet Control
- Pretreatment (Optional)
- Excavated Channel
- Soil& Vegetation
- Check Dams
- Stone (Optional)
- Underdrain (Limited Application)
- Outlet Control

Figure 4.3.4: Bioswale with Stone Check Dam

INLET CONTROL

Runoff can be directed to the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope as diffused sheet flow.

PRETREATMENT

Pretreatment is required for runoff from impervious surfaces with high sediment loads, and can extend the life of the SMP when not required. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet or the first swale segment, and a check dam may be used to design a sediment forebay. See Section 4.1 Common Components.

EXCAVATED CHANNEL

The channel itself provides the storage volume and conveyance capacity of the swale. Swale design balances needs for infiltration and treatment during small storms with needs for conveyance during large storms.

SOIL& VEGETATION

Soil

Prepared soil may consist of amended native soils or imported soil. See Section 4.1 Common Components for more information about soil mix requirements. A minimum of 6 inches of prepared soil is recommended for the channel bottom and slopes.

It is recommended that the swale be sized appropriately to convey the 10-year, 24-hour design storm without erosion. The PADEP *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) is recommended as a reference for these calculations.

Vegetation

The design professional should consider ponding depth, drain down time, sunlight, salt tolerance, larger storm event flow velocities, and other conditions when selecting plants from the approved vegetation list in Appendix 2 Landscape Guidance and Plant List.

Turf grass is generally acceptable for conveyance swales and/or pretreatment. Vegetation is required when a swale is not used in

Figure 4.3.5: Curbcut Inlets for Suburban Swale

conjunction with another SMP.

Adjust soil mix, vegetation, and temporary or permanent stabilization measures as needed.

CHECK DAMS

It is recommended that swale designs include check dams. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy. A check dam may also be used to create a forebay to trap sediment and floatables.

STORAGE STONE (OPTIONAL)

A washed, crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when included under locations behind check dams where ponding is desired. For Storage Stone specifications see Section 4.1 Common Components.

UNDERDRAIN (OPTIONAL)

In some cases, an underdrain and piping system may be designed to prevent prolonged ponding of stormwater or to collect and convey water to another SMP. Underdrained systems may be appropriate in locations where conditions are not ideal for infiltration. For Underdrain specifications see Section 4.1 Common Components.

OUTLET CONTROL

A swale may have an outlet control to convey water to another SMP, a storm sewer, or receiving water body. See Section 4.1 Common Components for more information.

DESIGN GUIDANCE

SIZING RECOMMENDATIONS

Table 4.3.1: Suggested Swale Starting Design Values

Bottom Width	2-8 feet
Side Slopes	3-4 Horizontal to One Vertical Recommended (3:1 or 4:1); 2:1 maximum*
Check Dams	Evenly spaced, 6-12 inches high **
*Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as general guide for parabolic channels.	
**Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions.	

- Using the infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long storage behind check dams will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. A surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust the channel shape, number of check dams, or check dam height. Adjust the design so that performance and drainage time constraints are met concurrently.
- Check the peak flow capacity of the swale. It is recommended that the swale convey the 10-year, 24-hour design storm with 6 inches of freeboard, an average ponding depth of 12 inches or less, and a maximum ponding depth of 18 inches or less. Flow over check dams may be estimated using a weir equation. For rock weirs that allow flow through the weir, an equation is suggested in Section 4.1 Common Components. Ultimately, the level of service provided on the site during large events is a joint decision of the Engineer and Owner based on safety, appearance, and potential property damage.

The table provided for SMP soil storage and stone reservoir storage (See Section 3.1 Preliminary Planning and Design) are useful in approximating the available storage a potential bioswale can provide. These tables can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

MATERIALS

SOIL

Swale soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle.Refer to Section 4.1 Common Components for prepared soil specifications.

VEGETATION

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in species in Appendix 2 Landscape Guidance and Plant List.

CHECK DAMS

- Check dams can be constructed from natural wood, concrete, stone, boulders, earth, or other materials.
- If a stone check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events.
    - In general, one stone size for a dam is recommended for ease of construction.
    - However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir.
    - Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side.
        - Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

Figure 4.3.6: Grassed Swale through Park with Stone Energy Dissipater Inlet

STORAGE STONE (OPTIONAL)

Stone used to provide additional storage should meet standards in Section 4.1 Common Components.

Stone shall be separated from soils by a non-woven geotextile or a pea gravel filter.

NON-WOVEN GEOTEXTILE

Geotextile should meet standards as found in Section 4.1 Common Components.

PIPE (IF NEEDED)

Pipe used for an underdrain should meet standards as found in Section 4.1 Common Components.

MAINTENANCE

Properly designed and installed swales require little maintenance. An overview of the long term maintenance needs for Bioswales are provided in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting activities and maintaining SW credits.

A swale should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Table 4.3.2: Suggested Swale Maintenance Activities

ACTIVITY	SCHEDULE
• Inspect for sediment buildup, erosion, vegetative conditions, etc. • Inspect trees and shrubs to evaluate health. • Remulch void areas • Treat or replace diseased trees and shrubs. • Keep overflow free and clear of litter and debris. • Inspect soil and repair eroded areas. • Clear litter and debris from overflow.	Every 3 Months
• Maintain records of all inspections and maintenance activity	Ongoing

GENERAL DO'S AND DON'TS OF SWALE SMP MAINTENANCE

DO:

- Check for signs of erosion, trash, or sediment build up especially around inlets.
- Remove any large sediment deposits that could block the flow of water or damage plants.
- Water plants and trees during establishment, and if they look dry or brown.

Don't:

- Use too much salt or sand around the swale during winter months.
- Apply fertilizer. Consult a local nursery or PWD if plants are not thriving.
- Pile snow in swales; this crushes plants.

Porous Pavement

chapter 4.4

4.4 Porous Pavement/Pavers

Porous pavement systems are ideal for retrofit projects as they are applicable to any type of development with hard surface pavement parking, drives, walks, or plazas.Porous pavement provides similiarload bearing supportto that of conventional pavement, but allows rainwater to drain directly through the surface. Porous pavement is designed with an uncompacted and level sub-grade that permitsinfiltration of stormwater, a stone sub-base which provides storage, and a positive overflow to prevent system flooding. There are porous varieties of asphalt, concrete, and interlocking paver stones.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA REDUCTION
• Infiltration • Detention and Slow Release
* May also be size to manage additional impervious area

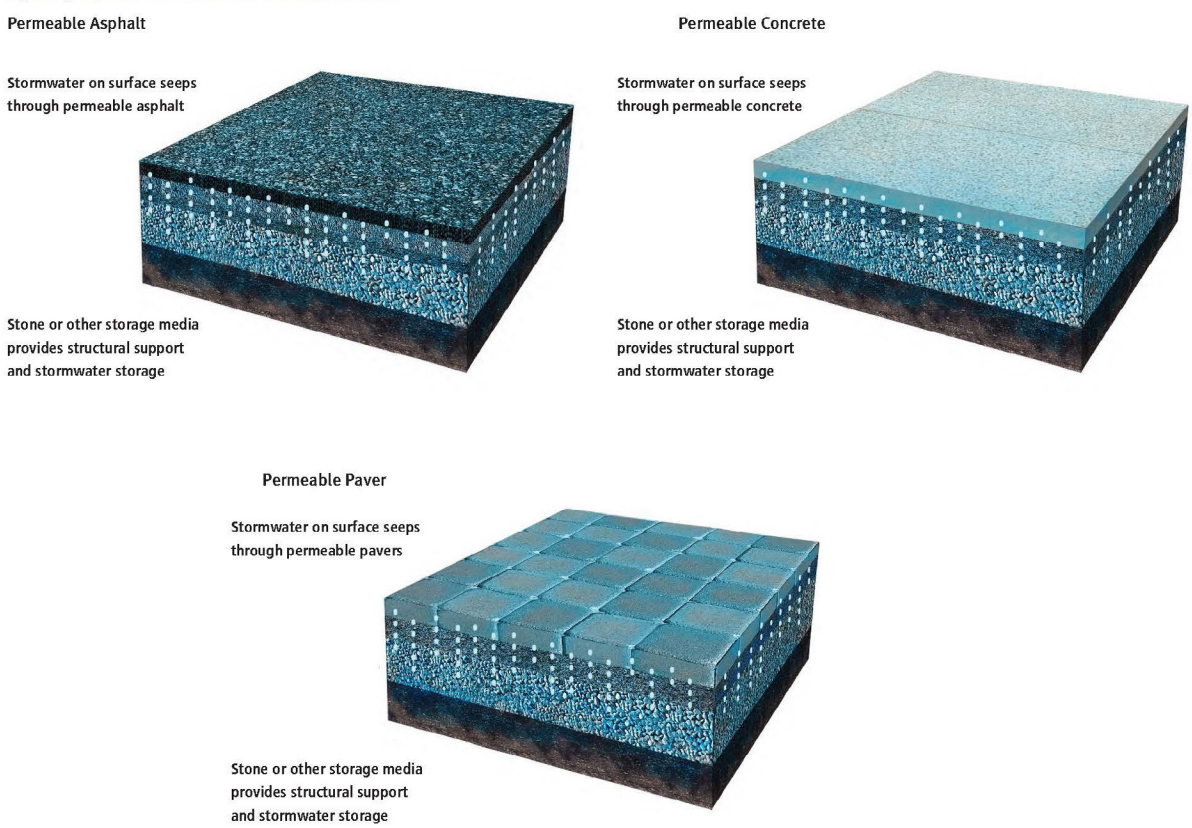


Figure 4.4.2: Typical Layouts of Porous Pavement Systems

LOCATION

Porous Pavement and Pavers are especially well suited for parking lots, walkways, sidewalks, plazas, patios, basketball courts, and playgrounds.When locating Porous Pavement systems:

- Investigate the subsurface soil and groundwater conditions.
  - Test the existing soil infiltration rate for the proposed porous pavement (Refer to Appendix 1 Soil Infiltration and Profile Guidelines).
  - If infiltration is not feasible, alternate locations or use of an underdrain should be considered.
  - In areas where infiltration is not appropriate due to potential contamination, an impervious liner may have to be utilized (See Appendix 1 Soil Infiltration and Profile Guidelines)
- Determine the location of underground utility lines and avoid conflicts.
- Maximize the surface area of the porous surface as much as possible given the site conditions.
- Provide the appropriate load bearing capacity for volume and traffic loads.
  - Porous pavers can be used on most travel surfaces with slopes less than 5%.
  - Parking lots with a high volume of heavy traffic can utilize porous pavement for parking stalls, walkways, and sidewalks, while maintaining conventional pavement for travel lanes.
- Consider if adjacent impervious areas can be directed to the porous pavement system. If so, provide sufficient storage to meet the water quality capture requirement.
  - For porous systems managing other areas, pretreatment may be necessary to prevent particulate materials from clogging the subbase of the porous pavement system. See Section 4.1 Common Components.

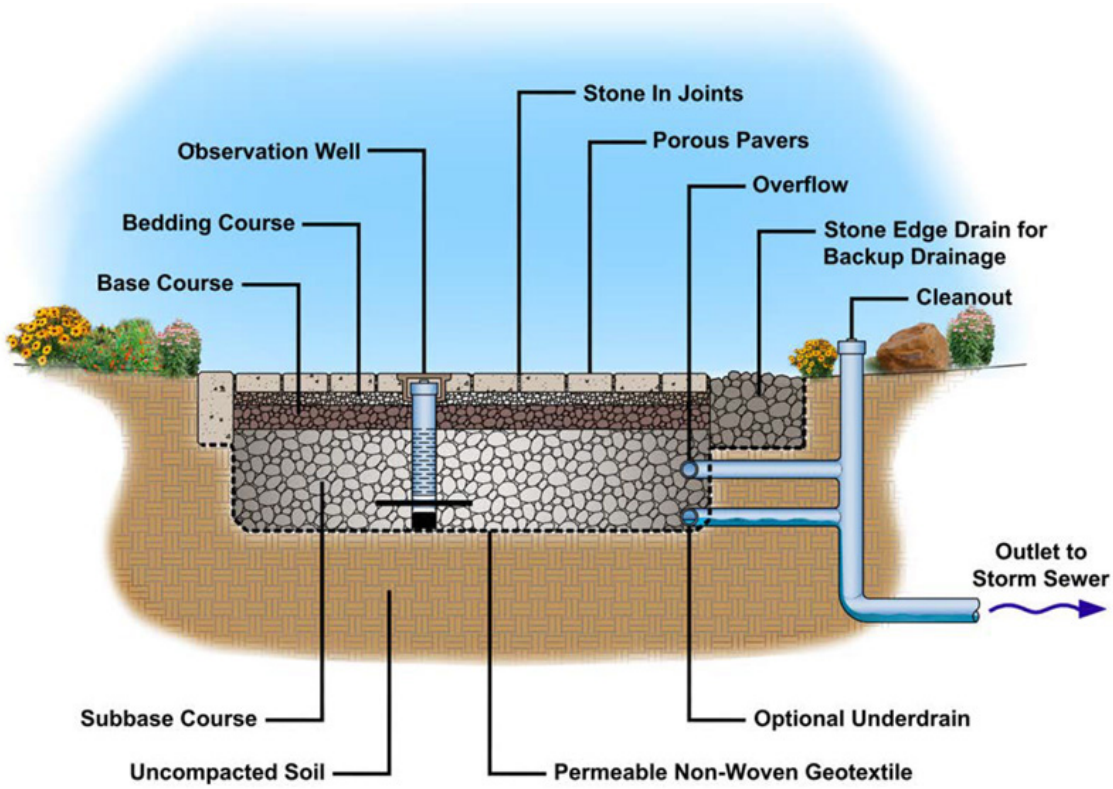


Figure 4.4.3: Components of a Porous Pavement System

DESIGN

Porous Pavement and Porous Paver designs will vary depending on each individual site. The systems can be design to simply replace existing pavement or to treat runoff from larger areas. Typical engineering details for porous pavement systems can be found in Appendix 4. An example of a porous pavement retrofit is provided in Appendix 3 Credit and Design Calculation Examples - Example Site 3.

COMPONENTS OF A POROUS PAVEMENT SYSTEM

- Porous Surface
- Choker Course
- Base Course
- Stone Storage Subbase
- Infiltration/Outflow
- Observation Well
- Distribution Pipes (optional)
- Sand bed or stone filter and underdrain, if necessary
- Positive Overflow

During a rain event, stormwater flows through the porous surface, drains into the crushed stone subbase beneath the pavement, and remains stored until stormwater can infiltrate into the soil. Porous asphalt and concrete mixes are similar to their impervious counterparts, but do not include the finer grade particles. Interlocking pavers have openings that are filled with stone to create a porous surface.

DESIGN GUIDANCE

GENERAL DESIGN GUIDANCE

- In accordance with Appendix 1 Soil Infiltration and Profile Guidelines, suitability of infiltration and the saturated vertical infiltration rate shall be determined. If infiltration is not feasible, consider the following in order of preference:

1. An alternate location for the porous pavement/ paver area,
2. The use of soil amendments (See Section 4.1 Common Components), or
3. The use of an underdrain

- Loading Ratio: A 5:1 loading ratio is recommended for porous pavement receiving run-on from other impervious drainage areas.
- Maximum Drain Down Time:
  - 72 Hours for entire storage volume
- Design system with a level bottom; use a terraced approach when grade changes are necessary.

Figure 4.4.4: Porous Asphalt Playground

POROUS SURFACE

Although surface material may vary, all have the same underlying storage systems and overflow systems. The choice of permeable surface is relevant to user needs, cost, material availability, constructability, and maintenance.

CHOKER/BEDDING COURSE

The Choker/Bedding course layer is permeable, is 1 - 2 inches thick and provides a level and stabilized bed surface for the porous surface.

BASE COURSE

This aggregate layer is immediately beneath the choker course and provides a transition between the bedding and subbase layers. Coarse aggregate laid beneath a porous surface provides the structural support necessary to distribute mechanical loads, and stores stormwater.

- Minimum Thickness: 4 inches for porous pavers, with additional depth as needed for load bearing capacity beneath Porous Asphalt.
- Composition: Typically crushed stones 3/4 to 3/16 inch.

Figure 4.4.5: Porous Asphalt Parking Lot with Stone Level Spreader

STONE STORAGE SUBBASE LAYER

A minimum thickness of stone is required to support site specific traffic loading conditions in conjunction with the overall pavement design. Stormwater may be stored within this thickness, and the stone depth may be increased to provide additional storage.

The aggregate is wrapped in a non-woven geotextile fabric to prevent migration of soil into the storage bed and resultant clogging. The subbase storage of porous pavement systems can be designed with extra capacity, and roof leaders and inlets from adjacent impervious areas can be tied into the subbase to capture additional runoff.

SUBSURFACE STORAGE CALCULATIONS

Subsurface stone storage beds can be sized to accommodate runoff from rooftops via direct connection or to supplement other SMPs. Storage Stone: Maximum 40% void space of the stone storage volume for AASHTO No 3 stone.

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for managing 1.0 inch of runoff:

Water Volume Control (cubic feet) = (1/12) * (IA)

Where: IA = Impervious Area Managed (square feet)

Figure 4.4.6: Porous Asphalt

The table provided for SMP stone reservoir storage (See Section 3.0 Preliminary Planning and Design) is useful in approximating the available storage potential porous pavement can provide. This table can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

OBSERVATION WELL

Observation wells provide access to inspect the system, as well as a means to dewater the system in the event of a failure. For Observation Well guidance see Section 4.1 Common Components.

Figure 4.4.7: Permeable Pavers

DISTRIBUTION PIPE

Distribution pipe within a subsurface storage/infiltration bed should be consistent with guidelines specified in Section 4.1 Common Components.

UNDERDRAINS

When infiltration is not feasible or when a back-up system is desirable, an underdrain may be used. Underdrains should be designed in accordance with Section 4.1 Common Components. If infiltration is not utilized, check that release rate requirements are met in accordance with See Section 3.0 Preliminary Planning and Design. Maximum release rate should be calculated based on the head of water at the Water Quality Volume storage elevation.

Figure 4.4.8: Reinforced Turf

POSITIVE OVERFLOW

If water from any impervious surfaces (i.e. roof leaders, inlets, adjacent surfaces) is directed onto porous pavement or into the stone bed, a positive overflow must be provided.

- Inlets can be used to provide positive overflow if additional rate control is not necessary.
- Design distribution and overflow piping to minimize chance of clogging.

MATERIALS

POROUS SURFACE SELECTION

Several of the most commonly used porous structural surfaces are described here, but this does not represent an exhaustive list of the porous surfaces appropriate for stormwater management applications.

- Porous concrete is produced by reducing the number of fine particles in the mix in order to establish open spaces in the concrete for drainage. Porous concrete has a coarser appearance than traditional concrete.
- Porous asphalt is very similar in appearance to conventional impervious asphalt. Porous asphalt consists of standard bituminous asphalt in which the fine particles have been screened and reduced from the mix, allowing water to pass through very small spaces in the asphalt. Additives and binders have been found to improve the performance of porous asphalt.
- Permeable pavers are interlocking units (often concrete) with openings that can be filled with a pervious material (i.e. gravel). Pavers are attractive and are especially well suited to plazas, patios, small parking areas, etc. There are also plastic grids that can be filled with gravel to create a fully gravel surface that is not as susceptible to rutting and compaction as traditional gravel lots. Gravel used in interlocking concrete pavers or plastic grid systems must be well graded to ensure permeability.
- Reinforced turf consists of interlocking structural support with openings designed to be filled with soil for the growth of turf grass and are suitable for traffic loads and parking (i.e. overflow or event parking). Reinforced turf grids can be made of concrete or plastic with a stone or sand subsurface drainage system. Plastic units may provide better turf establishment and longevity because the plastic does not absorb water and does not diminish soil moisture conditions.

SUBSURFACE STORAGE BEDS

- All Stone used in the infiltration bed should meet the following guidelines
    1. Maximum wash loss of 0.5%*
    2. Minimum Durability Index of 35*
    3. Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions.

Choker layer of stone should meet AASHTO No. 57 sieve analysis specifications.

Table 4.4.1: Suggested Choker Course Stone Size Gradation (Sieve Analysis)

U.S. STANDARD SIEVE SIZE	PERCENT PASSING
1 ½" (37.5 mm)	100
1" (25 mm)	95 – 100
½" (19 mm)	25 – 60
4 (4.75 mm)	0 – 10
8 (2.36 mm)	0 – 5

Storage layer of stone should meet AASHTO No. 3 sieve analysis specifications. Additional storage materials are discussed in Section X: Common SMP Components

Table 4.4.2: Suggested Storage Layer Stone Size Gradation (Sieve Analysis)

U.S. STANDARD SIEVE SIZE	PERCENT PASSING
2 ½ " (63 mm)	100
2" (50 mm)	90-100
1 ½" (37.5 mm)	35-70
1" (25 mm)	0-15
½" (12.5 mm)	0-5

Porous Bituminous Asphalt Surface

Table 4.4.3: Suggested Mixture composition for Bituminous Asphalt

Bituminous surface	Laid with a bituminous mix of 5.75% to 6% by weight dry aggregate
Drain down of binder	No greater than 0.3%*
Aggregate Grain in asphalt	Minimum 90% crushed material **

* In accordance with ASTM DS6390

**Table 4.4.4 presents the Suggested Porous Bituminous Aggregate Gradation

Table 4.4.4: Suggested Porous Bituminous Aggregate Gradation (Sieve Analysis)

U.S. STANDARD SIEVE SIZE	PERCENT PASSING
½ (12.5 mm)	100
3/8 (9.5 mm)	92 - 98
4 (4.75 mm)	34 – 40
8 (2.36 mm)	14 – 20
16 (1.18 mm)	7 – 13
30 (0.60 mm)	0 - 4
200 (0.075 mm)	0 - 2

NON-WOVEN GEOTEXTILE

Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

Table 4.4.7: Geotextile Properties

SPECIFICATION	REQUIREMENT
Grab Tensile Strength (ASTM-D4632)	≥ 120 lbs
Mullen Burst Strength (ASTM-D3786)	≥ 225 psi
Flow Rate (ASTM-D4491)	≥ 95 gal/min/ft2
UV Resistance after 500 hrs (ASTM-D4355)	≥ 70%
Heat-set or heat-calendared fabrics	not permitted

Figure 4.4.9: Porous Pavement Alleyway

MAINTENANCE

As with most SMPs, porous pavement systems require regular maintenance to extend their life.An overview of long term maintenance needs for porous surfaces are provided in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A porous pavement or paver system should be inspected four (4) times per year. Vacuuming a porous surface system can prevent clogging, air systems devices, which combine vacuum and aeration technology, are often the best to prevent long-term clogging. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Figure 4.4.**10**: Vacuuming Porous Paver Blocks

Table 4.4.8: Suggested Porous Pavement Maintenance Activities

ACTIVITY	SCHEDULE
• Mow grass in paver or grid systems that have been planted with grass.	As Needed
• Vacuum porous asphalt or concrete surface with regenerative air equipment (pavement washing systems and compressed air units are not recommended).	Biannually (Or as needed)
• Maintain records of all inspections and maintenance activity	Ongoing

GENERAL DO'S AND DON'TS OF POROUS PAVEMENT SMP MAINTENANCE

DO:

- Check regularly for ponding or runoff from the porous surface, as these can be early signs of clogging.
- Remove trash, leaves, and spills before these deposits become ground into and clog the porous surface.
- Vacuum using regenerative air equipment where available, to remove sediment and fine debris.

DON'T:

- Apply sand for snow management, salt is acceptable.
- Drive trucks or heavy machinery over the porous pavement as this can compact the surface.
- Hose, scrub, or power wash the system without using a vacuum at the same time.
- Plant trees where branches will overhang the porous surface; leaves and other debris can clog the surface.

Subsurface Infiltration

chapter 4.5

4.5 Subsurface Infiltration

Subsurface infiltration can be a simple cost effective retrofit option as the footprint of the SMP can be limited. Islands or other parking areas can incorporate them with simple modifications and they can often be integrated into parking lot resurfacing projects.Subsurface infiltration practices are typically stone-filled trenches beneath landscaped or paved surfaces.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA MANAGED CREDIT
• Infiltration
GROSS AREA STORMWATER CREDIT
• Manage First Inch of Runoff

Figure 4.5.2: Typical Layout of a Subsurface Infiltration System

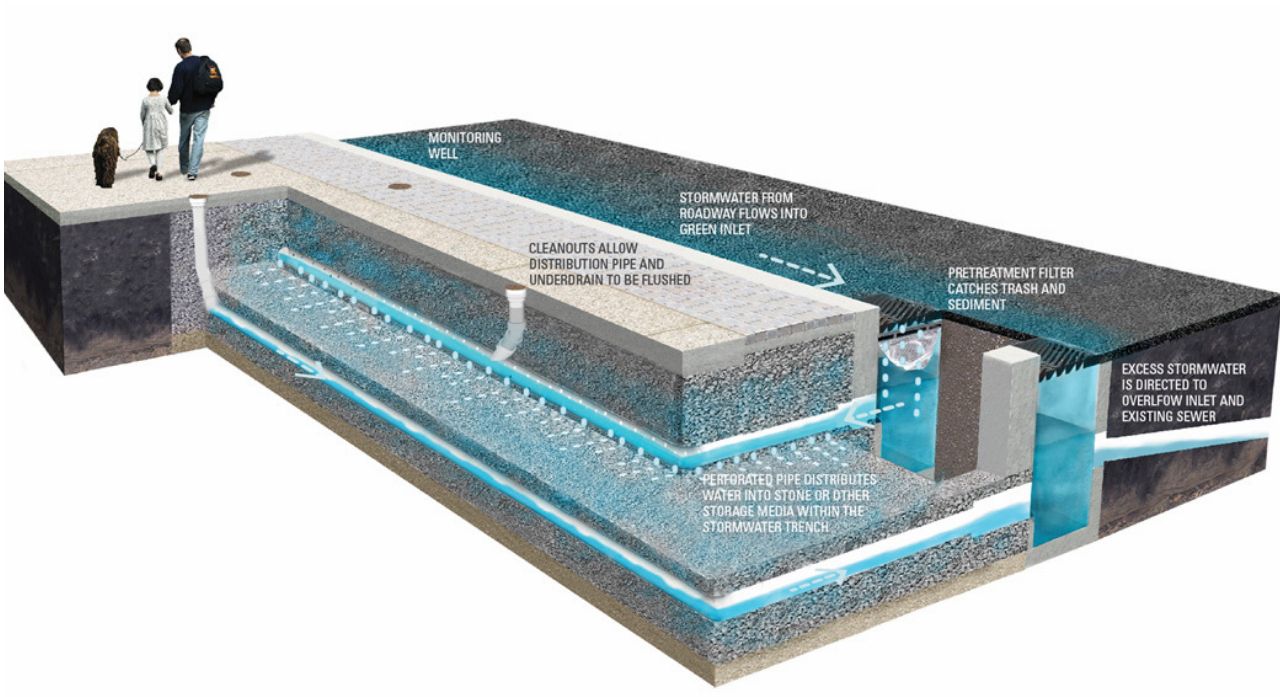


Figure 4.5.1: Newly Installed Subsurface Infiltration System

LOCATION

When locating subsurface infiltration practices:

- Investigate the subsurface soil and groundwater conditions.
  - Test the existing soil infiltration rate for the proposed subsurface infiltration area (Refer to Appendix 1 Soil Infiltration and Profile Guidelines).
  - In areas where infiltration is not appropriate due to potential contamination or unstable soils, an alternative location should be considered (See Appendix 1 Soil Infiltration and Profile Guidelines).
- Locate subsurface infiltration at least 10 ft away and down gradient from building foundations
- Provide a minimum of 2 feet from any limiting zone such as groundwater or bedrock.
- Locate the subsurface infiltration basin as close as possible to the source of runoff to limit the need for new storm water conveyance piping.
- Maximize the drainage area managed by the basin.
- Determine the location of underground utility lines and avoid conflicts.

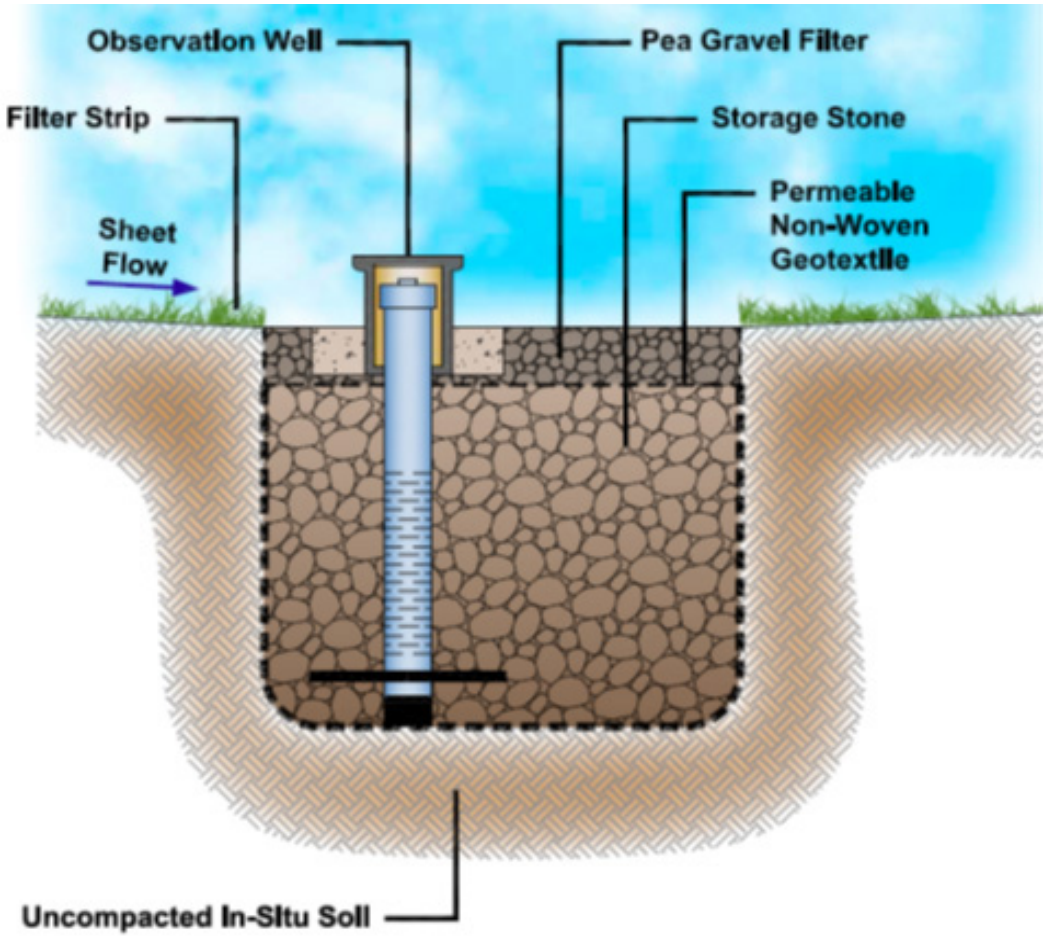


Figure 4.5.3: Components of a Subsurface Infiltration System

DESIGN

Subsurface infiltration can provide versatile management solutions for retrofitting a property with stormwater management practices.

COMPONENTS OF A SUBSURFACE INFILTRATION SYSTEM

- Inflow/Pretreatment
- Storage
- Observation Well
- Infiltration/Outflow

DESIGN GUIDANCE

GENERAL DESIGN GUIDANCE

In accordance with Appendix 1 Soil Infiltration and Profile Guidelines, suitability of infiltration and the saturated vertical infiltration rate shall be determined. If infiltration is not feasible, consider an alternate location for the subsurface infiltration practice.

- **Loading Ratio:** 10:1 contributing impervious drainage area to infiltration bed area.
- **Maximum Drain Down Time:** 72 Hours for entire storage volume.
- **Effective head** (total storage/SMP footprint): less than 2 feet.

INFLOW/PRETREATMENT

- It is important to prevent coarse sediment and debris from entering subsurface infiltration systems, as they could contribute to clogging and failure of the system.
- Additional guidance is provided in Section 4.1 Common Components.

STORAGE CALCULATIONS

Storage may be met through stone storage, perforated pipes, or a prefabricated structure, as follows:

- Stone storage: Maximum of 40% of the void space of the stone storage volume.
- Stone and prefabricated structures shall be separated from soil medium by a non-woven filter fabric or a pea gravel filter.
- Prefabricated Structure: Void spaces for prefabricated structures may be based upon manufacturer's specifications such that all other design requirements are met. Prefabricated structures can include, but are not limited to: storage chambers, interlocking plastic units, and concrete spanning arches, etc. See Materials Section.

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for managing 1.0 inch of runoff:

$$\text{Water Volume Control (cubic feet)} = (1/12) * (IA)$$

Where: IA = Impervious Area Managed (square feet)

STORAGE STONE (OPTIONAL)

Stone used to provide additional storage should meet standards in Section 4.1 Common Components.

Stone shall be separated from soils by a non-woven geotextile or a pea gravel filter.

The table provided for SMP stone reservoir storage (See Section 3.0 Preliminary Planning and Design) is useful in approximating the available storage potential. This table can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

OBSERVATION WELL

Observation wells provide access for inspecting the system, as well as a means to dewater the system in the event of a failure. For Observation Well guidance see Section 4.1 Common Components.

INFILTRATION/OUTFLOW

- A level infiltration area is required.
  - Bed bottoms should be graded into the existing soil mantle.
  - When needed for site grading purposes, use terracing to construct flat systems and allow for grade change.
- Positive overflow for large rainfall events must be provided.
  - All systems must include an overflow structure and piping design to safely convey larger storm events.
  - Outlet controls shall be designed in accordance with Section 4.1 Common Components.

MATERIALS

SUBSURFACE STORAGE

Stone Storage

- Storage stone should meet standards in Section 4.1 Common Components.
- Alternative Subsurface Storage Options
  - Prefabricated Structures or Chambers (up to 96% void space)
  - Perforated pipe in a stone bed

Note: Products with a higher void ratio typically require less excavation as the system size is reduced.

NON-WOVEN GEOTEXTILE

- Geotextile should meet standards as found in Section 4.1 Common Components.

PIPE (IF NEEDED)

- Pipe used for an underdrain should meet standards as found in Section 4.1 Common Components.

MAINTENANCE

As with all infiltration practices, subsurface infiltration systems require regular and effective maintenance. The following table describes typical maintenance requirements for subsurface infiltration systems.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A subsurface infiltration system should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Table 4.5.1: Suggested Subsurface Infiltration Maintenance Activities Suggested

ACTIVITY	SCHEDULE
Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise cleanpretreatment areas in directly connected systems. Keep inflow area and overflow structure free and clear of debris and obstructions.	As needed
Inspect and clean as needed all components of and connections to subsurface infiltration systems. Evaluate the drain-down time of the subsurface infiltration system to ensure the drain-down time of 24-72 hours.	Every 3 Months
Vacuum or flush pipes and underground chambers	As Needed
Maintain records of all inspections and maintenance activity.	Ongoing

GENERAL DO'S AND DON'TS OF SUBSURFACE INFILTRATION SMP MAINTENANCE

DO:

- Maintain inflow areas (e.g. inlets, filters, etc) to be free of trash, sediment, and debris.
- Seek professional assistance for areas in the system which can't be reached for maintenance.

DON'T:

- Flush a system with harsh chemicals.

Flow Through Planter Boxes

chapter 4.6

4.6 Flow Through Planter Boxes

Flow through planter boxes provide exceptional retrofit benefits, as they can be installed without requiring re-grading of the site. Planter Boxes reduce impervious cover by retaining stormwater runoff rather than allowing it to directly drain into nearby sewers. Planter boxes can play an important role in the city by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier look. Planter boxes can be used on sidewalks, plazas, rooftops and other impervious areas. They can also be constructed along side buildings, provided proper waterproofing measures are used to protect foundations.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA MANAGEMENT CREDIT
• Detention and Slow Release • Volume Reduction and Filtration
GROSS AREA STORMWATER CREDIT
• Manage First Inch of Runoff

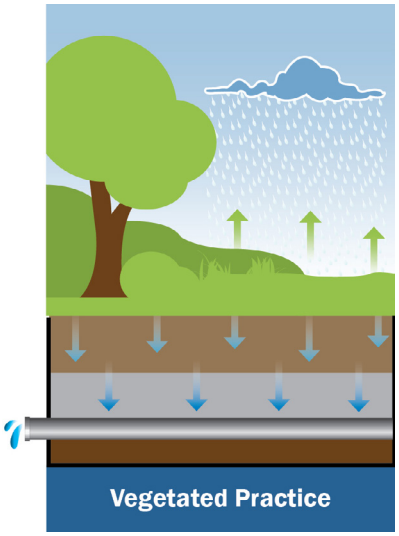


Figure 4.6.1: Flow Through Planter Receiving Stormwater from Downspout

Figure 4.6.**2**: Typical Layout of a Flow Through Planter Box

LOCATION

When locating planter boxes:

- Investigate potential runoff diversion locations for placement of the planter box.
- Place the planter box on an impervious surface or design with an impervious bottom.
- Locate the planter box at least 10ft. away from building foundations,
    - If lined properly with a waterproof membrane, locating the Planter adjacent to a building is acceptable.
- Multiple planters can be used to intercept a larger impervious area and create aesthetic appeal.

The planter may either be prefabricated or permanently constructed and cast in place to provide custom shapes and sizes. Commonly used retrofit locations are discussed in Appendix 3 Credit and Design Calculation Examples.

DESIGN

Planter box designs will vary depending on each individual site and the impervious area draining to the system. The following chapters provide general design guidance intended to assist with planter box design development.

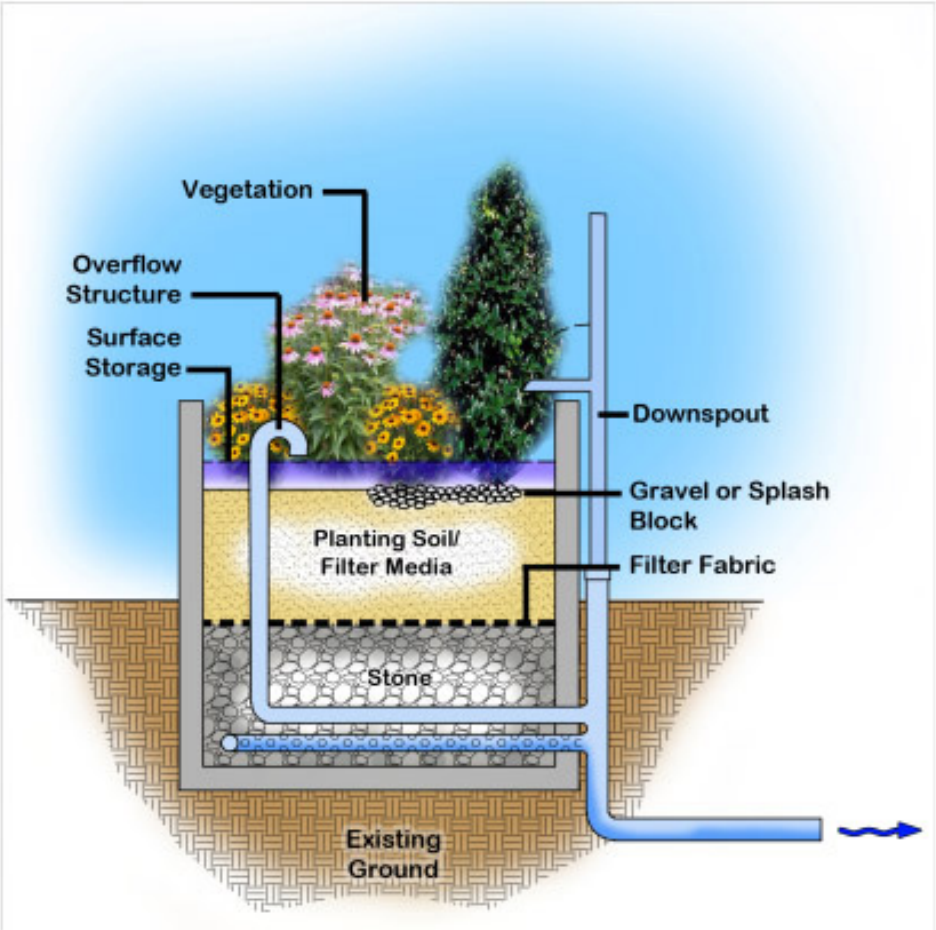


Figure 4.6.**3**: Components of a Flow Through Planter Box

COMPONENTS OF A PLANTER BOX

The primary components of a Planter Box are listed below.

- Flow diverter/downspout
- Pretreatment (e.g. concrete sills, curbstops, sawtooth curbs)
- Surface storage (ponding area)
- Planting soil and filter media
- Native plantings
- Sand bed or stone filter and underdrain,
- Stone reservoir for additional storage, if needed
- Positive overflow

DESIGN GUIDANCE

Design of planter box is flexible. The area, depth, and shape of the system can be varied to accommodate site conditions and constraints. The following design procedures are general guidelines that designers can follow. The typical engineering details for flow through planter boxes can be found in Appendix 4 -Typical Details. An example of a flow through planter box retrofit is provided in Appendix 3 Credit and Design Calculation Examples – Example Site 2.

SIZING RECOMMENDATIONS

- **Loading Ratio:** 10:1 contributing impervious drainage area to Planter Box area.
- **Maximum Drain Down Time:**
  - 72 Hours, applicable to the entire storage volume (surface, planting soil, and gravel if used)
  - 24 – 48 hours recommended for surface storage
- **Surface Ponding:** Typical depth of 1 foot. Minimum depth of 10 inches. For detailed requirements pertinent to Inlet and Outlet Controls see Section 4.1 Common Components.
- **Overflow:** Design a positive overflow for large storms.

STORAGE CALCULATIONS

Storage may be met by providing surface, soil and media storage or a combination thereof, as follows:

- Surface storage: Surface ponding below the overflow elevation;
- Soil media storage: Maximum of 20% of the void space within the soil media volume; and
- Stone storage: Maximum of 40% of the void space of the stone storage volume.

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for regulated activities managing 1.0 inch of runoff in Philadelphia County:

$$\text{Water Volume Control (cubic feet)} = (1/12) * (IA)$$

Where: IA = Impervious Area Managed (square feet)

The table provided for SMP soil storage and stone reservoir storage (See Section 3.1 Preliminary Planning and Design) can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

Inlet & Outlet Controls

- Inlet and outlet controls shall be designed in accordance with Section 4.1 Common Components.
- At inlet locations, design controls to meet energy dissipation requirements and provide pretreatment if required.
- Positive overflow for large rainfall events must be provided.

UNDERDRAINS

Underdrains should be designed in accordance with Section 4.1 Common Components. If the planter box is designed to meet slow release criteria, the applicable release rate requirements must be met in accordance with Section 3.1 Preliminary Planning and Design (i.e. Water Quality slow release in the CSS area and Channel Protection in the separate sewer area).

VEGETATION AND MATERIALS

PLANTING SOIL

The characteristics of the soil for the planter box are perhaps as important as the location, size, and treatment volume. Soils must balance soil chemistry and physical properties to support biotic communities above and below ground. Planting soil should meet the following specifications:

- Soil depth should be a minimum of 2 ft. The actual depth should accommodate both storage and necessary depth for healthy plant growth
- Soil Depth for Herbaceous Species – 24 inches
- Soil Depth for Woody Species – 4 inches deeper than largest root ball
- Engineered Soil Constituents:
    - Clay content: less than 5%
    - Sand content: 60%
    - Leaf compost or aged leaf mulch: 30%
    - High quality topsoil: 10%
    - Be free of stones, stumps, roots, or other woody material over 1 inch in diameter. It should also be free of brush or seeds from noxious weeds.
- Placement of the planting soil should be in lifts of 12-18 inches, loosely compacted.

Figure 4.6.5: Autumn Vegetation in a Flow Through Planter

PLANTS

Plants should be selected that are appropriate for soil, hydrologic, light, and other site conditions. Water plants immediately after planting and then weekly if it does not rain for the first six to eight weeks.

The intent is to establish a diverse, dense, plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure. The proper selection and installation of plant materials is key to a successful system.

- 1 large tree per 100 square feet of planter box area.
- 2-4 small trees or shrubs per 100 square feet of planter box area.
- 6 ferns or grass-like plants per 100 square feet of planter box area (1-gallon containers).
- Groundcover plantings and wildflower plugs with centers 12-inches apart in a triangular pattern.
- A native grass/wildflower seed mix can be used as an alternative to groundcover planting.
- Seed mix shall be free of weed seeds.

Planter Box plantings can be selected from the list of native species provided in Appendix 2 Landscape Guidance and Plant List.

STORAGE STONE (OPTIONAL)

- Stone used to provide additional storage should meet standards in Section 4.1 Common Components.
- Stone shall be separated from soils by a non-woven geotextile or a pea gravel filter.

Figure 4.6.**6**: Well Maintained Flow Through Planter

MAINTENANCE

Properly designed and installed planter boxes require little maintenance. During periods of extended drought, planter boxes may require watering. An overview of long term maintenance needs for planter boxes are provided in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

SUGGESTED PLANTER MAINTENANCE ACTIVITIES

ACTIVITY	SCHEDULE
During extended periods of drought, water plants when wilted as one would any garden or planter. Keep overflow structure free and clear of debris and obstructions. Repair eroded areas.	As needed
Inspect for sediment buildup, erosion, vegetative conditions, etc. Inspect trees and shrubs to evaluate health, replace or treat if necessary. Inspect underdrain cleanout Verify drained out time of system.	Every 3 Months
Maintain records of all inspections and maintenance activity.	Ongoing

GENERAL DO'S AND DON'TS OF PLANTER BOX SMP MAINTENANCE

DO:

- Check for signs of erosion, trash, sediment build up, or water standing for more than 3 days.
- Remove weeds that prevent water from entering or leaving the planter box.
- Water young plants, and established plants that look brown or wilted.

DON'T:

- Use too much salt or sand around the planter box during winter months.
- Apply fertilizer. Consult a local nursery or PWD if plants are not thriving.
- Pile snow in planter box; this crushes plants.

Tree Trenches

chapter 4.7

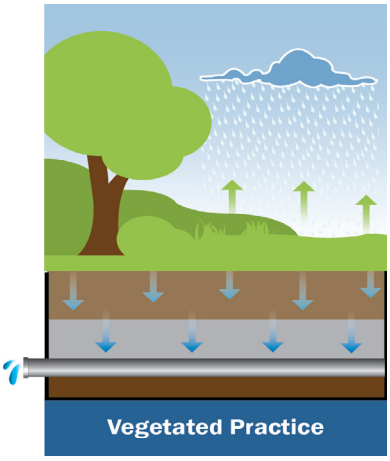
4.7 Tree Trenches

Tree trenches can be designed as mini treatment areas throughout a site with surface drainage, or connected to on-site storm sewer systems. Retrofitting with a tree trench can minimize the impact on an existing site as the surface footprint is similar to that of standard tree plantings. Care should be taken to ensure that the ponding area depth is appropriate for the tree size and species. Special attention should be paid to pretreatment, if water is conveyed to the trench via subsurface pipe. The stormwater runoff waters the trees and slowly infiltrates through the trench bottom. If the capacity of the system is exceeded, an underdrain or overland connection to a downstream inlet can be utilized.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA CREDITS
• Infiltration • Detention and slow release • Volume Reduction and Filtration
GROSS AREA STORMWATER CREDIT
• Manage First Inch of Runoff

Figure 4.7.1: Tree Trenches along Shissler Recreation Center



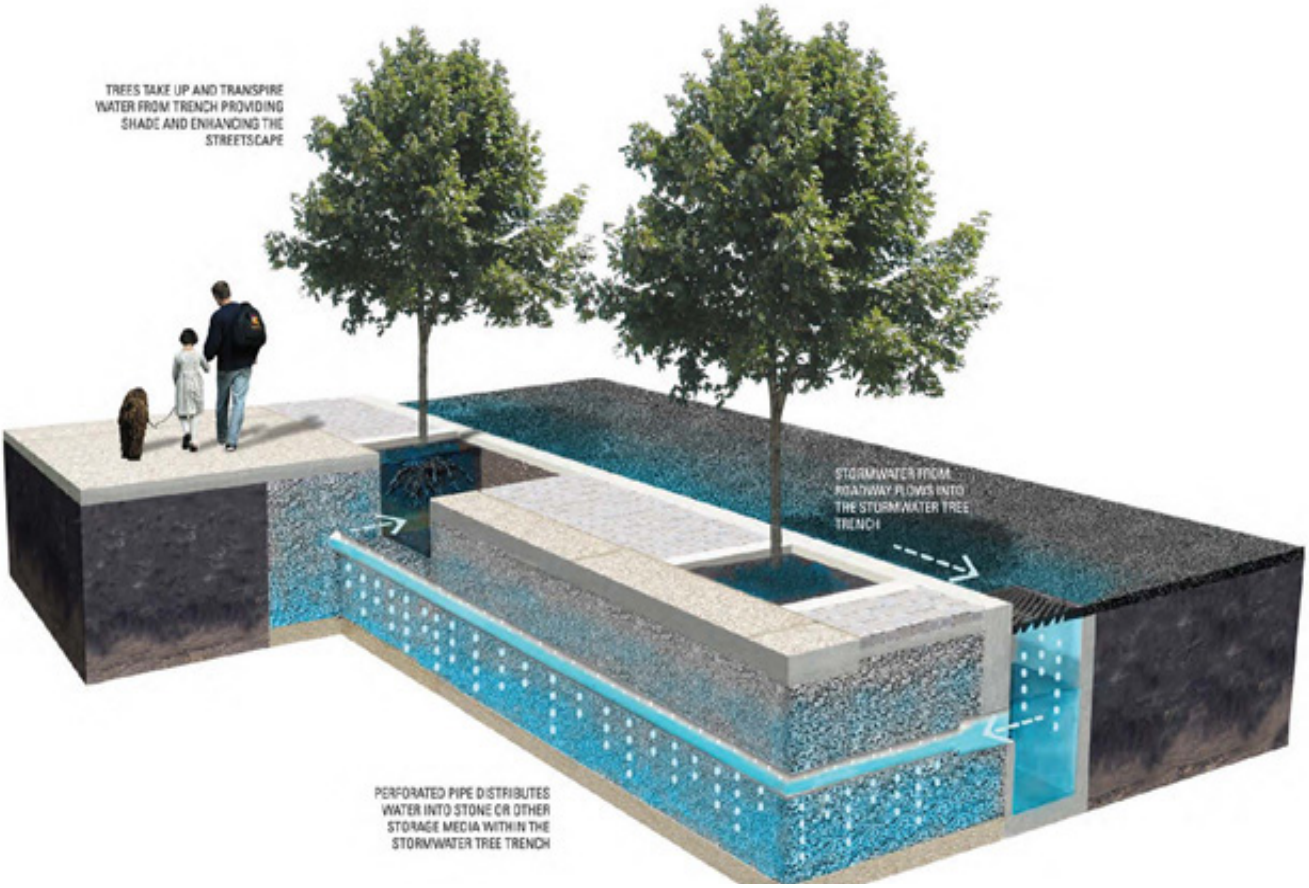


Figure 4.7.**2**: Typical Layout of a Tree Trench

LOCATION

When locating tree trench systems:

- Investigate the subsurface soil and groundwater conditions.
  - Test the existing soil infiltration rate for the proposed tree trench area (Refer to Appendix 1 Soil Infiltration and Profile Guidelines).
  - If infiltration is not feasible, alternate locations or use of an underdrain should be considered.
  - In areas where infiltration is infeasible due to a hotspot, an impervious liner may have to be utilized.
- Locate tree trenches at least 10 ft away from building foundations. Otherwise provide appropriate waterproofing (i.e. impermeable liner).
- Avoid the presence of underground utilities whenever possible.

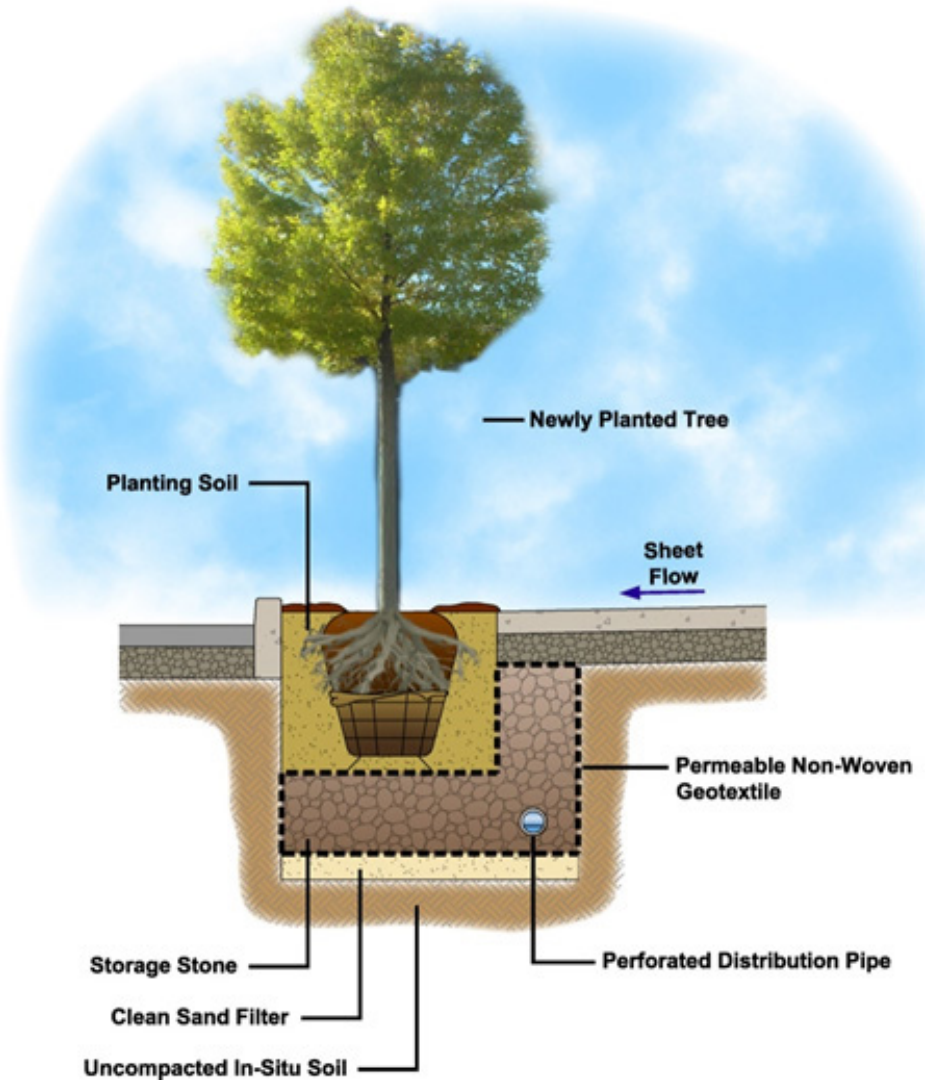


Figure 4.7.3: Components of a Tree Trench

DESIGN

Tree trench designs will vary depending on the individual site characteristics and available areas for implementation. The following chapters provide general design guidance intended to assist with tree trench design development.

COMPONENTS OF A TREE TRENCH SYSTEM

The primary components of a tree trench system are listed below.

- Pretreatment
- Flow entrance/inlet
- Surface storage (ponding area)
- Planting soil and filter media
- Distribution pipe and underdrain, if necessary
- Stone storage or other storage media
- Positive overflow

DESIGN GUIDANCE

Tree trenches provide an opportunity for stormwater management within the same surface footprint as previously landscaped areas, such as parking lots and adjacent walkways and outdoor areas. An engineer shall provide assistance in the design process to help adjust the design until the volume, drainage time, and site constraints are met. Refer to the design details in Appendix 4 for a detailed cross-section.

GENERAL DESIGN GUIDANCE

- In accordance with Appendix 1, suitability of infiltration and the saturated vertical infiltration rate shall be determined. If infiltration is not feasible, consider an alternate location or the use of an underdrain.
- **Loading Ratio:** 10:1 contributing impervious drainage area to tree trench bottom bed area.
- **Dimensions:** Recommended minimum tree pit dimensions are 3-feet by 3-feet, and larger tree trenches are preferred for the health of the tree and should be used if space is available.
- **Maximum Drain Down Time:**
  - 72 Hours for entire storage volume (including surface, soil, and stone if used)
  - 24 – 48 hours recommended for surface storage
- **Typical Surface Ponding Depth:** 1 foot maximum and should be appropriate for the species selected. Note: Tree species may not be able to tolerate 12-inches of ponded water. For reference, stormwater trees used as part of a green street design typically have ponding depths between 2 and 6 inches (refer to the City of Philadelphia's Green Streets Design Manual for further information).

INLET CONTROLS

- Runoff can enter a tree trench through a curb opening, pipe, weir, or other design.
- At inlet locations, design controls to provide pretreatment Positive overflow for large rainfall events must be provided.

STORAGE CALCULATIONS

Storage may be met by providing surface, soil and media storage or a combination thereof, as follows:

- Surface storage: Surface ponding below the overflow elevation;
- Soil media storage: Maximum of 20% of the void space within the soil media volume; and
- Stonestorageorotherstoragemedia:Maximumof40%ofthevoidspaceofthestonestoragevolume.Otherstoragemediamaybeusedwith proper documentation on storage capacity.

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for managing 1.0 inch of runoff:

$$\text{Water Volume Control (cubic feet)} = (1/12) * (IA)$$

Where: IA =managed impervious area (square feet)

The table provided for SMP soil storage and stone reservoir storage (See Section 3.0 Preliminary Planning and Design) are useful in approximating the available storage a potential tree trench can provide. These tables can be referenced to confirm that both WQV and the appropriate surface loading ratio requirements are met.

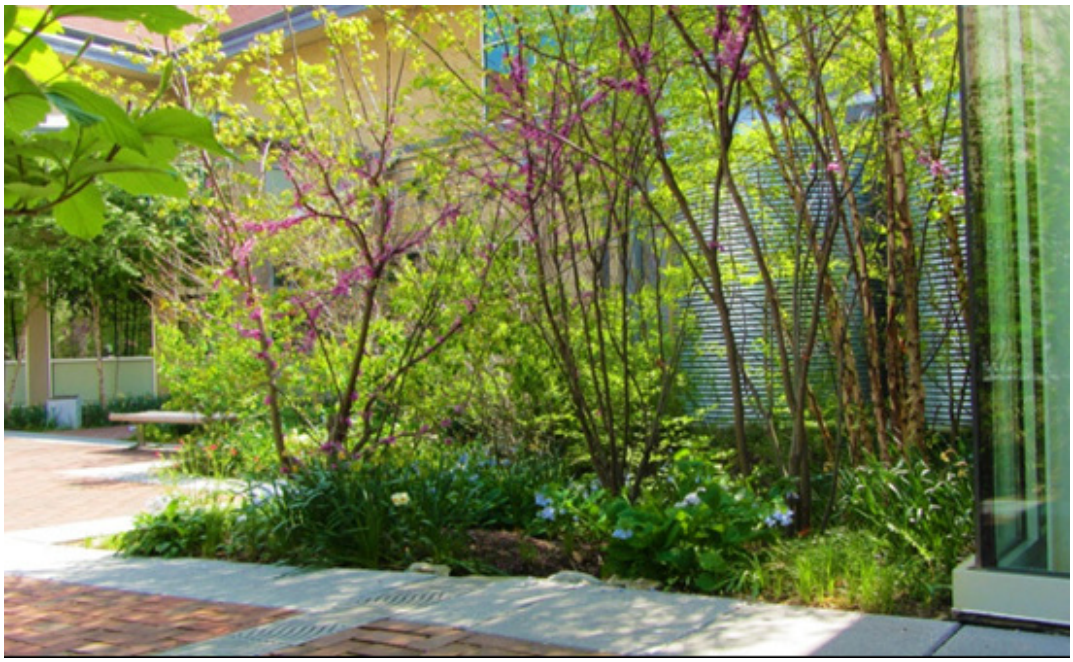


Figure 4.7.4: Flowering Redbud in Tree Trench

STORAGE STONE (IF USED)

A washed stone layer may be added beneath the soil to increase storage and promote infiltration. For Storage Stone specifications see Section 4.1 Common Components.

SOIL

Prepared soil may consist of amended native soils or imported soil. See Section 4.1 Common Components for more information about soil mix requirements.

UNDERDRAINS

Whe n infiltration is not feasible or when a back-up system is desirable, an underdrain may be used. Underdrains should be designed in accordance with Section 4.1 Common Components.

If infiltration is not utilized, check that release rate requirements are met in accordance with Section 3.0 - Preliminary Planning and Design. Maximum release rate should be calculated based on the head of water at the static Water Quality Volume storage elevation.

VEGETATION AND MATERIALS

PLANTING SOIL

Refer to Section 4.1 Common Components for prepared soil specifications.

Trees

Plants that are appropriate for soil, available water, light, and other site conditions should be selected. The proper selection and installation of trees will ensure a long lasting management practice. Select a tree which will thrive in the designed tree trench. Consider ample space for root growth such that the tree will not impact nearby concrete sidewalks or other structures and utilities. Tree Trench plantings can be selected from the list of native species provided in Appendix 2 Landscape Guidance and Plant List.

Consider the following recommendations when selecting vegetation:

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
  - 1 large tree per 100 square feet
  - 2-4 small trees or shrubs per 100 square feet.

MAINTENANCE

Properly designed and installed tree trench systems require little maintenance. A summary of basic maintenance is provided in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A tree trench should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Table 4.7.1: Suggested Tree Trench Maintenance Activities

ACTIVITY	SCHEDULE
Inspect trees and shrubs to evaluate health, replace or treat if necessary. Inspect underdrain cleanout. Verify drained out time of system. Inspect for sediment buildup, erosion, vegetative conditions, etc. Inspect soil and repair eroded areas. Clear litter and debris from overflow and inlet areas.	Every 3 Months
Maintain records of all inspections and maintenance activity.	Ongoing

GENERAL DO'S AND DON'TS OF TREE TRENCH SMP MAINTENANCE

DO:

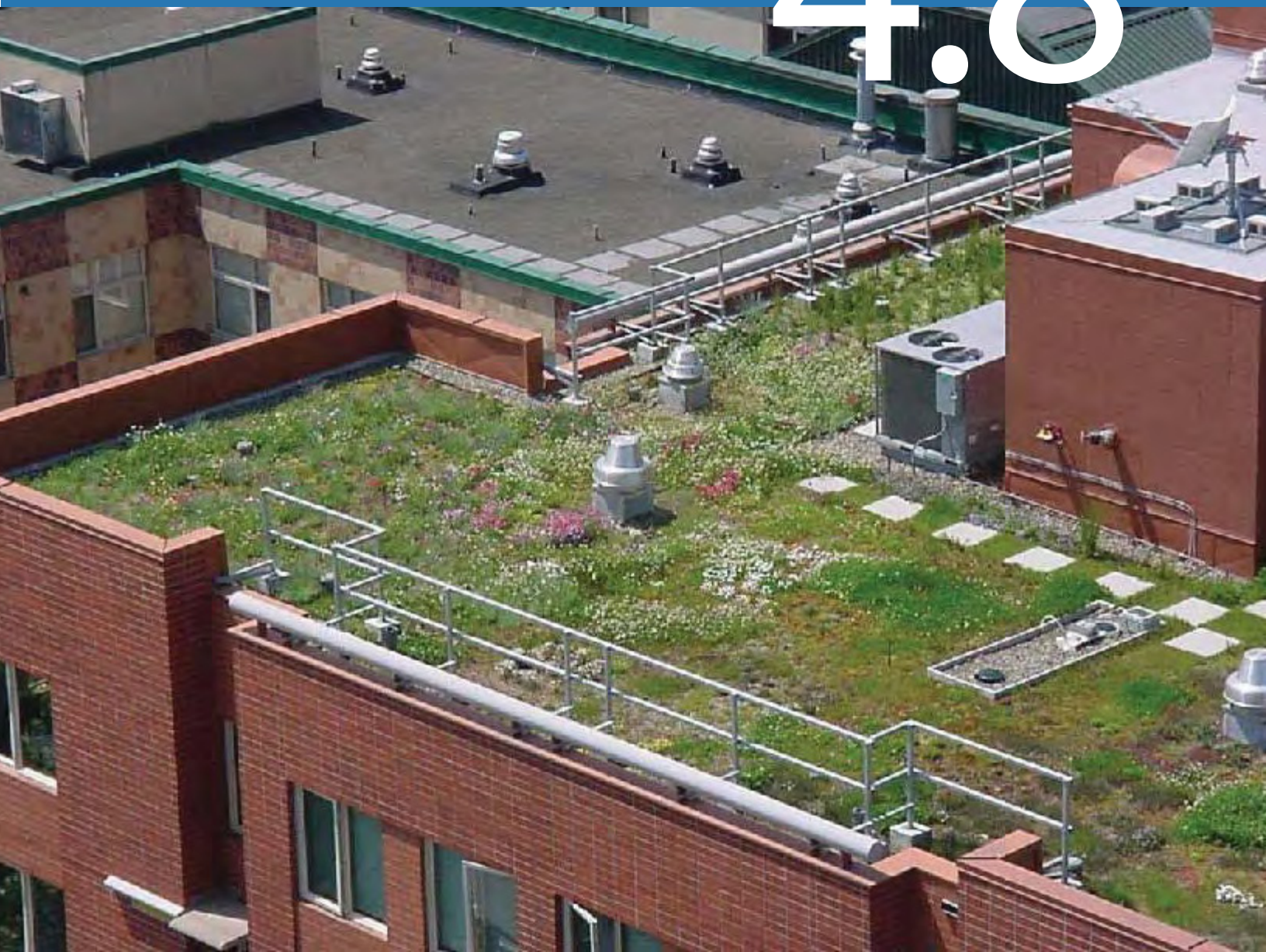
- Check for signs of erosion, trash, or sediment build up.
- Inspect for large stands of reeds or other invasive plant species, as these may require professional control.
- Water trees during establishment, and if they look dry or brown.

DON'T:

- Use too much salt or sand around the tree trenches during winter months.
- Apply fertilizer. Consult a local nursery or PWD if plants are not thriving.

Green Roofs

chapter 4.8



4.8 Green Roofs

Green roofs can be a valuable and cost effective retrofit option when replacing a roof by utilizing the existing footprint of a structure to improve the quality of stormwater, and reduce and delay stormwater runoff quantities. When it rains, green roofs react more like a lawn or meadow than a parking lot or regular roof. A green roof system is composed of multiple layers including waterproofing, a drainage layer, engineered planting media, and specially selected plants.

Green roofs can also provide additional benefits within the urban environment, such as:

- Provide urban green space and aesthetically pleasing views.
- Act as heat sink to reduce heating and cooling costs.
- Extend roof life by two to three times.
- Improve air quality by filtering dust particles.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA REDUCTION
• Volume Reduction and Filtration

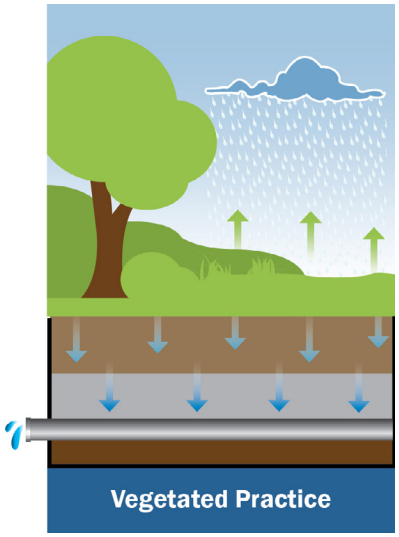


Figure 4.8.1: Green Roof Installed on an Industrial Building

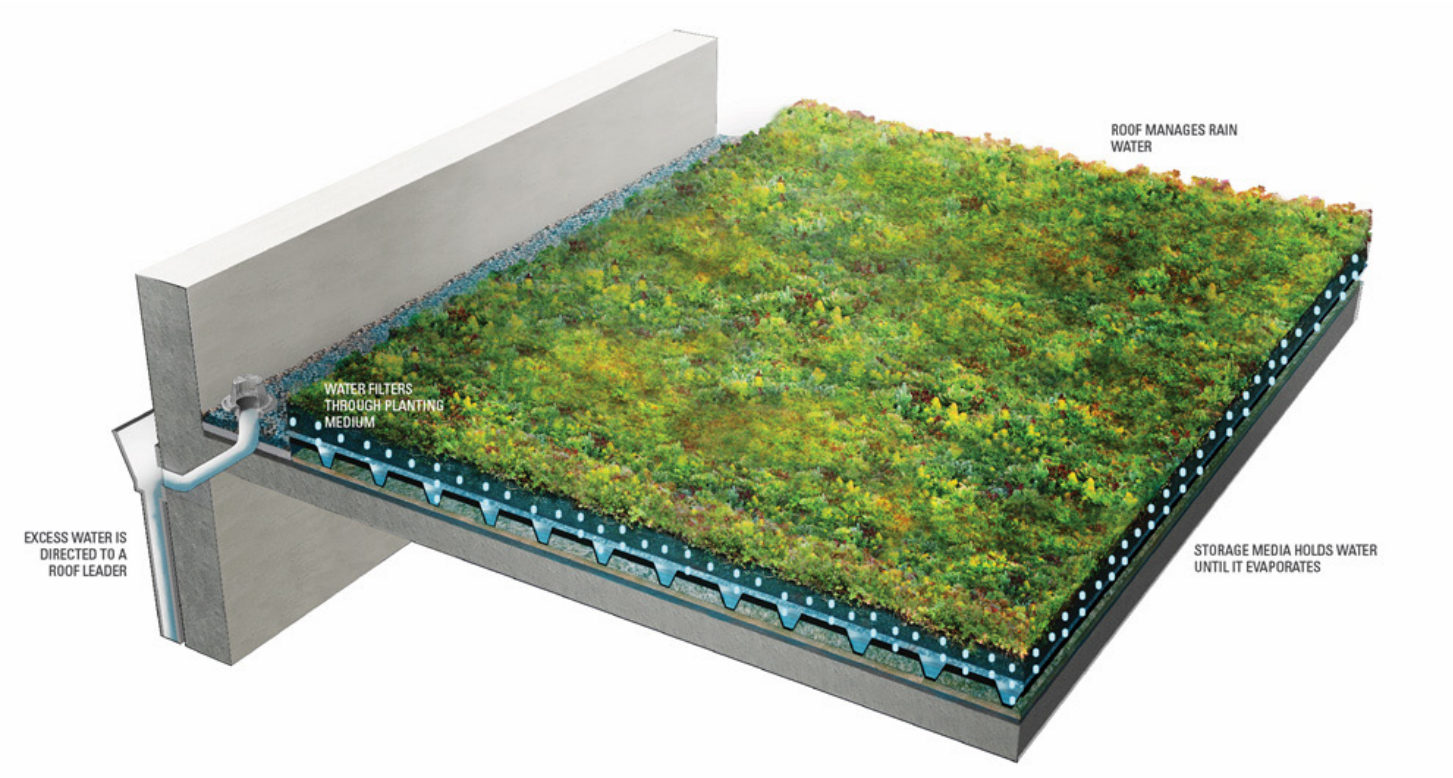


Figure 4.8.2: Typical Layout of a Green Roof

LOCATION

When evaluating an existing roof for a Green Roof Retrofit:

- Verify that the roof will support the weight of the green roof system. It is important to consider the saturated weight of the proposed growing media on the roof in these calculations. Note: A structural engineer should perform this analysis.
- Ensure sufficient accessibility and safety measures are in place as required for maintenance teams, and installation.
- Confirm that adequate drainage is in place to safely convey larger rainfall events.
- Evaluate the potential for integration with other building rooftop systems (e.g. HVAC and drainage systems).
- Consider the suitability of any existing waterproofing membrane. When retrofitting an existing roof, it is important to determine if the manufacturer is willing to warrant green roof instillation over their membrane.

DESIGN

Green roof installations will vary with each site, largely depending on structural suitability and the amount of existing roof area that is suitable for retrofitting. There are two basic types of green roofs. An extensive green roof system is a thin (usually less than 6 inches), lighter weight system planted predominantly with drought-tolerant plants and grasses. An intensive green roof is a deeper, heavier system designed to sustain more complex landscapes. Several types of pre-manufactured extensive roof tray systems are available from suppliers and are designed specifically for existing roof retrofits.

COMPONENTS OF A GREEN ROOF

A green roof system, extensive or intensive, is often comprised of the same components:

- Plant material
- Growing medium
- Filter fabric
- Drainage layer
- Waterproof membrane/root barrier
- Roof structure

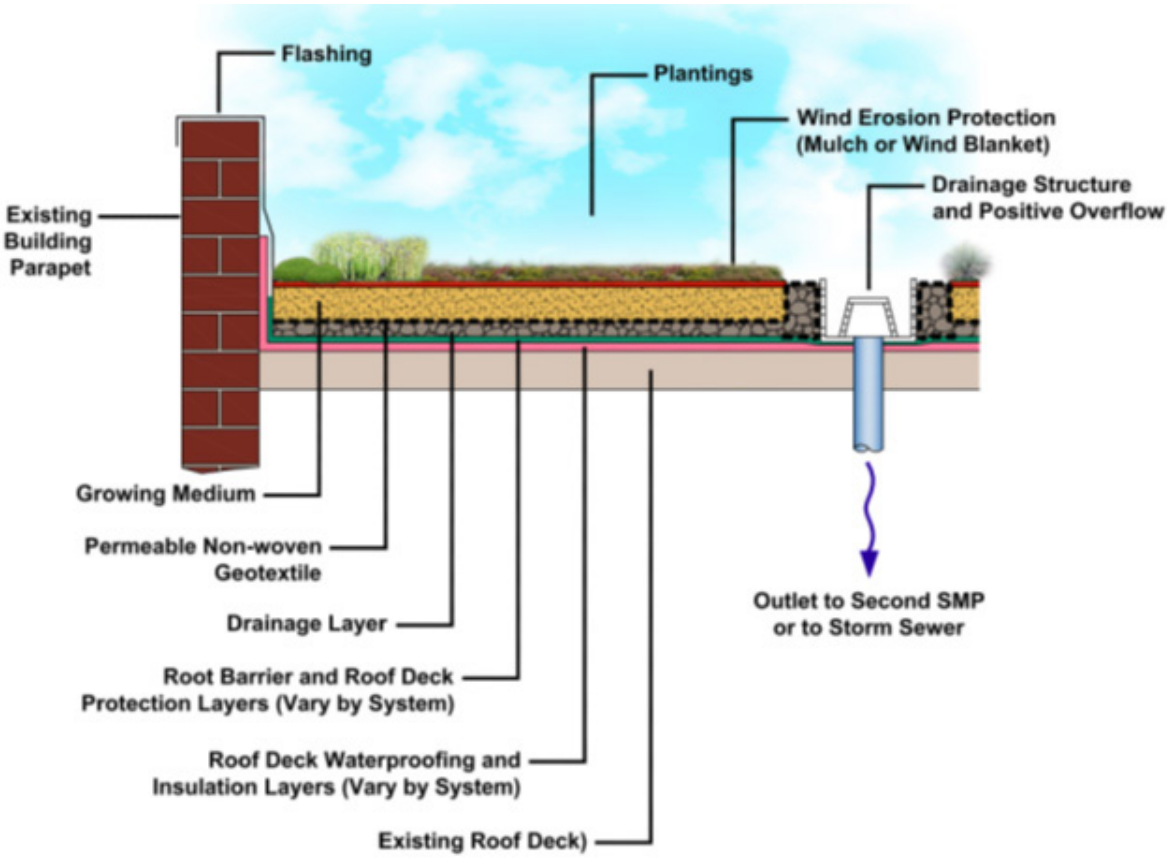


Figure 4.8.3: Components of a Green Roof

DESIGN GUIDANCE

A qualified professional should assist with the selection of materials and vegetation for a Green Roof, and confirm the structural stability of the existing roof. Refer to design details located in Appendix 4. An example of a green roof retrofit is provided in Appendix 3 Credit and Design Calculation Examples - Example Site 4.

Figure 4.8.4: Green Roof Installed on Urban Roof

GENERAL DESIGN GUIDANCE

- Green Roofs with a minimum thickness of 3 inches of engineered soil media are eligible to receive Impervious Area Reduction credit.

PLANT MATERIAL

- Green roof plantings should be able to withstand extreme temperature conditions and high winds.
- After establishment, the plants should be self-sustaining and tolerant of drought conditions.
- See Vegetation and Materials for more detailed specifications.

GROWING MEDIUM

- Green roof growing medium should be a lightweight mineral material with a minimal amount of bouquet organic material.
- See Vegetation and Materials for more detailed specifications.

FILTER FABRIC

- Filter fabric should be a non-woven polypropylene geotextile that can allow for root penetration, but prevent the growth medium from passing through into the drainage layer.

DRAINAGE LAYER

- A drainage layer is required to promote aerated conditions in the planting medium and to convey excess runoff during large rainfall events.
- For vegetated roof cover assemblies with thicknesses of less than 5 inches synthetic drainage layers may be used in lieu of granular drainage layers.

WATERPROOF MEMBRANE/ROOT BARRIER

- PVC,EPDM,andthermalpolyolefin(TPO)areinherentlyrootresistant;othercommonwaterproofingmaterialsmightrequirearootbarrier between waterproofing and vegetative cover.
- Avoid using herbicides to prevent root penetration of waterproofing.

SIZING RECOMMENDATIONS

- Area (surface area) should be the largest feasible on site.
- Design a positive drainage overflow route for large storms. This often consists of raising the elevation of the existing roof drains and allowing them to act as overflow.

Although green roofs are not considered as impervious surfaces, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff to the existing storm sewer, or receiving water body. The function of a green roof is highly dependent upon the design and materials used. Consult with an engineer or manufacturer when designing a green roof.

Figure 4.8.5: Urban Green Roof with Maintenance Access Paths

VEGETATION AND MATERIALS

MATERIALS

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below focus on those for extensive green roof requirements, which are required to receive Impervious Area Credit. Intensive Green Roofs are also acceptable but not required to be eligible for credits. See below for Testing Procedures and References of approved standards.

VEGETATION

Develop a Planting Plan based on the thickness of the planting media.

- For extensive green roofs;
  - Half of the plants should be varieties of Sedums.
  - At least four different species of sedum should be used.
  - The remainder of the plants should be herbs, meadow grasses, or meadow flowers, depending on the desired appearance.

Note: Sedum sarmentosum, commonly referred to as star sedum, gold moss, stringy stonecrop, or graveyard moss, is the only Sedum known to be invasive and should not be utilized.

- Vegetated roof covers intended to achieve water quality benefits should maintain a soluble nitrogen level of 4ppm.
- To minimize erosion in winter months, green roofs should include a significant percentage of evergreen plants.
- Green roofs can be established by dispersing fresh Sedum cuttings over the green roof area, during April- May and September-October. Temporary irrigation may be required in the first couple of months after planting.
- Plugs of Sedum and many perennial plants can be installed anytime between April and November. Temporary irrigation may be required depending on the time of installation.
- Perennials can be seeded, except during summer months.

- A biodegradable or photodegradable wind barrier or hydro mulch is required to prevent erosion during the establishment period. In general, it takes two growing seasons to fully establish green roof plantings.
- When fully established, the selected plantings should thoroughly cover the growing medium.

GROWING MEDIUM

Green roof growing medium should meet the following standards:

TABLE 4.8.1: GROWING MEDIUM STANDARDS	SPECIFICATION
Moisture content at maximum water holding capacity (ASTM E2399 or FLL*):	≥ 35%
Porosity at maximum water holding capacity (ASTM E2399 or FLL):	≥ 6%
Total organic matter (MSA)	3-8%
pH (MSA)	6.5-8.0
Soluble salts (DPTA saturated media extraction)	≤ 6 mmhos/cm
Water permeability (ASTM E2399 or FLL)	≥ 0.5 in/min

*Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL)

- Grain-size distribution, as recommended by FLL
- Nutrients should be initially incorporated in the formulation of the growing medium, for the support of the specified plant materials.

DRAINAGE LAYER

For vegetated cover assemblies with an overall thickness of 5 inches, or greater, the drainage layer shall meet the following specifications:

TABLE 4.8.2: DRAINAGE LAYER STANDARDS	SPECIFICATION
Abrasion resistance (ASTMC13196)	≤ 25% loss
Soundness (ASTMC88)	≤ 5% loss
Porosity (ASTMC29)	≥ 25%
Percent of particles passing 1/2inch sieve (ASTM C136)	≥ 75%

The minimum thickness of the granular layer shall be 2 inches. The granular layer may be installed in conjunction with a synthetic reservoir sheet.

MAINTENANCE

Properly maintained green roofs can remain healthy and functional for many years.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A green roof should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

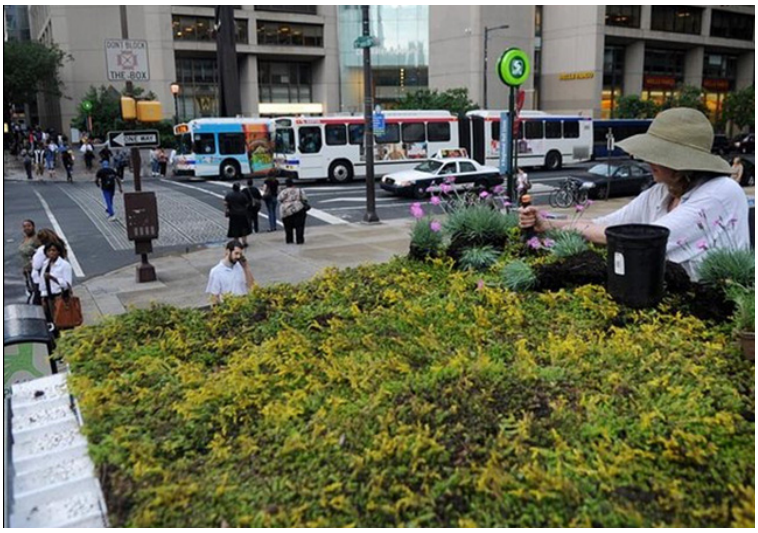


Figure 4.8.6: Replacing Dead Plants on a Green Roof

Table 4.8.3: Suggested Maintenance Guidelines

ACTIVITY	SCHEDULE
If necessary during the establishment period (initial 18 months), irrigation can be provided by hand watering or automatic sprinkler system.	First year after installation
Keep overflow structure free and clear of debris and obstructions.	As needed
Verify drained out time of system. Inspect for sediment buildup, erosion, vegetative conditions, etc. Remove litter and debris. Inspect for weeds and invasive plants and remove as necessary.	Every 3 Months
Maintain records of all inspections and maintenance activity.	Ongoing

GENERAL DO'S AND DON'TS OF GREEN ROOF SMP MAINTENANCE

DO:

- Check any drains, screens, and weirs for debris that could cause clogs.
- Check plants for signs of drought or nutrient deficiency (signs can include brown, bleached, or discolored leaves, or wilted plants).
- Remove weeds and invasive plants twice a year.

DON'T:

- Over-water plants.
- Apply fertilizer without consulting a professional. Talk to your local nursery or PWD if your plants are not thriving.

Cisterns - Capture and Reuse

chapter 4.9

4.9 Cisterns - Capture and Reuse

Cisterns and other tanks with similar functions such as stormwater reservoirs, and rainwater harvesting systems provide exceptional retrofit opportunities as they are designed to directly intercept and store runoff from impervious areas such as rooftops. Cisterns are best utilized where stormwater can be recycled for identified non-potable uses such as irrigation or toilet flushing. They can be incorporated into stormwater management plans where there is sufficient regular demand to empty the reservoir by supplementing non-potable water usage between storm events. The design of these systems is flexible in size, shape, materials, location and reuse purpose.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA MANAGED CREDITS
• Detention and Slow Release • Capture and Reuse
GROSS AREA STORMWATER CREDIT
• Manage First Inch of Runoff

Figure 4.9.1: Cistern with Overflow Pipe

Figure 4.9.2: Typical Layout of Underground Cistern

LOCATION

- Cisterns may be above or below ground and they may be indoor or outdoor systems.
- Systems may service the reuse application by gravity or may require pumping.
- Where possible, locate the Cistern at a higher elevation than that of the intended reuse in order to promote gravity flow.
- When determining the location of Cisterns, ensure that there is:
    - A logical point, such as a downspout, to intercept the runoff conveyance
    - Adequate space to safely discharge overflows away from adjacent buildings or site improvements
    - Adequate space for appropriate foundation and structural support
    - Access for cleaning and maintenance
    - Confirm that the roof surface material will not introduce contaminants

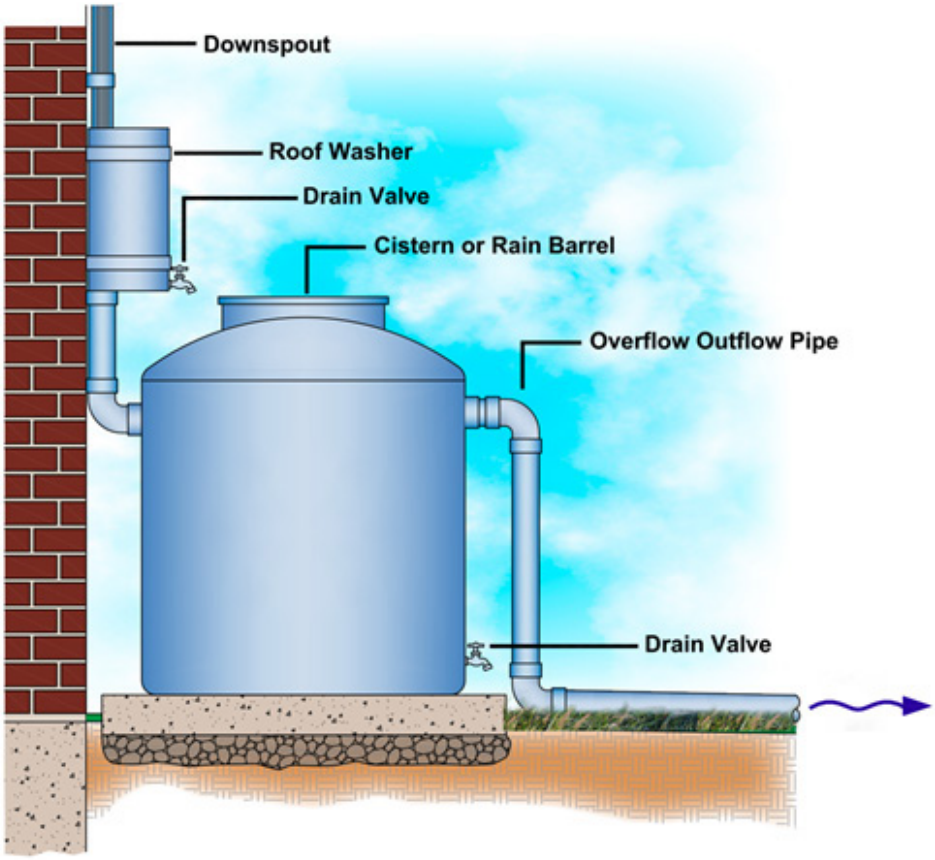


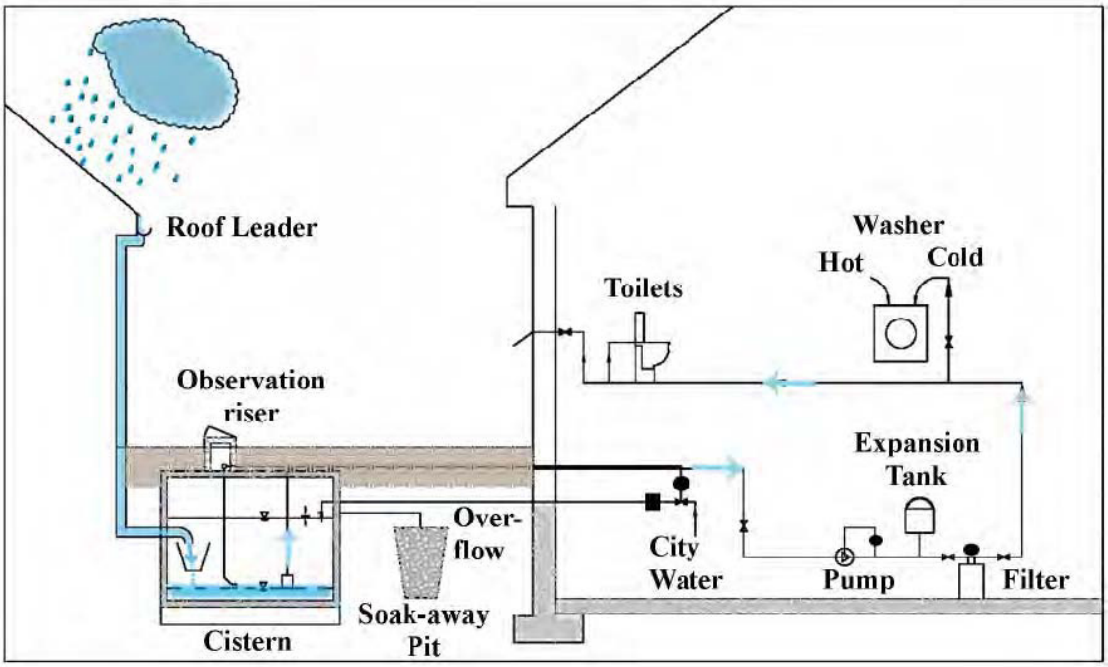
Figure 4.9.3: Components of a Cistern

KEY COMPONENTS

- Storage components may include underground concrete or prefabricated tanks, above ground vertical storage tanks, internal collection tanks, or other similar systems.
- Subsurface systems can be larger, typically have less structural design constraints, and minimally impact landscaping. They are most appropriate for commercial and institutional sites and often include pumping and pre-filtering.
- Systems must provide for overflow or bypass of large storm events.
- Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.
- For effective stormwater control, water must be used before the next storm event.
- Cistern Systems are most effective when designed to meet a specific water need for reuse.
- A supplemental source of water should be provided for the reuse application in the event that supply is not available from the Cistern.
- Pretreatment can be accomplished by use of screens, first flush diverters, in-line filters or roof washers.

DESIGN

In order to receive stormwater credit, the Water Quality Volume must be stored and used in the first 72 hours after the storm event. Therefore, water use demands must be documented and included as part of the design considerations. See Section 3.0 Preliminary Planning and Design to determine the Water Quality Volume of rooftop areas draining to downspouts where cisterns may be located. Typical engineering details for cisterns can be found in Appendix 4. An example of a cistern retrofit is provided in Appendix 3 Credit and Design Calculation Examples - Example Site 1.



COMPONENTS OF A CISTERN

Cisterns and tanks all include the following basic components:

- Roof leader or other stormwater conveyance,
- Screen,
- Storage element,
- Reuse opportunity, or infiltration area, and
- Overflow device

SCREEN

A screen prevents debris and mosquitoes from entering.

- Typically placed at the end of the roof leader, before flow enters the rain barrel.
- A leaf strainer or sediment trap may also be placed where the gutter connects to the roof leader.

STORAGE ELEMENT

The storage element is the cistern or tank itself. Tanks may be used above or below ground.

- Underground cisterns may be poured concrete or prefabricated plastic tanks similar to septic tanks.
- Proprietary products that store water in a variety of structures are also available.
- Some of these are designed to bear the weight of vehicles.
- Storage tanks should be made of material that is appropriate for the application and sealed with a water safe non-toxic substance.
- Multiple tanks in a variety of sizes may be used to meet requirements.

SLOW RELEASE MECHANISM OR PUMP

- Larger surface tanks may drain by gravity or may be pumped.
    - Subsurface systems and systems where stormwater is supplied for needs other than irrigation are typically pumped.
- To perform effective stormwater control and maintain available volume within the Cistern, the rate of use must be sufficient to empty the storage between most storms.

REUSE OPPORTUNITY

For cisterns and other tanks to provide effective stormwater management, an opportunity for reuse of the stormwater must exist. This opportunity might be provided by a garden or landscaped area that needs to be watered, by routing the stored volume to another SMP area, or by pumping to an irrigation tank or water truck for use in other locations.

Storing water for emergency purposes, such as fire protection, is not considered a suitable reuse opportunity, because the storage volume will not be emptied between each storm.

OVERFLOW MECHANISM

The storage capacity of cisterns and other tanks will be exceeded in large storms. The overflow from cisterns and larger tanks can occur through a hose, weir, pipe, or similar mechanism. Ensure that appropriate erosion control measures are designed for the discharge location of the overflow device. This may be a concrete splash pad or inlet controls built into a vegetated SMP.

DESIGN GUIDANCE

CONCEPTUAL DESIGN

- Identify opportunities and areas where:
    - water can be reused for irrigation; or
    - meet indoor non-potable use needs.
- Estimate the rate at which water can be reused.
    - Fo r irrigation or garden use, determine the water needs of the plants; an assumption of 1 inch per week over the soil area may be used for approximate results.
    - For flushing, calculate volume based on number of flushes per day times 1.6 gallons per flush (new toilet).
- Consider more than one tank if additional storage is required, making sure that there is sufficient demand for the water.

Table 4.9.1: Suggested Storage Design Values per Tank Type

Cistern	500-7,000 gallons
Larger Above Ground Tank	3,000 – 12,000 gallons

CISTERNS (SUBSURFACE OR SURFACE):

- Identify which roof leaders can drain to the cistern, and the area of roof draining to each leader.
- Estimate the storage needed. A rough estimate may be obtained by performing a weekly water balance of rainfall and water reuse. At a minimum, the cistern must be large enough to store 1 inch of runoff from the contributing impervious drainage area.
  - The table below lists average monthly rainfall amounts at the Philadelphia International Airport.
  - Estimate the difference on a weekly basis between rainfall depth and water depth needed.
  - Multiply this deficit by the roof drainage area to obtain an estimate of the cistern volume needed.
- The Design Professional may choose to do a more rigorous analysis using a long-term daily or hourly rainfall record, or using a dryer than average year.
- Determinethepumpingrequirementsordesignagravitysystemtomeetwaterreuserequirements.Thecisternmustdrainwithin72hoursto maximize available storage at the beginning of each storm.
- Recommended approach is to engage a design professional specializing in water reuse systems, familiar with Philadelphia Plumbing Code requirements, in order to develop any required mechanical, electrical, and/or plumbing designs. A detailed discussion of pumping and outlet hydraulics is beyond the scope of this manual.
- Several manufacturers of prefabricated rainwater harvesting systems provide full design services for their products.

Engage a design professional specializing in water reuse systems and familiar with Philadelphia Plumbing Code requirements, in order to develop any required mechanical, electrical, and/or plumbing designs.

Table 4.9.2:Average Monthly Rainfall at Philadelphia International Airport

	AVERAGE	AVERAGE TEMPERATURE		POTENTIAL
	PRECIPITATION	HIGH	LOW	EVAPORATION
MONTH	(IN)	(°F)	(°F)	(IN/MONTH)
January	3.3	39.2	24.4	2.1*
February	2.9	42.1	26.1	2.1*
March	3.6	50.9	33.1	2.1
April	3.4	63	42.6	4.5
May	3.5	73.2	52.9	5.4
June	3.6	81.9	61.7	6.3
July	4.1	86.4	67.5	6.6
August	4.3	84.6	66.2	5.7
September	3.4	77.4	58.6	4.2
October	2.8	66.6	46.9	2.7
November	3	55	37.6	2.1
December	3.3	43.5	28.6	2.1*

OVERFLOW:

- Check that any release rate requirements (including release through any positive overflow) are met by the system as designed.
- Do not direct overflow where the potential for freezing across a traveled area may occur.

MATERIALS

Cisterns may be constructed of fiberglass, concrete, plastic, brick, or other materials.

For a detailed discussion of cistern materials and construction, see the Texas Guide to Rainwater Harvesting.

MAINTENANCE GUIDELINES

As with other stormwater management practices (SMPs), these stormwater storage systems require regular maintenance to ensure a prolonged life. The following table suggests maintenance activities to perform on cisterns.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs which can be useful in documenting activities and maintain SW credits.

Stormwater storage systems should be inspected four (4) times per year. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Table 4..9.3: Suggested Cistern Maintenance Activities

ACTIVITY	SCHEDULE
Inspect all components of the cistern for trash, sediment, and debris Inspect cistern for any structural damage	Every 3 months
Occasional cleaning of the draining surface may be necessary to remove debris, such as leaves, coming off the drainage area Flush cisterns to remove sediment	As Needed
Brush the inside surfaces and thoroughly disinfect To avoid structural damage, the surface tanks should be drained prior to freezing weather	As Needed
Maintain records of all inspections and maintenance activity	Ongoing

GENERAL DO'S AND DON'TS OF SWALE SMP MAINTENANCE

DO:

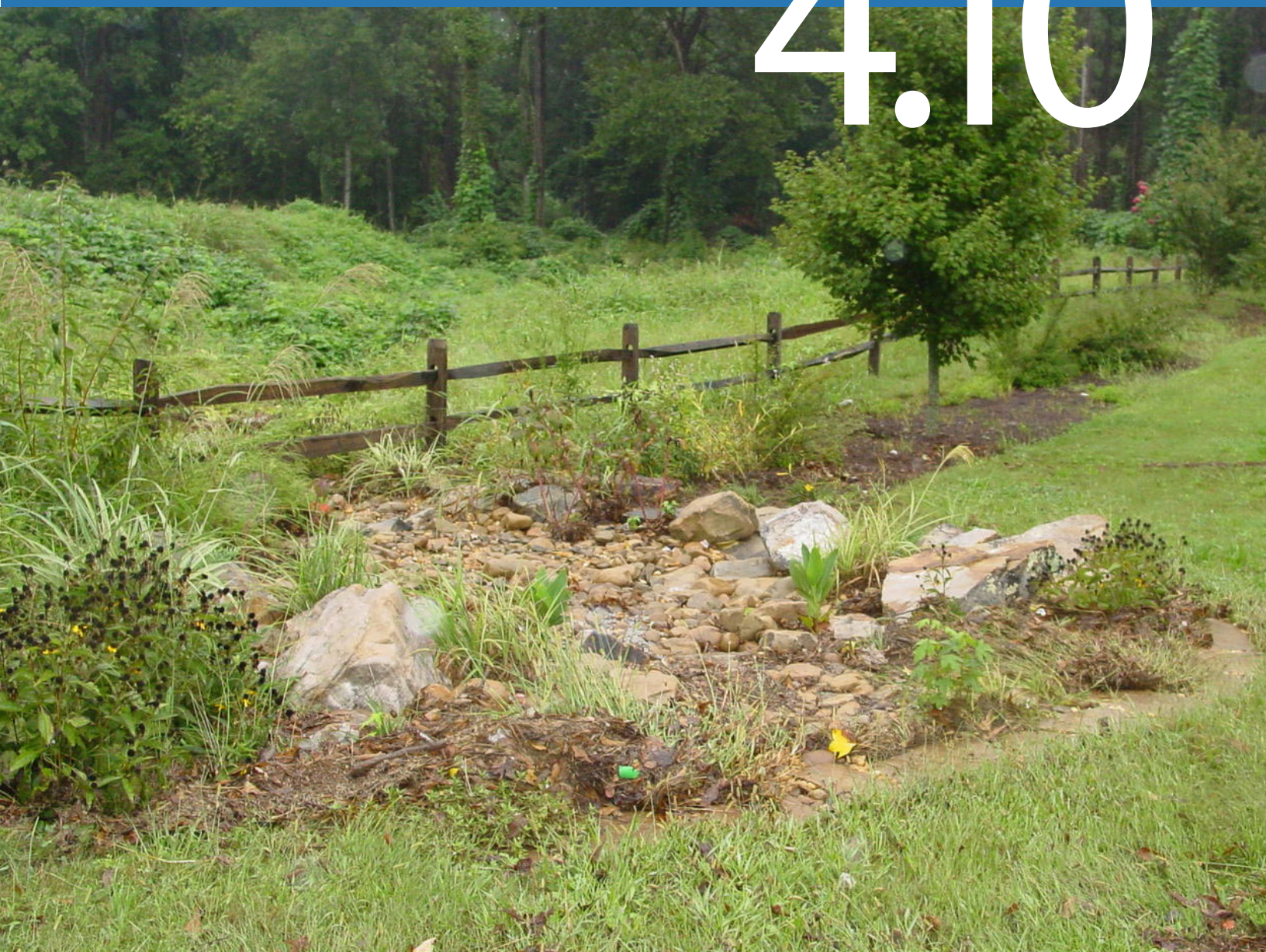
- Check inflow pipes, screens, and valves for debris that could cause clogs.
- Drain above-ground cisterns before the first frost and close valves to prevent freezing.
- Flush or vacuum underground cisterns, to remove trash, sediment, and debris.

DON'T:

- Flush a system with harsh chemicals. Organic cleaners, or sometimes just water and a scrub brush, are sufficient.

Dry Extended Detention Basin

chapter 4.10



4.10 Dry Extended Detention Basin

Dry extended detention basins provide temporary storage of runoff and function hydraulically to attenuate stormwater runoff peaks and to improve water quality. When infiltration is not feasible, detention basins can be used to meet slow release rate requirements. Existing surface basins, typically installed for flood contol, may not have incoporated Water Quality into the original design. These systems can usually be retrofitted to meet WQ requirements by increasing detention time through simple adjustments to the outlet control structure, micro-grading, and adding vegetation.

Detention basins are typically suitable for larger developments and high-density commercial projects. Depending on the design requirements, dry extended detention basins may require substantial open space; however, they can be designed to support alternative open space uses between storm events, creating recreational opportunities. Subsurface systems provide more flexibility and allow for installation under parking areas and other surfaces uses, but require pretreatment. Subsurface detention systems are very similar to subsurface infiltration practices, covered in Section 4.5, with an additional slow release outlet control structure.

STORMWATER CREDIT POTENTIAL

IMPERVIOUS AREA CREDITS
• Detention and Slow Release
GROSS AREA STORMWATER CREDIT
• Manage First Inch of Runoff

Figure 4.10.1: Extended Detention with Vegetation

Figure 4.10.**3**: Subsurface detention system in Parking Lot- Cardone Industries

Figure 4.10.3: CULTEC Subsurface detention system in Parking Lot

LOCATION

- Existing detention basins can be modified to meet slow release requirements.
- Avoid steep slope areas - Slopes may not be significantly altered or modified to reduce the steepness of the existing slope.
- Extended detention basins shall not be constructed within jurisdictional waters, including wetlands.
- Subsurface detention systems can be utilized when combined with pre-treatment to maximize usable surface space.

Note: Detention / slow release systems are only eligible for stormwater credit in the CSS area.

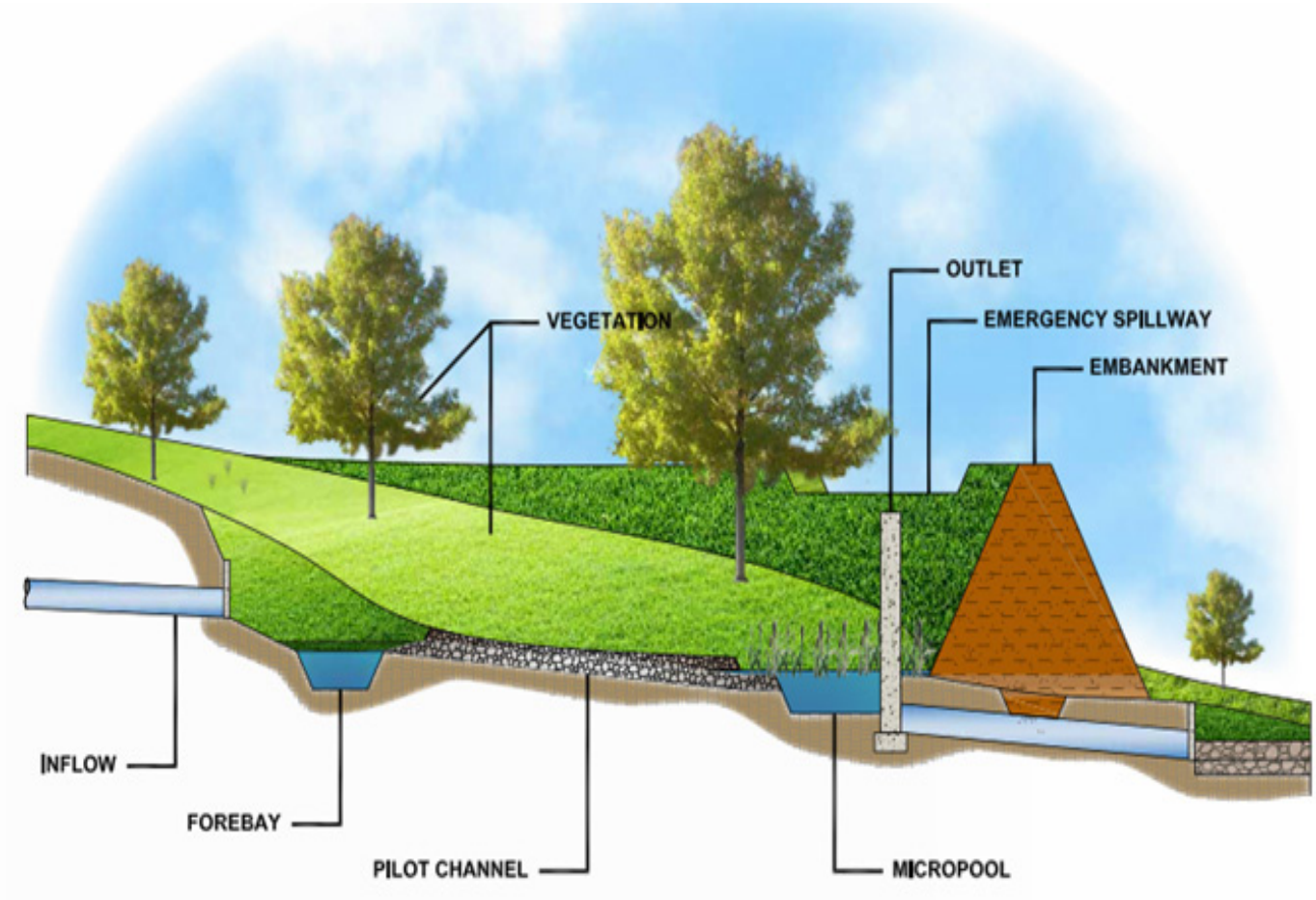


Figure 4.10.4: Cross Section of a Dry Extended Detention Basin

COMPONENTS OF A DRY EXTENDED DETENTION BASIN

Extended Detention Basins are typically comprised of the following components:

- Inflow
- Sediment forebay (pre-treatment)
- Vegetation
- Pilot Channel
- Micropool
- Outlet

DESIGN GUIDANCE

In accordance with Appendix 1, suitability of infiltration and the saturated vertical infiltration rate shall be determined. Only when infiltration is not feasible, should detention practices be considered. More information on dry extended detention basins can be found in the Pennsylvania Stormwater BMP Manual. Typical engineering details for dry extended detention basins can be found in Appendix 4. An example of a dry extended detention basin retrofit is provided in Appendix 3 Credit and Design Calculation Examples – Example Site 1.

- Maximum Drain Down Time:
    - 72 Hours for entire storage volume
    - 24 – 48 hours recommended for surface storage

WATER QUALITY MANAGEMENT VOLUME

The following equation shall be used to determine the Water Volume Control storage requirement in cubic feet for managing 1.0 inch of runoff:

Water Volume Control (cubic feet) = (1/12) * (IA)

Where: IA = Impervious Area Managed (square feet)

SIZING RECOMMENDATIONS

Sizing a detention system begins with determining the slow release rate requirement. Upon determination of the slow release rate requirement, the following method can be utilized to size a system:

- Select an appropriate orifice size to meet the release rate.
- Determine the maximum allowable head on the orifice that will meet the WQ slow release rate requirement, and size the basin footprint to statically store the WQ at this depth.

Note - If an orifice size less than 2-inches is required to meet WQ design requirements, contact PWD.

Table 4.10.1: Starting Design Parameters for Dry Extended Detention Basins

Detention time for water quality volume	24-hour minimum
Water depth	10 feet (Maximum)
Width	10 feet (Minimum)
Shape	To maximize length of stormwater flow pathways. To minimize short-circuited inlet-outlet systems.
Length to width ratio	2:1 (Minimum - recommended to maximize sedimentation)

Table 4.10.2: Contour Design Parameters for Detention Basins

Lowest basin elevation	2 feet above seasonal high water table (Minimum)
Basin shape	Irregularly shaped to appear more natural
Low flow channels	Only use where there is a concern for severe ponding due to native soils Always vegetate with a maximum slope of 3% to encourage sedimentation Consider other SMPs such as wet ponds, constructed wetlands or bioretention
Vegetated embankments	Less than or equal to 3 feet in height (Recommended) 15 feet in height (Maximum)* Maximum slope 3:1 (Horizontal to vertical)
Basin freeboard	Minimum 1 foot above the 100-yr design storm
*15 feet or higher or that which will impound more than 50 acre-feet of runoff during high-water condition will be regulated as dams by PADEP. Consult chapter 105 of the Pennsylvania State Code.	

SUBSURFACE DETENTION SYSTEMS

Subsurface systems can be designed with a variety of media types and configurations, to provide more flexibility with surface uses on a site. Storage media types can include pipe in stone, proprietary storage units (e.g. storage-crates, storage tanks, chambers), or vaults. Subsurface detention systems should be designed to meet target release rates, and can be sized using one of the two methods described above.

STORAGE STONE FOR SUBSURFACE SYSTEMS

For Storage Stone specifications see Section 4.1: Common Components.

Figure 4.10.5: Sediment Forebay

INLET CONTROL

Runoff can enter the detention system through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road, and down a swale slope in a diffuse manner. Inlets should protect against erosive forces and provide energy dissipation as described in Section 4.1 Common Components.

Subsurface detention systems require pretreatment, and sediment forebays provide pretreatment for surface practices. See Section 4.1 Common Components and Section 4.5 Subsurface Infiltration Practices.

SEDIMENT FOREBAY

The sediment forebay improves pollutant reduction by trapping larger particles near the inlet of the pond. A sediment forebay will reduce the potential for control structure failure due to clogging. Sediment forebays should be designed for ease of maintenance; therefore, they must be accessible to heavy machinery. Those constructed with a bottom made of concrete, or other solid materials, make sediment removal easier and more accessible by heavy machinery.

Sediment forebays should be sized to store approximately 10% of the water quality volume.

VEGETATION

Surface vegetation in the basin provides erosion control and sediment entrapment. Side slopes, berms, and the basin surface should be planted with appropriate native species. Appropriate species can be found in Appendix 2: Landscape Guidance.

MICROPOOL AT THE OUTLET (OPTIONAL)

The micropool is typically shallow and permanently inundated. Its function is to concentrate finer sediment and reduce re-suspension. The micropool is normally planted with wetland vegetation species such as cattails.

OUTFLOW STRUCTURE

Existing detention systems, being retrofitted into extended detention systems, for stormwater credit, must maintain the integrity of the original design for all stormwater management requirements including Flood Control requirements. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the structure. See Section 4.1: Common Components for more information.

- An overflow must be provided for larger events.
- If the basin discharges to a channel with dry weather flow, care shall be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.

MATERIALS

BASIN SOIL

A minimum of 6 inches of planting soil is recommended. Soil shall be a high-quality topsoil with a loam or sandy loam texture. Clay cores may be necessary in basins designed to withstand excessive pressures and seepage forces.

PLANTS

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions.Select plants from the list of native species in Appendix 2: Landscape Guidance.
- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.
- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

MAINTENANCE

Maintenance is required for the proper operation of detention basins. An overview of long term maintenance specific to Dry Extended Detention Basins can be found in this section.

PWD's SMP Operation & Maintenance Manual provides more detailed recommendations, along with inspection and maintenance logs, which can be useful in documenting maintenance activities and maintaining SW credits.

A dry extended detention system should be inspected four (4) times per year. A subsurface detention system should also be inspected four (4) times a year; however, Operation and Maintenance may be more similar to a subsurface infiltration system as described in Section 4.5. Regular inspections will provide opportunities to identify areas of the SMP which may need more attention.

Table 4.10.3: Recommended Dry Extended Detention Basin Maintenance Activities

ACTIVITY	SCHEDULE
Remove trash and debris. Remove invasive plants. Trees, shrubs, and other vegetative cover will require periodic maintenance such as, pruning, and pest control. Mow/trim detention basin vegetation. Sediment should be removed from the basin.	As needed
Inspect outlet control structure for clogging. Inspect detention basin for potential problems including: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks.	Every 3 months
Maintain records of all inspections and maintenance activity.	Ongoing

GENERAL DO'S AND DON'TS OF DETENTION SMP MAINTENANCE

DO:

- Inspect the outlet control structure on a routine basis and keep all orifices free of trash and debris.
- Surface Practices
  - Water non-aquatic plants and trees during establishment, and if they look dry or brown.
  - Check for signs of erosion, trash, or sediment build up, especially near inlets.
  - Inspect for large stands of reeds or other invasive plant species, as these may require professional control.
  - Remove any large sediment deposits that could take up volume in the wetland or damage plants.
- Subsurface Practices
  - Maintain inflow areas (e.g. inlets, filters, etc.) to be free of trash, sediment, and debris.
  - Seek professional assistance for areas in the system which can't be reached for maintenance.
  - Identify any subsidence or cracking in surface cover which could indicate failure.

DON'T:

- Surface Practices
  - Use too much salt or sand around the basin during winter months.
  - Apply fertilizer. Consult a local nursery or PWD if plants are not thriving.
- Subsurface Practices
  - Flush a system with harsh chemicals.

Appendix 1

Appendix 1 Soil Infiltration and Profiling/classification Guidelines

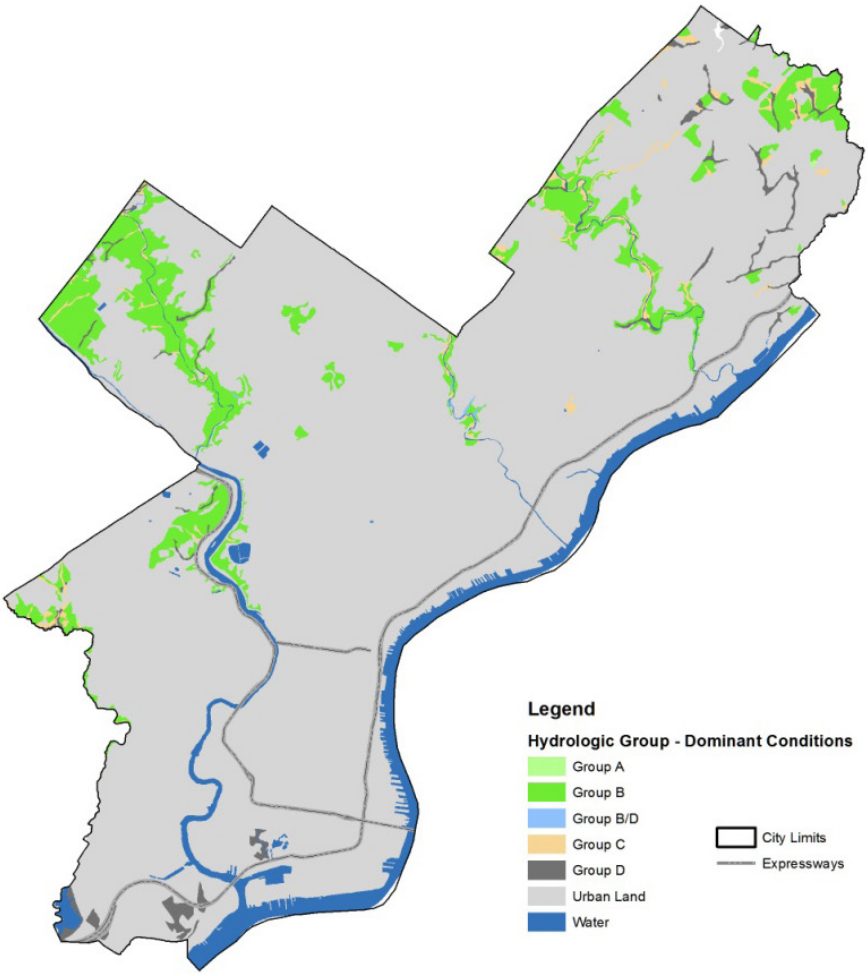


Figure 10: Philadelphia Soils Map.

SITE SOILS

- Infiltration testing is mandatory for all retrofit sites. Infiltration must be infeasible in order to use Volume Reducing or Detention and Slow Release Practices.
- The majority of soils in Philadelphia are classified as Urban Land. Urban soils are highly variable and amendment and over excavation on SMPs are likely to aid in functionality of SMPs.
- Hydrologic Soil Groups should not be considered a substitute for on-site soil testing. Often, soil designations do not reflect existing soils – especially if the site has been subject to previous development activity. These soil groups should be used for planning purposes only.
- Prior to design, on-site testing must be performed to measure the actual infiltrate rates on site.
    - In general, soils underlying infiltration practices must have a tested infiltration rate between 0.5 and 10 inches/hour.
    - For underlying soils that do not meet these infiltration rates, soil amendments and over excavation is the preferred method to underdrains.
    - Soil amendments shall be installed at a 2 foot thick layer from the final subgrade elevation of the infiltration SMP.

Additional testing may be required to verify depth of amendment needed.

INFILTRATION TESTING AND SOIL PROFILE/CLASSIFICATION DOCUMENTATION

INFILTRATION TESTING

Because it is important to establish the actual infiltration rate of the soils at the location and interface of the bottom of the SMP with the subgrade, on-site testing is required to obtain the design infiltration rates. Testing is to be completed by a qualified professional. The professional shall either be a registered professional engineer, soil scientist, or geologist and must be licensed in the state of Pennsylvania. A variety of field tests exists for determining the infiltration capacity of a soil. Laboratory tests are not recommended because a homogeneous laboratory sample does not represent field conditions.

In general, infiltration tests should not be conducted in the rain, within 24 hours of significant rainfall events (>0.5 inch), or when temperatures are below freezing. A minimum of two tests shall be performed per infiltration SMP. The tests should be conducted at the proposed bottom elevation of an infiltration SMP. If a confining layer is encountered at the bottom elevation, it is recommended that the extent of the confining layer be determined via additional soil exploration. Although there is a short term cost associated with over excavation and soil amendments, it may be a less expensive alternative when compared with the costs of operating and maintaining a failed infiltration SMP system over the long term. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

Soil Profile and Classification

Soil profile and classification information is important to collect and understand subsurface soil conditions to confirm performance of the SMP. Information to be collected and documented during a subsurface investigation at the proposed SMP location includes:

- Type and depth of soil layers
- Extent of confining layer
- Depth to groundwater
- General information to identify the boundary and elevations of any problem conditions such as fills, seasonal high groundwater table, or bedrock.

See Appendix 4 - Detail Req-A.1 for Infiltration testing and soil profile/classification information.

The preferred methodology for soil infiltration testing is the Double-ring infiltrometer test. If other methodologies are desired for use on site, contact PWD for approval.

- Double-ring infiltrometer test[2]: A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The results from this test, generally reported in centimeters per second (cm/sec) or inches per hour (in/hour), are appropriate for use in sizing the SMP. Key points are summarized below:
    - Double-ring infiltrometer testing methodology is provided in ASTM D 3385.
    - Two concentric metal rings are driven into the ground and filled with water. The outer ring helps to reduce lateral movement of water in the soil while the inner ring is used to calculate an infiltration rate.
    - Test holes must be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated condition in the environment and to minimize the influence of unsaturated flow.
    - The tests must be performed for at least 6 hours or a length of time adequate for the infiltration rate to stabilize.
    - It is strongly advised that a double-ring infiltrometer test be performed instead of a percolation test.
- Geotechnical investigations may include laboratory test results for permeability (K), which is typically reported in in/hr. This information can be used for preliminary design and sizing of SMPs, but field testing should be completed for final design calculations.
- If additional geotechnical investigations are not performed for the project, or if results do not indicate the seasonal high groundwater elevation, a hole must be excavated to a minimum of 2 feet below the bottom interface of the SMP with the

[2] Refer to Pennsylvania Department of Environmental Protection Best Management Practice (BMPs) Manual Appendix C-Protocols for Structural BMPs

subgrade to confirm that the seasonal high groundwater elevation or bedrock is not within 2 feet of the bottom of the infiltration SMP.

- A geotechnical report summarizing the above information shall be submitted for all infiltration SMPs.

HOTSPOT INVESTIGATION (INFILTRATION RESTRICTIONS)

Hotspot investigation procedures shall be followed to determine if there is the potential to contaminate groundwater and surface water through the use of infiltration SMPs. In general the following steps shall be followed and documented:

- Step 1: Review of prior land use at the retrofit site, and review of any data on soil or groundwater quality.
    - For larger retrofit sites, a formal Phase 1 site assessment may be required by a lender in order to determine if any environmental hazard exists on the site. A determination of prior land use is part of this assessment.
    - On sites where a formal Phase I is not conducted, methods to determine prior land use may include a title search, aerial photographs, soil surveys, topographic maps, city and state regulatory databases, and a review of state and local records.
- Step 2: Determine the potential for contamination based on available data and prior land use.
    - The following land uses are considered to have a potential for contaminated soil which may adversely affect the quality of groundwater discharging to surface water.
        - Sites designated as CERCLA (Superfund) sites
        - Auto recycler facilities and junk yards
        - Commercial laundry and dry cleaning
        - Commercial nurseries
        - Vehicle fueling stations, service and maintenance areas
        - Toxic chemical manufacturing and storage
        - Petroleum storage and refining
        - Public works storage areas
        - Airports and deicing facilities, railroads and rail yards, marinas and ports
        - Heavy manufacturing and power generation
        - Metal production, plating, and engraving operations
        - Landfills and hazardous waste material disposal
        - Sites on subsurface material such as fly ash known to contain mobile heavy metals and toxins
    - Perform due diligence to determine whether any contamination is present on-site if the site has a history of hotspot usage. It is not sufficient to rule out infiltration based on historical site use alone. Testing must be performed to determine whether the site is contaminated and in what areas any contamination is concentrated. Even if the site is contaminated, infiltration may still be feasible. Contamination should be evaluated per PADEP guidelines, including, but not limited to, comparing MSC levels, evaluating contaminant solubility, and conducting SPLP testing.
    - Step 3: For sites that do not qualify as hotspots, proceed with design of infiltration facilities for retrofit sites. For sites that qualify as hotspots, determination of infiltration feasibility is still required. A contained slow release system or a lined/isolated volume reducing practice may be appropriate for hotspot locations.

Appendix 2

Appendix 2 Landscape guidance

INTRODUCTION

Landscaping is a critical element to improve both the function and appearance of stormwater management practices (SMPs). Integrated stormwater landscapes can provide many benefits such as construction cost savings, reduced maintenance, aesthetic enhancement, and improved long-term functionality. A well-designed and established landscape will also prevent post-construction soil erosion. Additionally, these approaches can help mitigate urban heat island effects, improve air quality, and reduce atmospheric carbon levels.

Vegetated stormwater management systems are a preferred practice. SMPs can be integrated within planned landscape areas, with minor modifications to conventional landscape design. It is essential that impervious surfaces be graded toward the vegetated areas that are used as SMPs and that these SMPs are depressed to allow for flow and/or surface ponding. Guidance for the design of inlets to vegetated SMPs can be found in Section 4.1: Common Components. Since these design approaches are still new to many construction contractors it is advisable to clearly show these details in cross section and plan view drawings.

This section provides landscaping criteria and plant selection guidance for effective SMPs and is organized as follows:

- Planting Guidance contains general guidance that should be considered when landscaping any SMP.
- SMP Specific Landscaping Requirements includes specific planting and site preparation information for selected SMPs.
- Native and Recommended Non-invasive Plants lists appropriate plants for use in SMPs in this region. Key information useful for the selection of plant material for stormwater landscaping is presented, including National Wetland Indicator Status, preferred hydrologic zones, and aesthetic considerations.
- Prohibited Non-native Invasive Plants lists prohibited invasive plants.

PLANTING RECOMMENDATIONS / GUIDELINES

GENERAL GUIDANCE FOR ALL SMP PLANTINGS:

Plant selection and arrangement

- Existing native and non-invasive vegetation should be preserved where possible.
- Noxious weeds and invasive species shall not be specified or used. Prohibited noxious weeds, as identified in Pennsylvania Code Section 110.1. Noxious Weed Control List, are as follows:
    - Marijuana (Cannabis sativa)
    - Purple Loosestrife (Lythrum salicaria)
    - Canada Thistle (Cirsium arvense)
    - Multiflora Rose (Rosa multiflora)
    - Johnson Grass (Sorghum halepense)
    - Musk Thistle, or Nodding Thistle (Carduus nutans)
    - Bull Thistle, or Spear Thistle (Cirsium vulgare)
    - Jimson Weed (Datura stramonium)
    - Mile-a-minute (Polygonum perfoliatum)
    - Kudzuvine (Puerria lobata)
    - Shattercane (Sorghum bicolor)

- Giant Hogweed (Heracleum mantegazzianum)
- Goatsrue (Galega officinalis)

Plant stream and water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade. This will help to reduce thermal warming, reduce erosion, increase roughness and protect habitat.

Avoid plantings that will require routine or intensive chemical applications (i.e. turf area). Use low maintenance ground cover as an alternative to turf.

- Stressors (e.g. wind, exposure, exposure to deicing salt, salt tolerance, insects, drought and inundation tolerance, and disease), micro-climates, and sunlight conditions should also be considered when laying out the planting plan.
- Aesthetics and visual characteristics should be a prime consideration. Plant form, texture, color, bloom time and fragrance are important to the overall feel of the site. Plants can be used to enhance and frame desirable views or screen undesirable views. Care should be taken to not block views at entrances, exits, or along difficult road curves.
- Trees and shrubs should be placed in a manner that restricts pedestrian access to steep pools or slopes without blocking maintenance access.
- Existing and proposed utilities must be identified and considered.

Maintenance considerations

- The designer should carefully consider the long-term vegetation management strategy for the SMP, keeping in mind the maintenance legacy for the future owners. The SMP maintenance agreement must include requirements to ensure vegetation cover in perpetuity.
- Provide signage to help educate the public about SMPs and to designate limits of mowing (wildflower areas, meadows, etc.).

Embankments, spillways, dams, and orifices

- Planting of trees, shrubs, and/or any type of woody vegetation is not allowed on structural embankments.
- All emergency spillways should be stabilized with plant material that can withstand strong flows. Root material should be fibrous and substantial but lack a taproot.
- Trees or shrubs known to have long taproots should not be planted within the vicinity of an earthen dam or subsurface drainage facilities.
- Plant trees and shrubs at least 25 feet away from a principal spillway structures.
- Plant trees and shrubs at least 15 feet away from the toe of slope of a dam.

SOILS

SMP soils should provide adequate infiltration rates and be suitable for healthy tree and vegetation growth. Soil analysis shall be conducted within the SMP area to determine appropriate levels and types of soil amendments.

If topsoil exists on site and is stockpiled for re-use, appropriate erosion control measures as required by the Pennsylvania Department of Environmental Protection (PADEP) Erosion and Sediment Pollution Control Manual, shall be used. Soil analysis tests shall be performed on stockpiled soil if it will be used within the SMP area. See Section 3.1 for SMP specific soil requirements and Appendix 1 for Soil Infiltration and Profile Guidelines.

Site Selection, Preparation and Grading

When selecting a location for the SMP, take into consideration the physical variables of the site and the effects they will have on the SMP. Some variables to consider include amount of sunlight received and solar orientation, wind speed and direction, temperature gain and surface character. For example: sites facing northeast receive morning sun and tend to be cooler and

wetter than those facing southwest; runoff from asphalt will be hotter than that from concrete; etc. Combinations of these variables create different micro-climates and should be taken into account when placing the SMP and selecting plants.

Unwanted vegetation in the SMP area shall be removed during site preparation with equipment appropriate for the type of material encountered and site conditions. It is recommended that the maximum amount of pre-existing native vegetation be retained and protected.

No material storage or heavy equipment is allowed within the SMP area after site clearing and grading has been completed, except to excavate and grade as needed to build the SMP. No compaction of infiltration areas should occur during this excavation.

After the SMP area is cleared and graded, any necessary soil amendments should be added and tilled into the existing soil to the depth specified for each SMP. No tilling shall occur within the drip line of existing trees. After tilling is complete, no other construction traffic shall be allowed in the area, except for planting and related work. Where topsoil is needed, (for example swales and dry detention basins) it should be spread to a depth of 4-8 inches and lightly compacted to minimum thickness of 4 inches. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

MULCH

The mulch layer helps maintain soil moisture and avoid surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. Approved mulching materials include organic materials such as compost, bark mulch, leaves, as well as small river gravel, pumice, or other inert materials. Grass clippings should not be used as mulch. For ground cover plantings, the mulch shall be applied to cover all soil between plants. Care should be exercised to use the appropriate amount of mulch – any more than 3-4 inches can negatively impact growing conditions and cause excessive nutrients to leach into the SMP. Mulch shall be weed-free. Manure mulching and high-fertilizer hydroseeding are prohibited in a SMP area during and after construction.

IRRIGATION

Newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided during establishment of the SMP, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

Permanent irrigation systems are allowed, but designers are encouraged to minimize the need for permanent irrigation. Innovative methods for watering vegetation are encouraged, such as the use of cisterns and air conditioning condensate.

SMP SCREENING

SMP elements such as chain link fences, concrete bulkheads, outfalls, rip-rap, gabions, large steel grates, steep side slopes, manhole covers/vault lids, berm embankments planted only with grasses, exposed pipe, banks, retaining walls greater than 2 feet high, and access roads are generally not aesthetically pleasing. When these elements face public right-of-way or other private property, the Philadelphia Water Department (PWD) recommends that they be screened with plant materials. Designers are strongly encouraged to integrate aesthetically pleasing landscape design with SMPs.

POLLUTION PREVENTION

Stormwater pollution prevention practices related to landscaping can be categorized into two broad categories: Toxic Substance Use Reduction and Pollutant Source Reduction.

Toxic Substance Use Reduction

Projects shall be designed to minimize the need for toxic or potentially polluting materials such as herbicides, pesticides, fertilizers, or petroleum based fuels within the SMP area before, during, and after construction. Use of these materials creates the risk of spills, misuse, and future draining or leaching of pollutants into facilities or the surrounding area.

Pollutant Source Reduction

Materials that could leach pollutants or pose a hazard to people and wildlife shall not be used as components of a SMP. Some examples of these materials are chemically treated railroad ties and lumber and galvanized metals. Many alternatives to these materials are available.

SMP ESTABLISHMENT AND MAINTENANCE

Establishment procedures should include: control of invasive weeds, prevention of damage from animals and vandals, use of erosion control mats and fabrics in channels, temporary diversion of flows from seeded areas until stabilized, mulching, re-staking, watering, and mesh or tube protection replacement, to the extent needed to ensure plant survival. To ensure landscape plant survival and overall stormwater facility functional success, the design and construction documents must include elements that help achieve these results. Construction specifications and details need to include staking, irrigation schedule, soil amendments, plant protection, over planting, and potentially mycorrhizal inoculation.

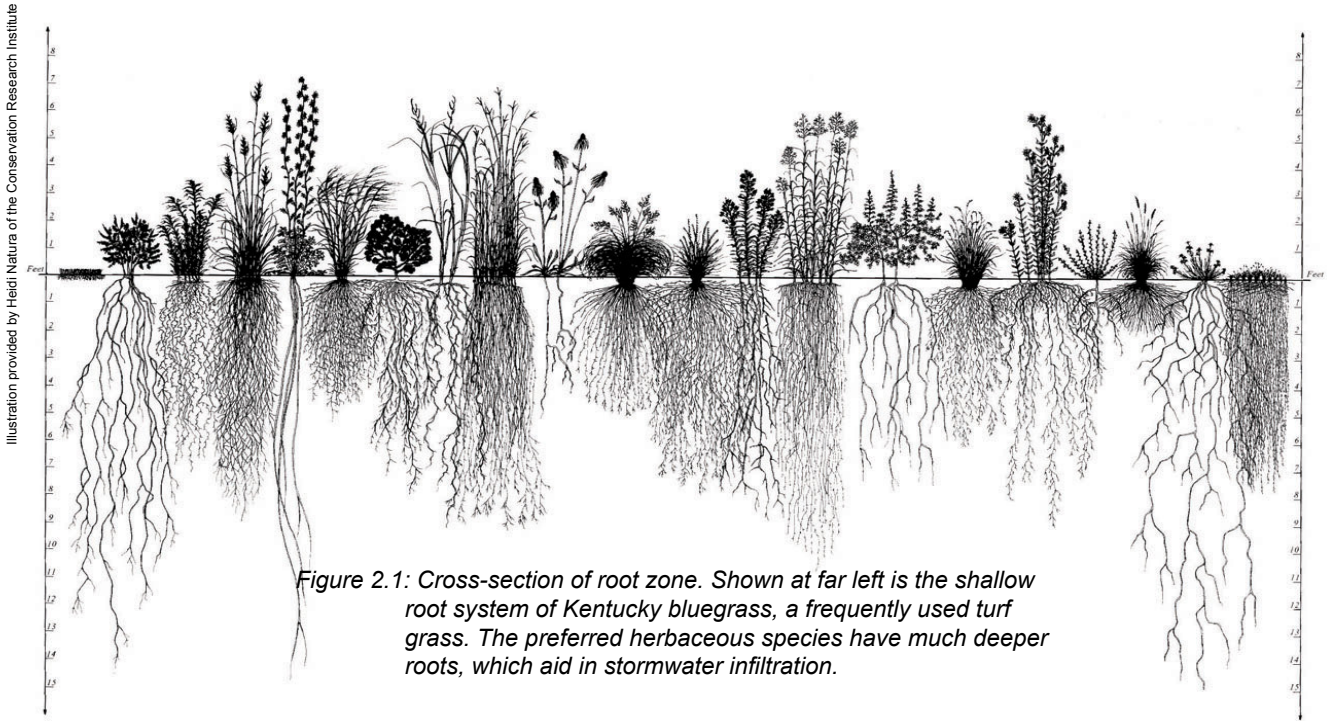


Figure 2.1: Cross-section of root zone. Shown at far left is the shallow root system of Kentucky bluegrass, a frequently used turf grass. The preferred herbaceous species have much deeper roots, which aid in stormwater infiltration.

Table 1: Planting Specifications

ELEMENT	SPECIFICATION REQUIREMENTS
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.

Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering amount and schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	All systems should contain a 2 year warranty. Specifications should contain the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

FACILITY SPECIFIC LANDSCAPING GUIDANCE

The planting recommendations shown under this section are based on research, local experience and/or standard landscape industry methods for design and construction. It is critical that selected plant materials are appropriate for soil, hydrologic, and other site conditions. SMPs shall use appropriate native and recommended non-invasive species from the Recommended Plant Lists in Table 2.

The design for plantings shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Plantings should be designed to minimize the need for mowing, pruning, and irrigation. Grass or wildflower seed shall be applied at the rates specified by the suppliers. If plant establishment cannot be achieved with seeding by the time of substantial completion of the SMP portion of the project, the contractor shall plant the area with wildflower sod, plugs, container plants, or some other means to complete the specified plantings and protect against erosion.

GREEN ROOF LANDSCAPING REQUIREMENTS

Plantings used on green roofs shall be self-sustaining, with little to no need for fertilizers or pesticides. Shrubs, herbs, succulents, and/or grasses shall be used to cover most of the green roof. See Section 4.8: Green Roofs for more specific information on green roof requirements.

FLOW THROUGH PLANTER BOX LANDSCAPING RECOMMENDATIONS

The following quantities per 100 square feet of planter box area are recommended:

- 4 - Large shrubs/small trees 3-gallon containers or equivalent.
    - 6 - Shrubs/large grass-like plants 1-gallon containers or equivalent
    - Ground cover plants: 1 per 12 inches on center, triangular spacing. Minimum container: 4-inch pot. Spacing may vary according to plant type.

Note: Container planting requires that plants be supplied with nutrients that they would otherwise receive from being part of an ecosystem. Since they are cut off from these processes they must be cared for accordingly.

Note: Tree planting is not required in planters, but is encouraged where practical. Tree planting is also encouraged near planters.

INFILTRATION AND FILTER SYSTEM RECOMMENDATIONS

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for water quality and groundwater recharge volume. In some instances where permeability is high, these facilities may be used for the Channel Protection requirement as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters. When properly planted, vegetation will thrive and enhance the functioning of these systems. For

example, pre-treatment buffers will trap sediment that is often bound with phosphorous and metals. Vegetation planted in the SMP will aid in nutrient uptake and water storage. Additionally, plant roots will create macropores for stormwater to permeate soil for groundwater recharge (see Figure 2.1). Finally, successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Design Constraints:

Along with the guidelines listed at the start of this section, the following should be adhered to:

- Determine areas that will be saturated with water and water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 2.2 and associated tables for planting material guidance).
- Plants shall be located so that access is possible for structure maintenance.

VEGETATED SWALE LANDSCAPING RECOMMENDATIONS

The following quantities per 200 square feet of swale area are recommended:

- 1 Evergreen or Deciduous tree:
    - Evergreen trees: Minimum height: 6 feet.
    - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
    - Multi-stem trees: Minimum root ball diameter: 20 inches
- Grass: Seed or sod is required to completely cover the swale bottom and side slopes.

Vegetation or ground cover within the swale should be suitable for expected velocities. For the swale flow path, approved native grass mixes are preferable. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff should be allowed to flow in the swale until grass is established. Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas. This type of landscape can be designed to require mowing only once or twice annually.

VEGETATED INFILTRATION BASIN AND DRY DETENTION POND LANDSCAPING RECOMMENDATIONS

Vegetation increases evapotranspiration, helps improve infiltration functions, protects from rain and wind erosion and enhances aesthetic conditions. The following quantities per 300 square feet of basin area are recommended:

- 1 Evergreen or Deciduous tree:
    - Evergreen trees: Minimum height: 6 feet.
    - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
    - Multi-stem trees: Minimum root ball diameter: 20 inches
- 4 Large shrubs/small trees 3-gallon containers or equivalent.
- 6 Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified. Minimum container: 4-inch pot. At least 50 percent of the SMP shall be planted with grasses or grass-like plants.

Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas.

This type of landscape can be designed to require mowing only once or twice annually.

Appropriate plants should be selected based on ponding depth and drain-down time in the basin. Infiltration systems will be dry much of the time and should be vegetated with drought tolerant species especially if they will not be irrigated.

BIORETENTION LANDSCAPING RECOMMENDATIONS

PLANTING SOIL BED CHARACTERISTICS

The characteristics of the soil for the bioretention system are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

Planting soil should meet all the specifications listed below and should be a fertile, natural soil, free from large stones, roots, sticks, clods, plants, peat, sod, pockets of coarse sand, pavement and building debris, glass, noxious weeds including invasive species, infestations of undesirable organisms and disease causing pathogens, and other extraneous materials harmful to plant growth.

Texture of planting soil should conform to the classification within the USDA triangle for Sandy Loam or Loamy Sand. Planting soil should be a mixture of sand, silt, and clay particles as required to meet the classification. Ranges of particle size distribution, as determined by pipette method in compliance with ASTM F-1632:

Sand	(0.05 to 2.0 mm)	50 - 85%
Silt	(0.002 to 0.05mm)	40% maximum
Clay	(less than 0.002mm)	10% maximum
Gravel	(2.0 to 12.7 mm)	15% maximum

Planting soil should be screened and free of stones larger than a half-inch (½"; 12.7 mm) in any dimension. No more than ten percent (10%) of the soil volume should be composed of soil peds greater than one inch (1").

Clods, or natural clumps of soils, greater than three inches (3") in any dimension should be absent from the planting soil. Small clods ranging from one to three inches (1-3") and peds, natural soil clumps under one inch (1") in any dimension, may be present but should not make up more than ten percent (10%) of the soil by volume.

The pH of the planting soil should have a range of 5.8 to 7.1. Extremes should be avoided.

Soluble salts should be less than 2.0 mmhos/cm (dS/m), typically as measured by 1:2 soil-water ratio basic soil salinity testing. Sodic soils (Exchangeable Sodium Percentage (ESP) greater than 15 and/or Sodium Adsorption Ratio (SAR) greater than 13) shall not be acceptable for use regardless of amendment.

Organic content of planting soil should have a range of three to fifteen percent (3-15%) by weight as determined by loss on ignition (ASTM D2974). To adjust organic content, planting soil may be amended, prior to placing and final grading, with the addition of organic compost.

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species.

Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant

Planting Plan Guidance

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
- Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens.
- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

The following quantities per 100 square feet of bioretention area are recommended:

- 1 large tree per 100 square feet of bioretention area
- 2-4 small trees or shrubs per 100 square feet of bioretention area
- 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers)
- Groundcover plantings and wildflower plugs on 12 inch centers with triangular spacing.
- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention system (Figure 2). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. However, plants in all the zones should be drought tolerant. Plants should also have high salt tolerance if bioretention area receives runoff from ground level impervious surfaces.

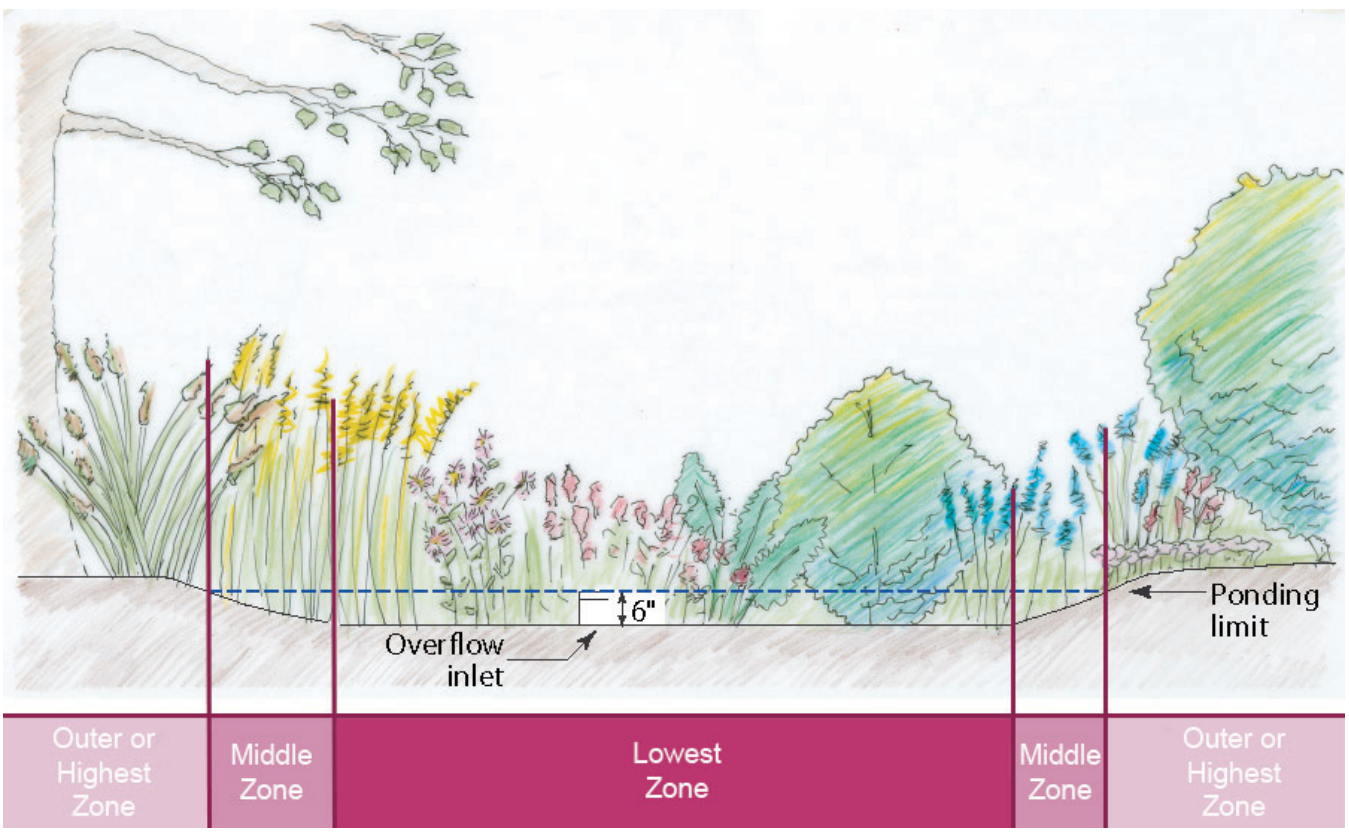


Figure 2.1: Hydrologic zones of a bioretention basin

cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

Lowest Zone (Hydrologic zones 2-4):

Plant species adapted to standing and fluctuating water levels. Frequently used native plants include*:

Asters (Aster Spp.)	*Winterberry (Ilex Verticillata)*
Goldenrods *(Solidago Spp.)*	Arrowwood *(Viburnum Dentatum)*
Bergamot (Monarda Fistulosa)	Sweet Pepperbush *(Clethra Alnifolia)*
Blue-Flag Iris *(Iris Versicolor)*	Bayberry *(Myrica Pensylvanica)*
Sedges (Carex Spp.)	Buttonbush *(Cephalanthus Occidentalis)*
Iironweed *(Vernonia Noveboracensis)*	Swamp Azalea *(Rhododendron Viscosum)*
Blue Vervain *(Verbena Hastata)*	Elderberry *(Sambucus Canadensis)*
Joe-Pye Weed *(Eupatorium Spp.)*	Green Ash *(Fraxinus Pennsylvanica)*
Swamp Milkweed *(Asclepias Incarnata)*	River Birch *(Betula Nigra)*
Switchgrass *(Panicum Virgatum)*	Sweetgum *(Liquidambar Styraciflua)*
Shrub Dogwoods *(Cornus Spp.)*	Northern White Cedar *(Juniperus Virginiana)*
Swamp Rose *(Rosa Palustris)*	Red Maple *(Acer Rubrum)*

** Refer to the plant list for a complete listing*

Middle Zone (Hydrologic zones 4-5):

This zone is slightly drier than the lowest zone, but plants should still tolerate fluctuating water levels. Some commonly planted native species include*:

Black Snakeroot *(Cimicifuga Racemosa)*	Spicebush *(Lindera Benzoin)*
Switchgrass *(Panicum Virgatum)*	Hackberry *(Celtis Occidentalis)*
Spotted Joe-Pye Weed *(Eupatorium Maculatum)*	Willow Oak *(Quercus Phellos)*
Cutleaf Coneflower *(Rudabeckia Lacinata)*	Winterberry *(Ilex Verticillata)*
Frosted Hawthorn *(Crataegus Pruinosa)*	Slippery Elm *(Ulmus Rubra)*
Marginal Wood Fern *(Dryopteris Marginalis)*	Viburnums *(Viburnum Spp.)*
Ironwood *(Carpinus Caroliniana)*	Witch-Hazel *(Hamamelis Virginiana)*
Serviceberry *(Amelanchier Canadensis)*	Steeplebush *(Spiraea Tomentosa)*
Obedient Plant *(Physostegia Virginiana)*	Blueberry *(Vaccinium Spp.)*

** Refer to the plant list for a complete listing*

Outer Zone (Hydrologic zones 5-6):

Generally supports plants adapted to drier conditions. Examples of commonly planted native species include*:

Many Grasses & Wildflowers	Juniper *(Juniperus Communis)*
Basswood *(Tilia Americana)*	Sweet-Fern *(Comptonia Peregrina)*
White Oak *(Quercus Alba)*	Eastern Red Cedar *(Juniperus Virginiana)*
Scarlet Oak *(Quercus Coccinea)*	Smooth Serviceberry *(Amelanchier Laevis)*
Black Oak *(Quercus Velutina)*	American Holly *(Ilex Opaca)*
American Beech *(Fagus Grandifolia)*	Sassafras *(Sassafras Albidum)*
Black Chokeberry *(Aronia Melanocarpa)*	White Pine *(Pinus Strobus)*

** Refer to the plant list for a complete listing*

FILTER STRIP LANDSCAPING REQUIREMENTS

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select vegetation from the list of native species found in this appendix (Table 2). Take soil infiltration capacities, sunlight, pollution tolerances, root structure, and other considerations into account when selecting plants from this list.

Filter strips should be planted with meadow grasses, shrubs, and native vegetation (including trees) from the list provided in: Native and Recommended Non-invasive Plants discussion below.

For the filter strip, approved native grass mixes are preferable. Seed shall be applied at the rates specified by the supplier. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff shall be allowed to flow across the filter strip until the vegetation is established. Trees and shrubs may be allowed in the flow path if the filter strip exceeds the minimum length and widths specified.

Filter strips often make a convenient area for snow storage. Therefore, filter strip vegetation should be salt-tolerant, and the maintenance schedule should involve removal of sand build-up at the toes of the slope. If the filter strip cannot provide pretreatment in the winter due to snow storage or vegetation choice, other pretreatment should be provided.

NATIVE AND RECOMMENDED NON-INVASIVE PLANTS

Native plant species are recommended over exotic foreign species because they are well adapted to local climate conditions. This will result in less replacement and maintenance, while supporting the local ecology.

The pages at the end of this section present a list of herbaceous, tree and shrub plants native to Philadelphia and Pennsylvania and suitable for planting in stormwater management facilities (.2). The list is intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology. Because individual plants often have unique growing requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Table 2 lists native and recommended plants, trees, shrubs, and grasses and is organized by Type and Latin name. Additional information given for each species includes: Common name, National Wetland Indicator Status, hydrologic zone, inundation tolerance, drought tolerance, salt tolerance, mature canopy spread, mature height, light requirements, nativity, commercial availability, and notes to provide guidance for application and selection. For example, some trees are well suited to landscaped areas that will receive stormwater runoff, while others may not tolerate the additional moisture.

HYDROLOGIC ZONES

For planting within a SMP, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water (see Figure 8.2 for an example of hydrologic zones in a bioretention basin). Plants have differing tolerances to inundation and as an aid to landscape designers, these tolerance levels have been divided into six zones and corresponding plant species have been identified. In Table 2 each plant species has a corresponding hydrologic zone provided to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrologic conditions. Just as plants may, on occasion, be found outside of their hardiness zone, they may also be found outside of their hydrologic zone. Additionally, hydrologic conditions in a SMP may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, thus exposing the soil and increasing the chance for erosion.

WETLAND INDICATOR STATUS

The Wetland Indicator Status (from Region 1, Reed, 1988) has been included to show "the estimated probability of a species occurring in wetlands versus non-wetlands" (Reed, 1988). Reed defines the indicator categories as follows:

- Obligate wetland (OBL): Plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.

- Facultative Wetland (FACW): Plants, which usually occur in wetlands (from 67 to 99% of the time), but occasionally found in non wetlands.
- Facultative (FAC): Plants, which are equally likely to occur in wetlands and non wetlands and are found in wetlands from 34 to 66% of the time.
- Facultative Upland (FACU): Plants, which usually occur in non wetlands (from 67 to 99% of the time), but occasionally found in wetlands.
- Upland (UPL): Plants, which almost always (more than 99% of the time) under natural conditions occur in non wetlands.
- A given indicator status shown with a "+" or a "-" means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the "+" or "-" designation.

INUNDATION TOLERANCE

Since the Wetland Indicator Status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the "Inundation tolerance" column is designed to provide further guidance. If a plant is capable of withstanding permanent saturation, the depth of this saturation is listed (for example, "saturated" indicates the soil can be moist at all times, "sat, 0-6"" indicates that the species can survive in constantly moist soil conditions with up to 6" of standing water). Conversely, a

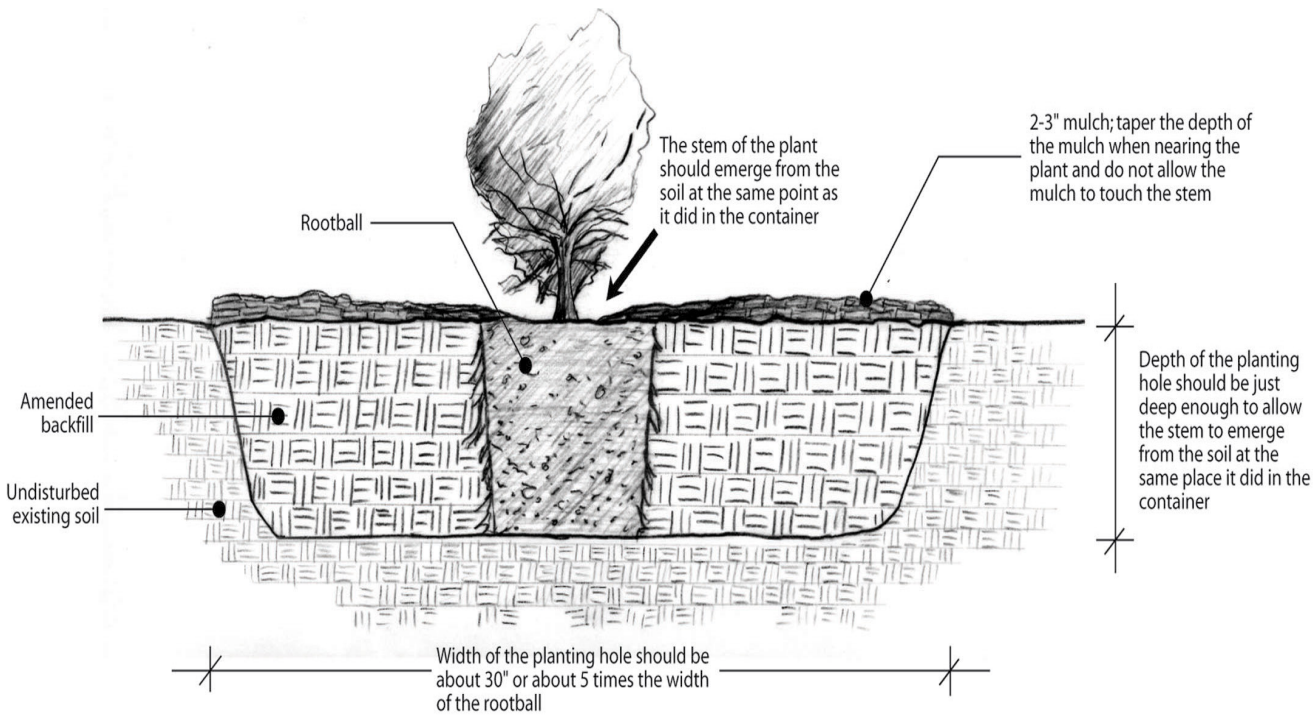


Figure 2.4: Containerized tree and shrub planting diagram

plant may only tolerate seasonal inundation – such as after a storm event – or may not tolerate inundation at all. This type of plant would be well suited for an SMP that is expected to drain quickly or in the drier zones of the SMP.

MATURE CANOPY SPREAD

This column gives the SMP designer a rough estimate of the diameter (or spread) of a tree species' branching when it has matured. This information indicates what the light conditions will be like beneath the tree for understory plantings; how much space should be left open between the tree planting pit and any vertical structures, such as buildings; how far apart the trees should be planted; and it gives an idea, along with the mature height of the species, of the tree's growth habit. The mature canopy spread also provides a rough idea for how much leaf surface area will be available to intercept stormwater before it reaches the ground.

MATURE HEIGHT

This column provides the approximate mature height of plant species in optimal growing conditions. This height may be reduced dramatically in the urban environment where light, space, and other factors may not be as readily available as in a forest or field setting. However, by providing as much space as possible for a plant to grow and by choosing appropriate species for a planting area, improved – if not optimal - growing conditions can be achieved. For example, a tree planted in a sidewalk pit measuring 4 feet x 4 feet may only reach half its mature height, while a tree planted in a 4 foot wide "trough" style planting bed will grow taller and live longer, because it will have greater access to air and water.

LIGHT REQUIREMENT

The light requirements for each species are listed as ranges between full shade and full sun. At the bottom of the range – full shade – plants thrive in conditions where they receive filtered, or dappled, light for the entire day (such as under an oak tree). In the middle of the range are plants that grow best in part shade, where they are in full shade for 2-3 hours during midday. Plants that require full sun should be sited so that they receive 5 or more hours of direct sun during the growing season. Some plants requiring full sun may still do well in a part shade environment, depending on the quality and duration of the light the plants receive when they are not in the shade.

NATIVITY

A native plant is an indigenous species that occurred in the region prior to settlement by the Europeans. In this column, each species is located within a range of nativity to Philadelphia. Plants known to have existed in Philadelphia County are native to Philadelphia, while a wider geographic range lists plants native to the state, but not necessarily to the county. The widest geographic range lists a few species native to the United States, but not necessarily to Pennsylvania. The plants listed that are not specifically native to Philadelphia are included because of their demonstrated success within SMPs.

COMMERCIAL AVAILABILITY (C=CONTAINER; P=PLUG; S=SEED)

Wildflower and grass species often come in a form known as a plug. These are often grown and sold in trays of 50 of the same species. They are essentially very small container plants, with a root/soil mass about an inch wide and 2-4 inches long. Most species available in plug form are also sold as seed. Often, a combination of plugs and seed will be used to establish a SMP quickly and provide immediate visual interest and stabilization.

Container-grown plants include trees, shrubs, wildflowers, ferns, grasses, and sedges. This is an excellent alternative to the far more expensive balled-and–burlapped (B&B) form of trees and shrubs, although the size of the tree is almost always smaller. Nurseries often provide a few container sizes for each species.

NOTES

PWD has included the recommendations for street trees in the notes section of the native plant list and recommended non-invasive plants, trees, shrubs, and grasses list to assist designers in selection of vegetation most appropriate for the harsh conditions which are often associated in close proximity to streets. It is likely that most of these areas will be hot in summer months until the trees become established.

PROHIBITED NON-NATIVE AND INVASIVE PLANTS

Invasive non-native plants reproduce rapidly, degrade and take over natural ecosystems and have few, if any natural controls to keep them in check. Brought in to new areas by people for a specific purpose or by accident these species have characteristics that allow them to grow out of control and usually favor disturbed sites like areas of new construction. Under no circumstance should they be planted in a SMP. Because of appealing characteristics, some of these plants are available for sale and care should

be taken not to purchase them. Additionally, the ability to identify and remove them before they can establish themselves is important as they almost always invade due to their gregarious reproductive strategies. They can be especially hard to get rid of once they take hold. Table 3 lists common invaders for the Mid-Atlantic region.

Table 3: Common Invasive Species of the Mid-Atlantic Region

TYPE	LATIN NAME	COMMON NAME	AVAILABILITY
forb	*Hemerocallis fulva*	Common daylily	commercially available
forb	*Alliaria petiolata*	Garlic mustard	
forb	*Polygonum cuspidatum*	Japanese knotweed	
forb	*Ranunculs ficaria*	Lesser celadine	
forb	*Lythrum salicaria*	Purple loosetrife	
forb	*Cirsium arvense*	Canada thistle	
forb	*Lespedeza cuneata*	Chinese lespedeza	
forb	*Heracleum mantegazzianum*	Giant hogweed	
forb	*Murdannia keisak*	Marsh dewflower	
forb	*Centaurea biebersteinii*	Spotted knapweed	
grass	*Bambusa, Phyllostachys, Pseudosassa*	Bamboo	commercially available
grass	*Microstegium vimineum*	Japanese stiltgrass	
grass	*Miscanthus sinensis*	Chinese silvergrass	
grass-like	*Phragmites australis*	Common reed	
grass-like	*Arundo donax*	Giant reed- wild cane	
shrub	*Berberis thunbergii*	Japanese barberry	commercially available
shrub	*Ligustrum spp.*	Privets	commercially available
shrub	*Euonymus alata*	Winged burning bush	commercially available
shrub	*Buddleja davidii*	Butterfly bush	commercially available
shrub	*Spiraea japonica*	Japanese spiraea - Japanese meadowsweet	commercially available
shrub	*Elaeagnus umbellata*	Autumn olive	
shrub	*Lonicera spp.*	Bush honeysuckles	commercially available
shrub	*Rosa multiflora*	Mulitflora rose	
shrub	*Rubus phoenicolasius*	Wineberry	
shrub	*Rhodotypos scandens*	Jetbead	
Tree	*Pyrus calleryana 'Bradford'*	Bradford pear	commercially available
Tree	*Acer platanoides*	Norway maple	commercially available
Tree	*Quercus acutissima*	Sawtooth oak	commercially available
Tree	*Paulownia tomentosa*	Princess tree	
Tree	*Ailanthus altissima*	Tree of Heaven	
Tree	*Albizia julibrissin*	Silk tree - mimosa tree	commercially available
Tree	*Broussonetia papyrifera*	Paper mulberry	
Tree	*Morus alba*	White mulberry	
Vine	*Hedera helix*	English Ivy	commercially available
Vine	*Wisteria sinensis, W. floribunda*	Wisteria, exotic	commercially available
Vine	*Eunonymus fortunei*	Creeping euonymus	commercially available
Vine	*Lonicera japonica*	Japanese honeysuckle	commercially available
Vine	*Pueraria montana v. lobata*	Kudzu	
Vine	*Polygonum perfoliatum*	Mile-a-minute	
Vine	*Celastrus orbiculatus*	Oriental bittersweet	
Vine	*Ampelopsis brevipedunculata*	Porcelain berry	commercially available
Vine	*Akebia quinata*	Five-leaved akebia	
Vine	*Cynanchum louiseae*	Louis' swallowwort	

Appendix 3

Appendix 3 Credit and design calculation examples

The four sites discussed in this appendix provide examples of practical retrofits spanning various site conditions and land uses that might be encountered across the City along with the implementation of several different types of SMPs. Each example is structured using the same format.

SITE RENDERING

A rendering is provided for each example site. The image indicates the location of each proposed SMP as well as the contributing drainage area.

Existing conditions maps or site plans are useful for identifying potential SMP opportunities. Potential SMP installations resulting in Impervious Area Management (IAM) Credits as well as Impervious Area Reduction (IAR) can easily be determined based on the existing land use. Landowners are encouraged to print out and mark up a site map of their property when starting a retrofit project to help identify potential SMP locations and to help approximate potential management areas.

INITIAL CONDITIONS

The initial conditions are presented for each example site. The initial conditions contain four key parameters:

Gross Area Initial (GAi): Gross Area Initial includes all property area within the legally described boundaries except streets, medians, and sidewalks in the public right-of-way. For these examples, Gross Area Initial was assumed to be the entire parcel. Gross Area Initial is rounded up to the nearest 500 square feet to determine the Gross Area (GA) fee associated with the overall Storm Water Management Service (SWMS) Charge.

Impervious Area Initial (IAi): Impervious Area Initial includes all surfaces which are compacted or covered with material that restricts infiltration of water. For these examples, the Impervious Area Initial was broken into three categories: Buildings, Sidewalks, and Parking & Drives. Impervious Area Initial is rounded up to the nearest 500 square feet in determining the initial Impervious Area (IA) fee associated with the total SWMS Charge.

Green Space: Green Space is defined as the pervious portion of the property and is calculated as Gross Area Initial minus Impervious Area Initial.

Initial Fee: The Initial Fee is the SWMS Charge for the example site based on the site conditions prior to retrofit. The charges presented in the examples were developed calculated using the SWMS rates effective July 1, 2014 (note these are subject to change). The total SWMS Charge is calculated using the following formula:

$$Initial\ Fee = \frac{GAi\ x\ GA\ \ Fee}{500\ sf} + \frac{IAi\ x\ IA\ Fee}{500\ sf} + \text{B\&}C$$

SWMS Rates (Effective July 1, 2014)	
Gross Area (GA) Rate:	$0.590/500 sf
Impervious Area (IA) Rate:	$4.746/500 sf
Billing & Collections (B&C) Charge:	$2.19

INITIAL SIZING CHECK

Stormwater Credits are earned by managing the Water Quality Volume for a given area of impervious surface and an SMP must capture the Water Quality Volume of its drainage area in order for it to be considered for the Stormwater Credits Program. Water Quality Volume (WQv) is defined as:

$$WQv = (P \div 12)\, x\, IA$$

Where:

WQv= Water Quality Volume (cubic feet)

P = 1.0 Inch of Rainfall

IA = Impervious Area (square feet)

The first value listed in the Initial Sizing Check section is the Water Quality Volume for all of the Impervious Area on the example site.

A good early check is to determine how much pervious area onsite can potentially be utilized toward SMP installation. This check allows a landowner to determine whether or not they have enough pervious area to install surface level / vegetated SMPs or whether or not they will need to consider converting current impervious surface to an approved SMP. The second value listed is the minimum site loading if all of the Impervious Area was drained to the Green Space. The maximum loading recommended for most SMPs is 10 ft of Impervious Area drained to 1 ft of Green Space (10:1). If the loading value is greater than 10:1, the landowner will need to consider converting impervious surface to an approved SMP if they wish to earn credits for capturing their property's entire Water Quality Volume.

The third value listed is the minimum SMP footprint needed to manage all of the Impervious Area assuming a 10:1 loading rate. This value helps the landowner begin the SMP selection and location process and helps them fit the SMP(s) into the existing site conditions.

SMPS

The next section discusses the SMPs chosen for the example site. For each SMP, the following information is provided (if applicable):

- SMP chosen
- Narrative description of drainage area
- Contributing impervious drainage area in square feet
- Storage volume required to capture the WQV
- WQ slow release rate for SMPs in the Combined Sewer areas
- Storage volume provided using design parameters discussed in this manual
- Final SMP loading rate

The required volume and discharge equations are provided for each SMP for quick reference.

FINAL CONDITIONS

The Final Conditions section summarizes the site's SWMS Charges after the retrofit has been completed. For these examples, it was assumed that sites drained to either the City's combined or separate sewer system. In addition, it is assumed that none of the sites have industrial NPDES permits. The maximum IAM Credit these sites could achieve is 80%. In addition, IARs are granted

100% reduction in IA charges for the footprint of the SMP. Note – the potential maximum credit for your site might be higher. As discussed in Section 2.0 Credits and Incentives, it's important to identify your sewershed and know if your property has an active NPDES Industrial permit. The Final Conditions section has six key parameters:

1. Impervious Area Reduced (IAR): Impervious Area Reduced is the square footage of Impervious Area Initial that has been converted into either Porous Pavement (Section 4.4) or Green Roofs (Section 4.8). If neither of these SMPs is utilized on the example site, then IAR = 0 sf.

2. Impervious Area Managed (IAM): Impervious Area Managed is the square footage of Impervious Area Initial that drains to an SMP. If no portion of the example site drains to an SMP, then IAM = 0 sf

3. Gross Area Final (GAf): Gross Area Final is defined as:

$$GAf = GAi - IAM\ x\ X$$
$$-OR-$$
$$GAf = GAi - IAM\ x\ 0.8$$

4. Impervious Area Final (IAf): Impervious Area Final is defined as:

$$IAf = IAi - IAR - IAM\ x\ X$$
$$-OR-$$
$$IAf = IAi - IAR - IAM\ x\ 0.8$$

5. Final Fee: The Final Fee is calculated using the same rates as the Initial Fee and uses the equation:

$$Final\ Fee = \frac{GAf\ x\ GA\ \ Fee}{500\ sf} + \frac{IAf\ x\ IA\ Fee}{500\ sf} + \text{B\&}C$$

6. Percent Reduced: Percent Reduced is the percent the Initial Fee was reduced by compared to the Final Fee.

EXAMPLE SITE 1

Site 1 is a school located in the CSO area. Infiltration tests performed in accordance with Appendix 1 Soil Infiltration and Profile Guidelines on site determined that the location has very low infiltration rates and is not suitable to infiltration based SMPs. The school decided to collect a portion of the runoff from their roof into a cistern (See Section 4.9 for specific SMP design information) for use in landscape watering and vehicle cleaning. Based on their water demands, they determined they could confidently use the Water Quality Volume from half of their roof (275 cubic feet) within 72 hours. To manage the remaining portion of their roof as well as the sidewalks and parking lot, they decided to install a dry extended detention basin (See Section 4.10 for specific SMP design information) in the existing green space located in the corner of their lot. Through the use of regrading, they were successfully able to route the remaining Water Quality Volume to the dry extended detention basin.

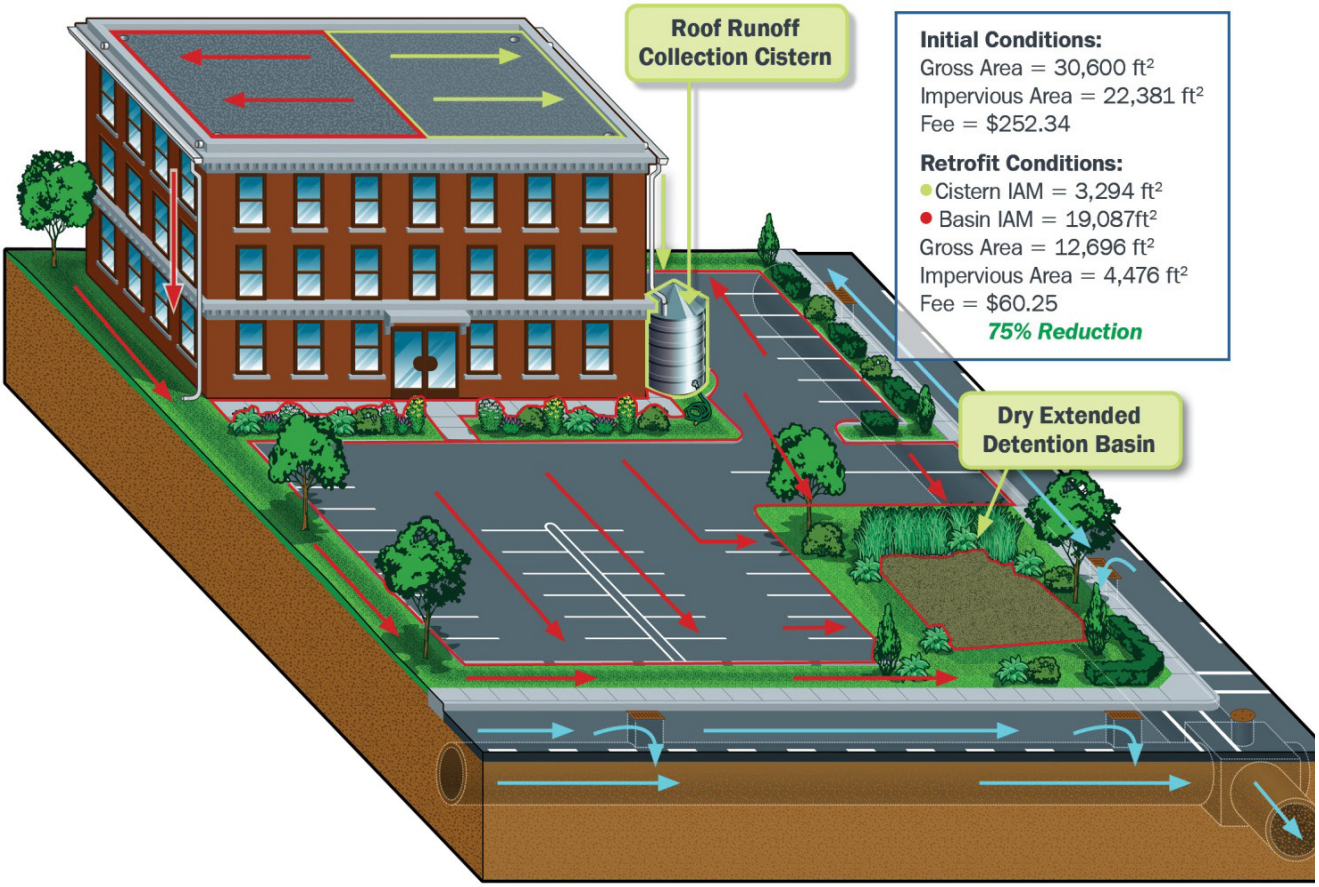


Figure A3.**1**: Site 1 Rendering

SITE 1 CALCULATIONS

Site 1

Initial Conditions

Gross Area Initial (GAi) = 30,600 sf
GAi Rounded Up = 31,000 sf

Impervious Area Intial (IAi) = 22,381 sf
IAi Rounded Up = 22,500 sf
Building = 6,588 sf
Sidewalk = 736 sf
Parking and Drives = 15,057 sf

Green Space = 8,219 sf

Initial Fee = [(GAi ÷ 500) x $0.59] + [(IAi ÷ 500) x $4.746] + $2.19
= $ 252.34

SWMS Rates (Effective July 1, 2014)

Gross Area :	*$0.590/500 sf*
Impervious Area:	*$4.746/500 sf*
Billing & Collections:	*$2.19*

Initial Sizing Check

Water Quality Volume For All Impervious Area
(WQv) = (1-in Rainfall ÷ 12 in per ft) x IAi
= 1,865 cf

Min Site Loading If All Green Space Is Utilized= 2.7 :1

Min Area Required (10:1) = 2,238 sf

WQv = (P ÷ 12) x IA *Eqn: 1*

Where:
WQv= Water Quality Volume (cubic feet)
P = 1.0 Inch of Rainfall
I A = Impervious Drainage Area

WQv = (1.0 ÷ 12) x 22,381 ft² = 1,865 ft³

SMPs - Roof Runoff Collection Cistern (See Section 4.X) and Dry Extended Detention Basin (See Section 4.X)

Total Volume Managed = 1,865 sf

Roof Runoff Collection Cistern: Collects runoff from half of the roof
Impervious Drainage Area (I) = 3,294 sf
Water Quality Volume (WQv) = (1-in Rainfall ÷ 12 in per ft) x I
= 275 cf 2,053 gal

WQv = (P ÷ 12) x IA *Eqn: 1*

WQv = (1.0 ÷ 12) x 3,294 ft² = 275 ft³

Dry Extended Detention Basin Collects runoff from all of the pavement and half of the roof
Impervious Drainage Area (I) = 19,087 sf
Water Quality Volume (WQv) = (1-in Rainfall ÷ 12 in per ft) x I
= 1,591 cf
Because infiltration is not feasible - this SMP must meet the WQ slow release rate requirements
SMP Discharge Rate (Qcss) = 0.05 * (I/43560)
= 0.02 cfs
Using a 1-inch orifice, the maximum allowable head on the outlet is:
Maximum Head = h = (Q/Cd A)^2 ÷ 2g
= 0.58 ft
Static Storage Footprint based on maximum allowable head = WQv ÷ Hmax
= 2,742 sf

WQv = (P ÷ 12) x IA *Eqn: 1*

WQv = (1.0 ÷ 12) x 19,087 ft² = 1,591 ft³

$$Q_{CSS} = 0.05 * \left(\frac{IA}{43,560}\right)$$ *Eqn: 2*

Where:
Q_{CSS} = SMP discharge rate in CSO areas (cfs)
IA= Impervious Area Managed (square feet)

*Qcss = 0.05 * 19,087/43,560 = 0.02 cfs*

Final Conditions

IAR = 0 ft²
IAM (DA Cistern + DA Basin) = 22,381 ft²

Gross Area Final (GAf) = GAi – (IAM x Credit Multiplier)
= 12,695.2 ft²
GAf Rounded Up = 13,000 ft²

Impervious Area Final (IAf) = IAi – IAR – (IAM x Credit Multiplier)
= 4,476.2 ft²
IAf Rounded Up = 4,500 ft²

Final Fee = [(GAf ÷ 500) x $0.59] + [(IAf ÷ 500) x $4.746] + $2.19
= $ 60.24
Percent Reduced = 76%

$$H_{max} = \left(\frac{Q_{CSS}}{C_d * A}\right)^2 / 2g$$ *Eqn: 3*

Where:
Q_{CSS} = SMP discharge rate in CSO areas (cfs)
Cd =Discharge Coefficient – 0.6
A = Orifice Area - $A = \pi r^2$(square feet)
g = Gravity (32.2 ft/sec²)

Hmax = [0.02/0.6(3.14*(0.5/12)²)² /2*32.2 = 0.58 ft*

EXAMPLE SITE 2

Site 2 is a store located in the MS4 area. Infiltration tests were performed (see Appendix 1 Soil Infiltration and Profile Guidelines) and determined that the site had soils suitable for infiltration based SMPs. The store owner decided to implement a sidewalk stormwater planter (see Section 4.6 Flow Through Planter Boxes) along the entrance of the building to collect the Water Quality Volume from the front half of the roof and the entry sidewalk as well as increase the aesthetics of the face of the building. The parking lot and a portion of the sidewalk were regraded to drain to a bioretention system (see Section 4.2 Bioretention) installed in the green space along the sidewalk. The remaining portion of roof was disconnected and the drive-thru lanes were regraded to drain to a swale (see Section 4.3 Swales/Bioswales) along the back and side of the property. The swale was designed around the existing trees on site.

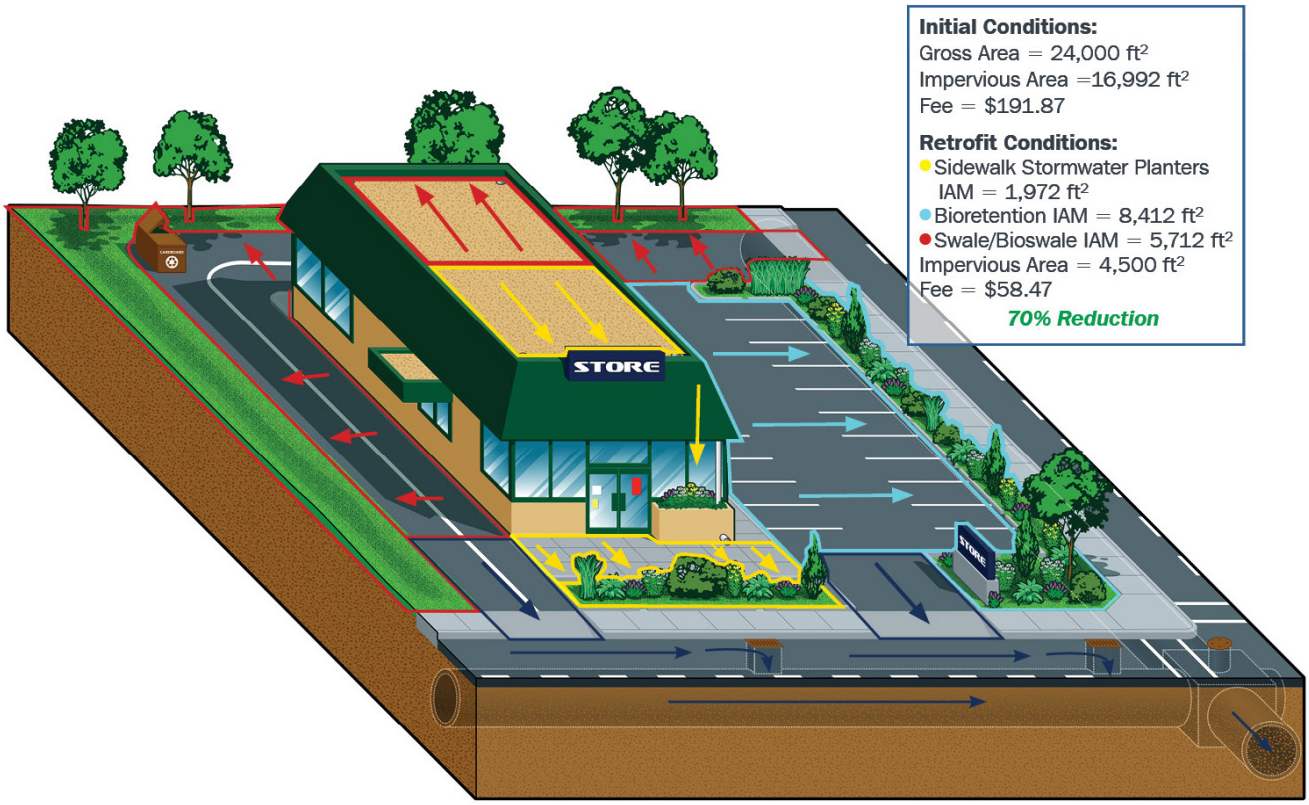


Figure A3.**2**: Site 2 Rendering

SITE 2 CALCULATIONS

Site 2

Initial Conditions

Gross Area Initial (GAi) =	24,000	sf
GAi Rounded Up =	24,000	sf
Impervious Area Intial (IAi) =	16,992	sf
IAi Rounded Up =	17,000	sf
Building =	3,240	sf
Sidewalk =	852	sf
Parking and Drives =	12,900	sf
Green Space =	7,008	sf

SWMS Rates (Effective July 1, 2014)

Gross Area :	*$0.590/500 sf*
Impervious Area:	*$4.746/500 sf*
Billing & Collections:	*$2.19*

Initial Fee = [(GAi ÷ 500) x $0.59] + [(IAi ÷ 500) x $4.746] + $2.19
= $ 191.87 per month

Requirements

Water Quality Volume For All Impervious Area
(WQv) = (1-in Rainfall ÷ 12 in per ft) x IAi
= 1,416 cf

Min Site Loading If All Green Space Is Utilized= 2.4 :1

Min Area Required (10:1) = 1,699 sf

WQv = (P ÷ 12) x IA *Eqn: 1*

Where:
WQv= Water Quality Volume (cubic feet)
P = 1.0 Inch of Rainfall
I = Impervious Drainage Area

WQv = (1.0 ÷ 12) x 16,992 sf = 1,416 cf

SMPs - Flow Through Planter Boxes (See Section 4.6), Bioretention System (See Section 4.2), and Swale/Bioswale (See Section 4.3)

Total Volume Managed = 2,578 cf

Sidewalk Stormwater Planters: Collects runoff from half of the roof and a portion of sidewalk

Drainage Area =	1,972	sf
Storage Volume Required =	164	cf
Footprint (50 ft x 4 ft) =	200	sf
Storage Volume Provided (1 ft Surface + 2 ft Planting Media + 2 ft Clean Stone) =	440	cf
Loading =	10	:1

WQv = (P ÷ 12) x IA *Eqn: 1*

WQv = (1.0 ÷ 12) x 1,972 sf = 164 cf

Bioretention: Collects runoff from the parking lot and a portion of the sidewalk

Drainage Area =	8,412	sf
Storage Volume Required=	701	cf
Footprint (99 ft x 4 ft Along Parking Lot + 24 ft x 24 ft In Corner) =	972	sf
Storage Volume Provided (1 ft Surface + 2 ft Planting Media + 2 ft Clean Stone) =	2,138	cf
Loading =	9	:1

WQv = (P ÷ 12) x IA *Eqn: 1*

WQv = (1.0 ÷ 12) x 8,412 sf= 701 cf

Swale/BioSwale: Collects runoff from the drivethrough lanes and half the roof

Drainage Area =	5,712	sf
Storage Volume Required=	476	cf
Footprint (160 ft x 5 ft) =	800	sf
Storage Volume Provided (160 ft x [5 ft Top + 1 ft Bottom] ÷ 2 x 1 ft Depth) =	480	cf
Loading =	7	:1

WQv = (P ÷ 12) x IA *Eqn: 1*

WQv = (1.0 ÷ 12) x 5,712 sf = 476 cf

Final Conditions

IAR = 0 sf
IAM (DA Planters + DA Bioretention + DA Swale)
= 16,096 sf

Gross Area Final (GAf) = GAi – (IAM x Credit Multiplier)
= 11,123.2 sf
GAf Rounded Up = 11,500 sf

Impervious Area Final (IAf) = IAi – IAR – (IAM x Credit Multiplier)
= 4,115.2 sf
IAf Rounded Up = 4,500 sf

Final Fee = [(GAf ÷ 500) x $0.59] + [(IAf ÷ 500) x $4.746] + $2.19
= $ 58.47 per month
Percent Reduced = 70%

EXAMPLE SITE 3

Site 3 is an industrial site located in the MS4 area. Infiltration tests were performed (see Appendix 1 Soil Infiltration and Profile Guidelines) and determined that the site had soils suitable for infiltration based SMPs. The site was entirely impervious, so the landowner needed to consider converting impervious area into an approved SMP. The landowner wanted to manage the entire Water Quality Volume from the site and chose to replace the entire parking area with porous pavement (see Section 4.4 Porous Pavement/Pavers). The roof downspouts were disconnected and discharged directly onto the porous parking area. This design allowed the landowner to manage the Water Quality Volume from the roof as well as convert a large portion of the site from impervious to pervious.

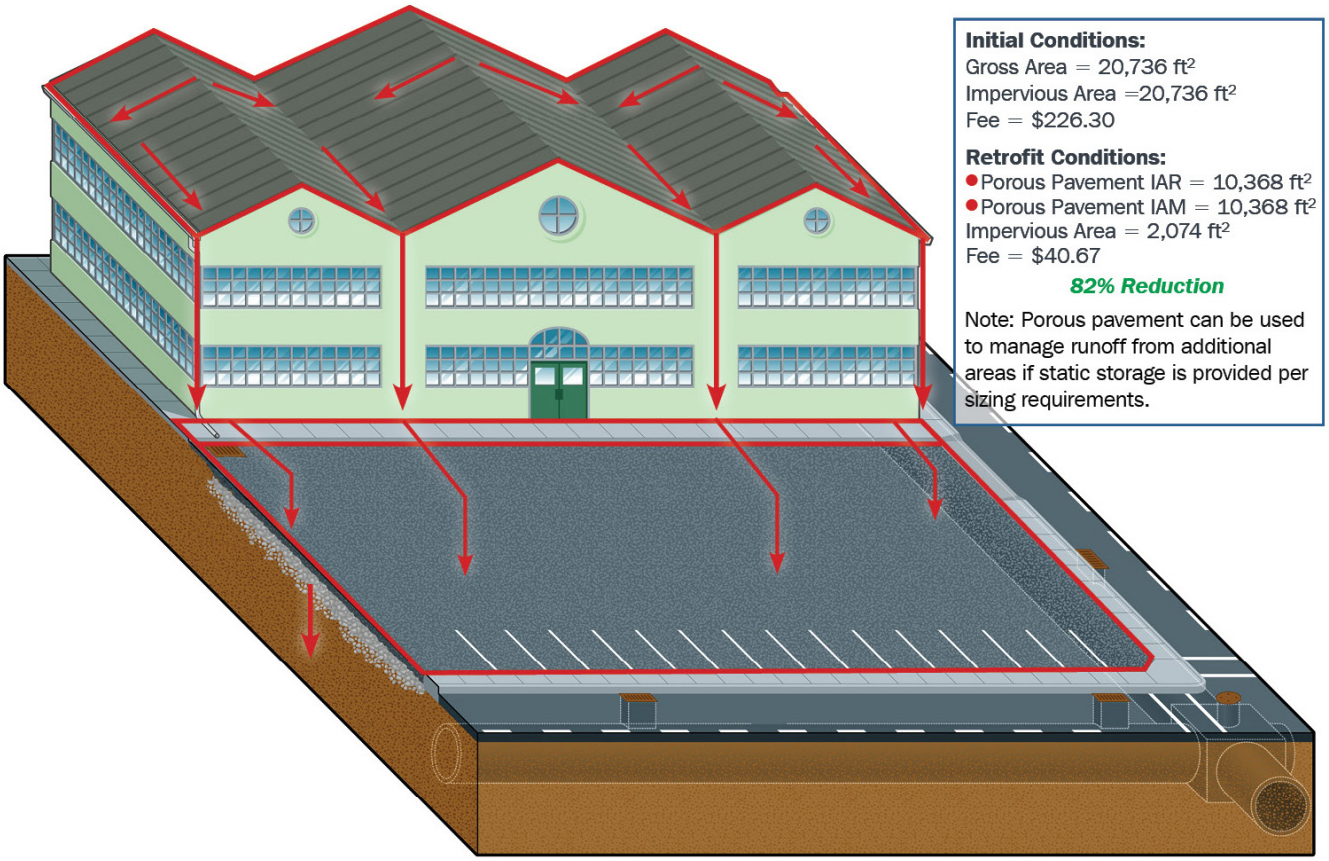


Figure A3.**3**: Site 3 Rendering

SITE 3 CALCULATIONS

Site 3

Initial Conditions

Gross Area Initial (GAi) =	20,736	sf
GAi Rounded Up =	21,000	sf
Impervious Area Intial (IAi) =	20,736	sf
IAi Rounded Up =	21,000	sf
Building =	9,248	sf
Sidewalk =	1120	sf
Parking and Drives =	10,368	sf
Green Space =	0	sf

SWMS Rates (Effective July 1, 2014)

Gross Area :	*$0.590/500 sf*
Impervious Area:	*$4.746/500 sf*
Billing & Collections:	*$2.19*

Initial Fee = [(GAi ÷ 500) x $0.59] + [(IAi ÷ 500) x $4.746] + $2.19
= $ 226.30 per month

Requirements

Min Area Required (10:1) = 2,074 sf

Water Quality Volume For All Impervious Area
(WQv) = (1-in Rainfall ÷ 12 in per ft) x IAi
= 1,728 cf

WQv = (P ÷ 12) x IA *Eqn: 600.1*

Where:
WQv= Water Quality Volume (cubic feet)
P = 1.0 Inch of Rainfall
I = Impervious Drainage Area

WQv = (1.0 ÷ 12) x 20,736 sf = 1,728 cf

SMPs - Porous Pavement (See Section 4.4)

Total Volume Managed = 8,294 cf

Porous Pavement: Replaces entire parking area and collects roof and sidewalk

Drainage Area (Enitre Site) =	20,736	sf
Storage Volume Required=	1,728	cf
Footprint (All Parking and Drives) =	10,368	sf
Volume Availble (2 ft Gravel Storage) =	8,294	cf
Loading =	2	:1

WQv = (P ÷ 12) x IA *Eqn: 600.1*

WQv = (1.0 ÷ 12) x 20,736 sf = 1,728 cf

Final Conditions

IAR (Porous Pavement Footprint) =	10,368	sf
IAM (DA Porous Pavement) =	10,368	sf

Gross Area Final (GAf) = GAi – (IAM x Credit Multiplier)
= 12,441.6 sf
GAf Rounded Up = 12,500 sf

Impervious Area Final (IAf) = IAi – IAR – (IAM x Credit Multiplier)
= 2,073.6 sf
IAf Rounded Up = 2,500 sf

Final Fee = [(GAf ÷ 500) x $0.59] + [(IAf ÷ 500) x $4.746] + $2.19
= $ 40.67 per month
Percent Reduced = 82%

EXAMPLE SITE 4

Site 4 is an urban office building located in the CSO area. This site had no available ground surface to utilize for SMP implementation. The only feasible SMP was to install a green roof. The landowner chose to install the green roof (see Section 4.8 Green Roofs) across the entire roof surface; converting the entire area from impervious to pervious for purposes of Stormwater Credit calculations. The green roof had to be designed with an appropriate drainage system to discharge the overflow volumes to the combined sewer at an approved rate (see Section 3.0 Planning and Process).

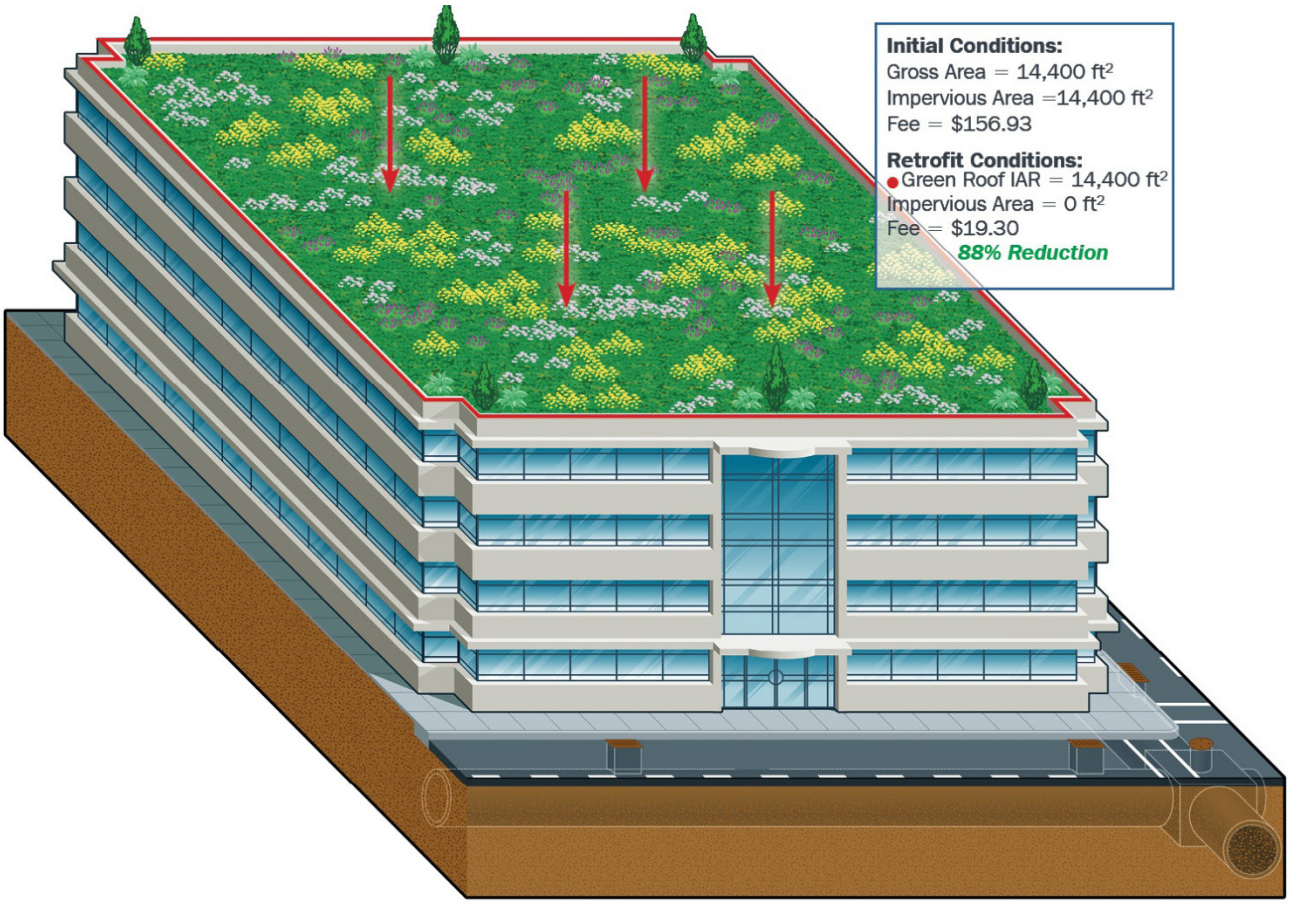


Figure A3.**4**: Site 4 Rendering

SITE 4 CALCULATIONS

Site 4

Initial Conditions

Gross Area Initial (GAi) = 14,400 sf
GAi Rounded Up = 14,500 sf

Impervious Area Intial (IAi) = 14,400 sf
IAi Rounded Up = 14,500 sf
Building = 14,400 sf
Sidewalk = 0 sf
Parking and Drives = 0 sf

Green Space = 0 sf

Initial Fee = [(GAi ÷ 500) x $0.59] + [(IAi ÷ 500) x $4.746] + $2.19
= $ 156.93 per month

SWMS Charges (Effective July 1, 2014)

Gross Area :	*$0.590/500 sf*
Impervious Area:	*$4.746/500 sf*
Billing & Collections:	*$2.19*

Requirements

Min Area Required (10:1) = 1,440 sf

Water Quality Volume For All Impervious Area
(WQv) = (1-in Rainfall ÷ 12 in per ft) x IAi
= 1,200 cf

WQv = (P ÷ 12) x IA *Eqn: 600.1*

Where:
WQv= Water Quality Volume (cubic feet)
P = 1.0 Inch of Rainfall
I = Impervious Drainage Area

WQv = (1.0 ÷ 12) x 14,400 sf = 1,200 cf

SMPs - Green Roof (See Section 4.8)

Total Volume Managed = 1,680 cf

Green Roof: Replaces entire roof
Drainage Area = 14,400 sf
Storage Volume Required= 1,200 cf
Footprint = 14,400 sf
Volume Available (3 in Growning Medium and 2 in Granular layer) = 1,680 cf
Loading = 1 :1

WQv = (P ÷ 12) x IA *Eqn: 600.1*

WQv = (1.0 ÷ 12) x 14,400 sf = 1,200 cf

Final Conditions

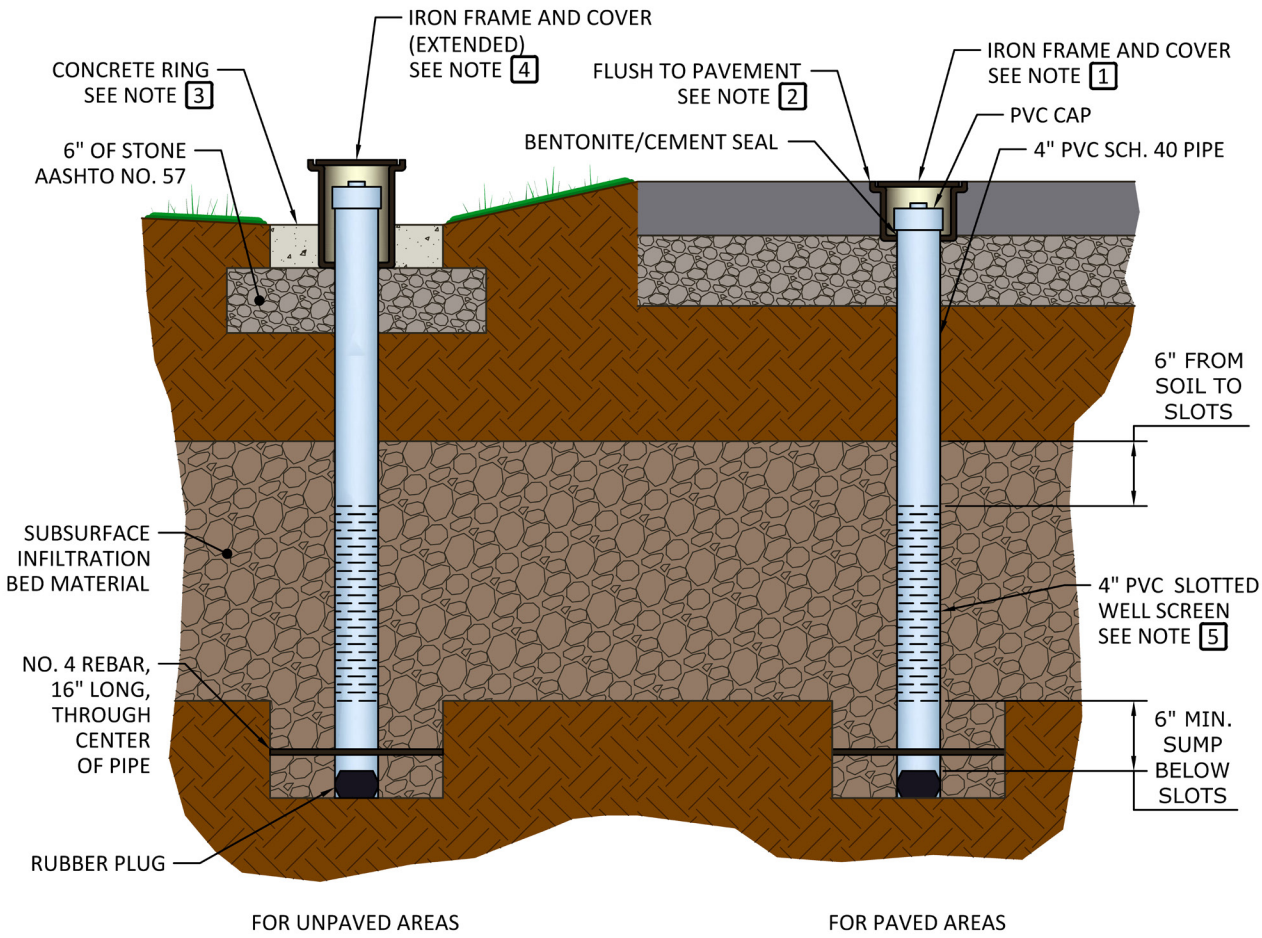
IAR = 14,400 sf
IAM = 0 sf

Gross Area Final (GAf) = GAi – (IAM x Credit Multiplier)
= 14,400.0 sf
GAf Rounded Up = 14,500 sf

Impervious Area Final (IAf) = IAi – IAR – (IAM x Credit Multiplier)
= 0 sf
IAf Rounded Up = 0 sf

Final Fee = [(GAf ÷ 500) x $0.59] + [(IAf ÷ 500) x $4.746] + $2.19
= $ 19.30 per month
Percent Reduced = 88%

Appendix 4



NOTES

1. OBSERVATION WELL SHALL BE CAPPED WITH A DUCTILE IRON BOLTED COVER WITH A GRAY IRON FRAME.
2. FRAME AND COVER SHALL BE AS FLUSH TO SURROUNDING PAVEMENT AS POSSIBLE. IF FRAME IS NOT HELD SECURELY BY SURROUNDING PAVING MATERIAL, A CONCRETE RING SHALL BE USED TO PROTECT AND SECURE THE FRAME. SEE NOTE 3.
3. IN UNPAVED AREAS, THE FRAME SHALL BE SET IN A CONCRETE RING 16" IN DIAMETER AND 4" THICK. WELDED WIRE MESH SHALL BE USED FOR REINFORCEMENT. CONCRETE SHALL HAVE 2,500 PSI COMPRESSIVE STRENGTH.
4. IN UNPAVED AREAS, THE GRAY IRON FRAME SHALL BE TALL ENOUGH TO ALLOW PVC PIPE TO EXTEND 6" ABOVE BOTTOM OF FRAME.
5. THE WELL SCREEN SHALL BE 4" PVC WITH 0.01 SLOT SIZE.
6. EACH INFILTRATION SMP SHALL BE PROVIDED WITH A MINIMUM OF ONE OBSERVATION WELL. LARGE SMPS SHOULD HAVE AT LEAST ONE WELL PER 1,000 SQUARE FEET OF INFILTRATION AREA. LONG AND NARROW SMPS SHOULD HAVE AT LEAST ONE WELL PER 50 LINEAR FEET. WELLS SHOULD BE CENTERED AND EVENLY SPACED WITHIN THE SMP.

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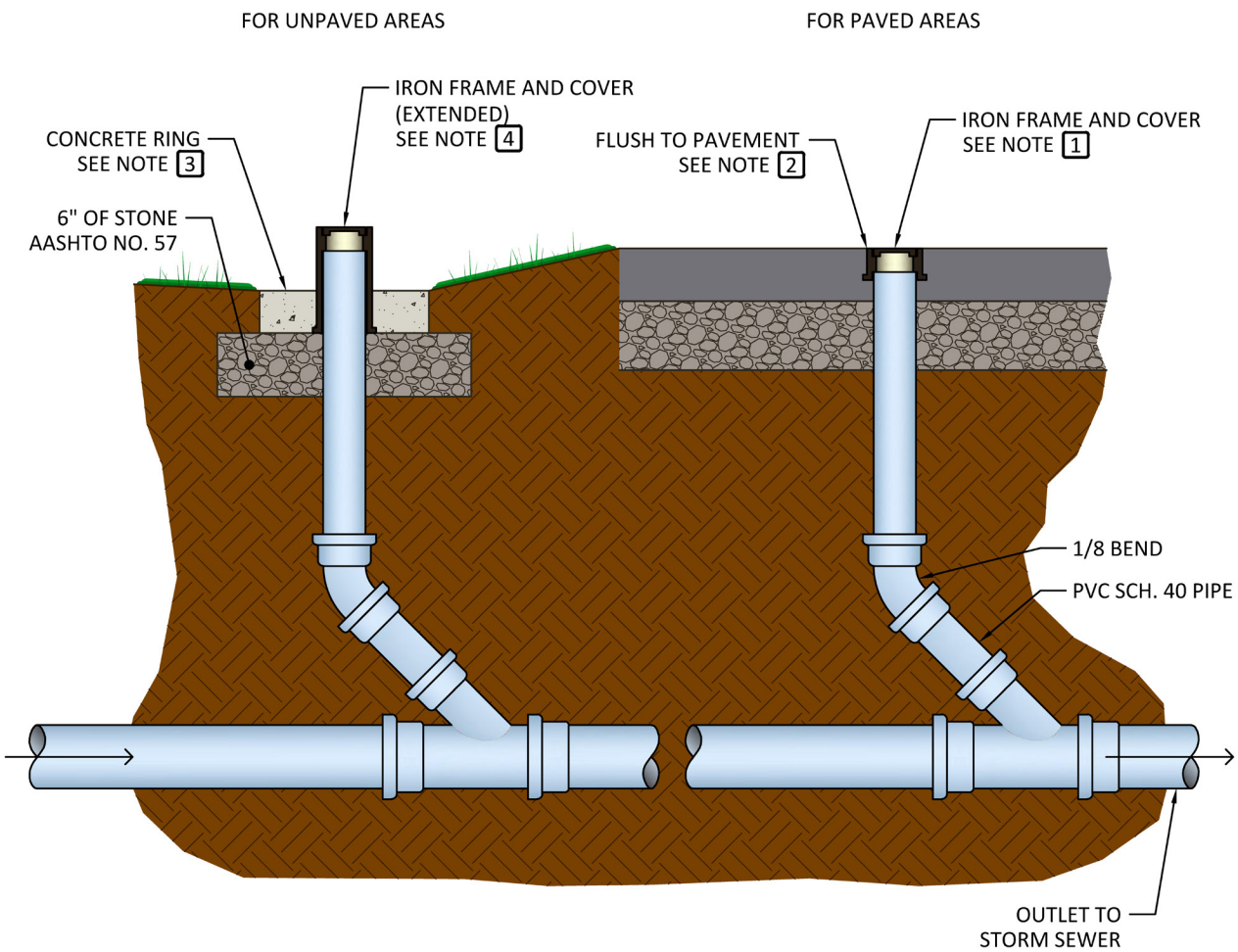
OBSERVATION WELL COM-A.1



NOTES

1. CLEANOUT SHALL HAVE AN IRON FRAME AND COVER.
2. FRAME AND COVER SHALL BE AS FLUSH TO SURROUNDING PAVEMENT AS POSSIBLE. IF FRAME IS NOT HELD SECURELY BY SURROUNDING PAVING MATERIAL, A CONCRETE RING SHALL BE USED TO PROTECT AND SECURE THE FRAME. SEE NOTE 3.
3. IN UNPAVED AREAS, THE FRAME SHALL BE SET IN A CONCRETE RING 16" IN DIAMETER AND 4" THICK. WELDED WIRE MESH SHALL BE USED FOR REINFORCEMENT. CONCRETE SHALL HAVE 2,500 PSI COMPRESSIVE STRENGTH.
4. IN UNPAVED AREAS, THE FRAME AND COVER SHALL STAND PROUD OF THE SURROUNDING GRADE. IF FRAME IS NOT TALL ENOUGH, A LENGTH OF IRON PIPE MAY BE USED TO EXTEND THE CLEANOUT ABOVE GRADE.
5. ONE CLEANOUT SHOULD BE PLACED AT EACH PIPE BEND OR TEE, AT THE THE END OF EACH STRAIGHT PIPE RUN, AND EVERY 75 LINEAR FEET ON LONGER STRAIGHT PIPE RUNS.

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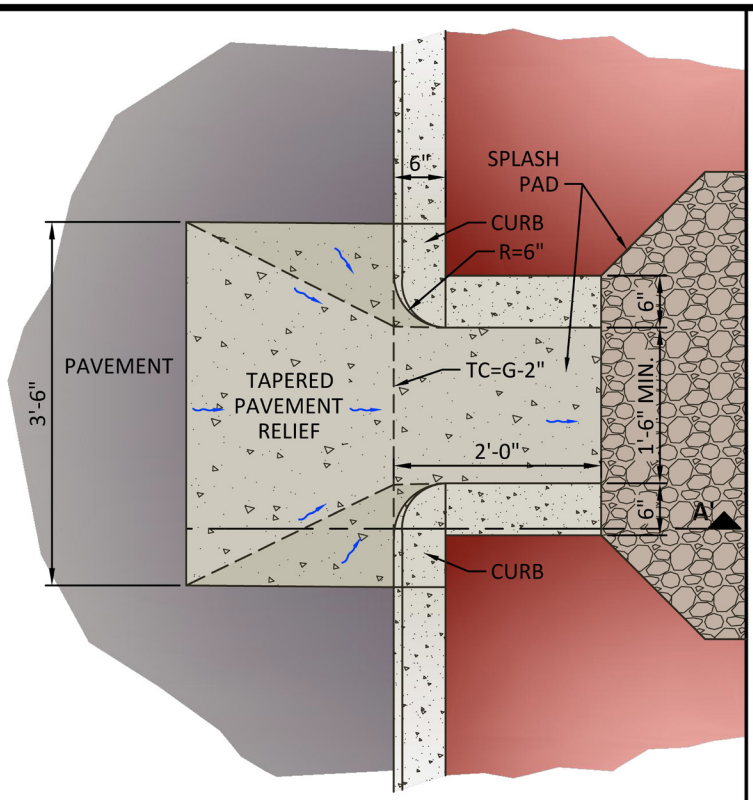
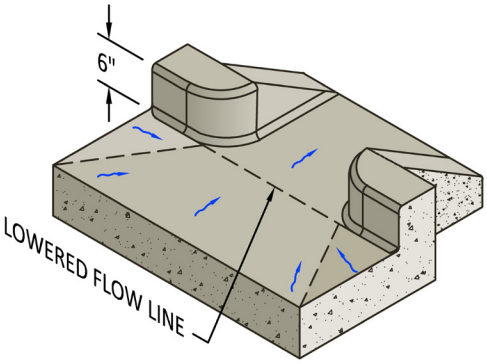
CLEANOUT

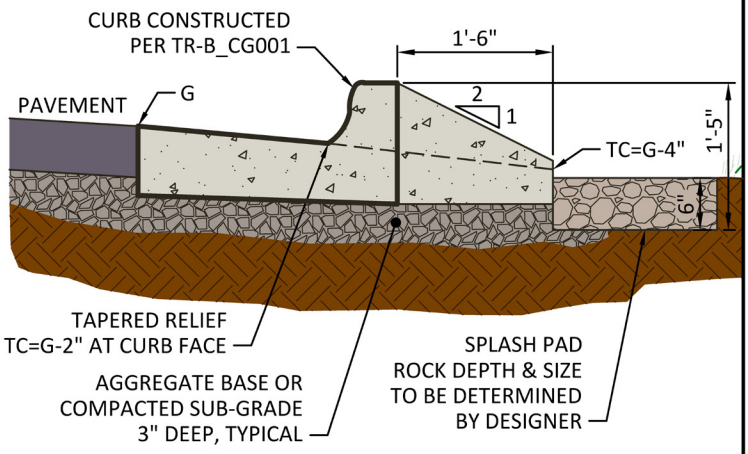
COM-A.2



PLAN VIEW



ISOMETRIC VIEW



TC = TOP OF CONCRETE
G = GUTTER

SECTION A - A'

NOTES

1. CONCRETE SPLASH PAD NECESSARY WHERE WATER ENTERS AND/OR EXITS FACILITY.
2. FOR STORMWATER FACILITIES, INSTALL CONCRETE OR RIVER COBBLE TO TRANSITION FROM SPLASH PAD TO TOPSOIL.
3. SEE TYPICAL DETAIL FOR CURB TURNOUT OUTLET PROTECTION.
4. ENGINEER TO PROVIDE SPACING CALCULATIONS FOR CURB TURNOUTS TO ENSURE PONDING DEPTH IN STREET IS WITHIN ACCEPTABLE LIMITS PER CITY OF PHILADELPHIA REQUIREMENTS.

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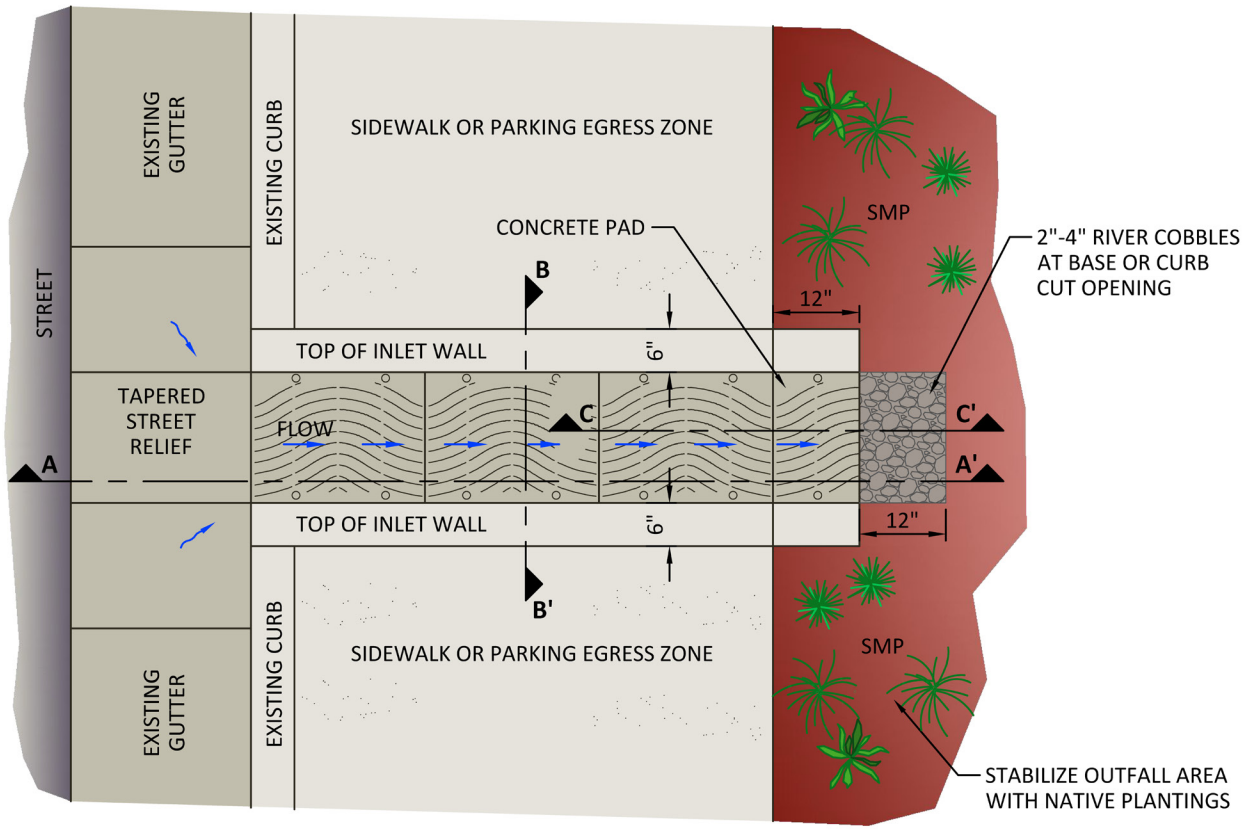
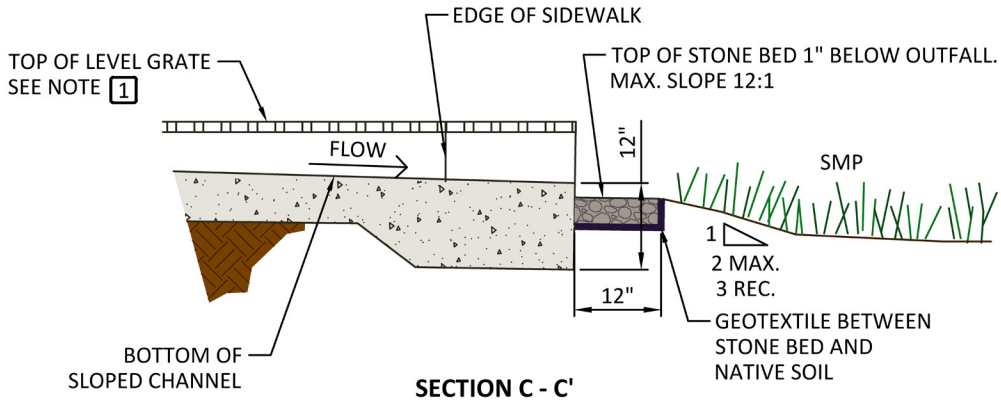
INLET - CURB CUT

COM-A.3



PLAN VIEW



SECTION C - C'

NOTE

1 GRATE MAY NEED TO MEET ADA REQUIREMENTS DEPENDENT UPON SITE USE.

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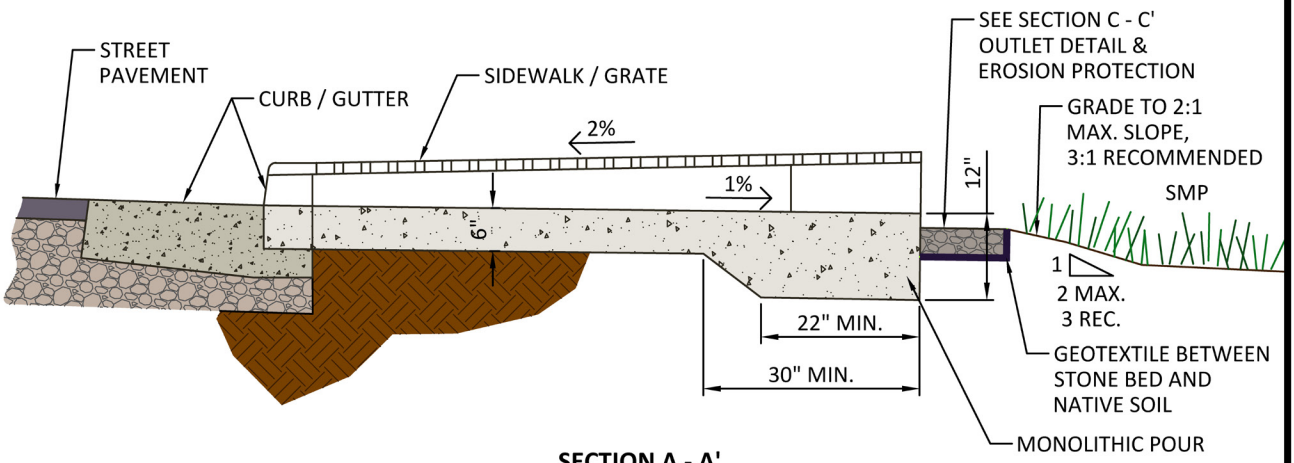
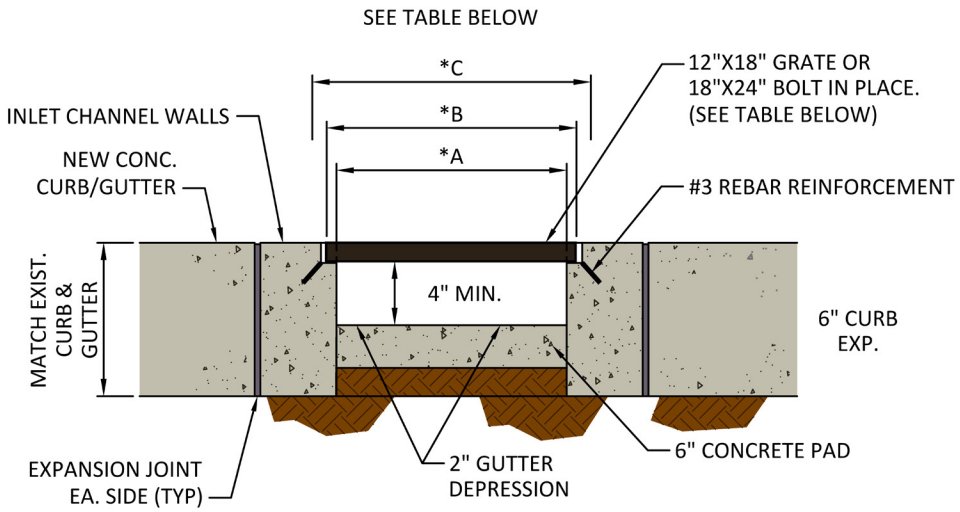
INLET - TRENCH DRAIN
SHEET 1 OF 2

COM-A.4



SECTION A - A'



SECTION B - B'

NOTE

MAXIMUM GRATE HOLE WIDTH (OPEN) 1/4 INCH. GRATE SIZE 12" X 18" OR 18"X24".

*TRENCH GRATING

A TRENCH WIDTH	B GRATE WIDTH	C FRAME WIDTH
10"	11 7/8"	12 1/8"
16"	17 7/8"	18 1/8"

Stormwater Retrofit Manual ***SMP Design Details***

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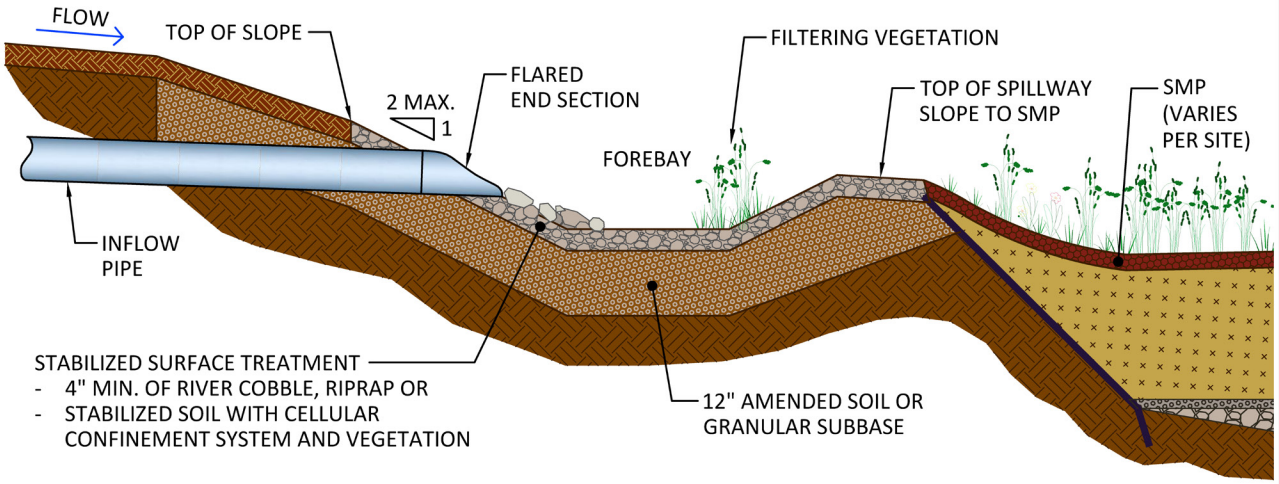
INLET - TRENCH DRAIN
SHEET 2 OF 2

COM-A.4



NOTES

1. THE MAIN GOAL OF PRE-TREATMENT FILTERING IS TO CAPTURE FLOATABLES, DEBRIS, GREASE, OILS, SILT AND SEDIMENT WHERE THEY CAN BE EASILY CLEANED AT THE SURFACE OF THE PRE-TREATMENT THROUGH REGULAR MAINTENANCE, AND BEFORE THEY HAVE THE OPPORTUNITY TO CLOG THE SMP.
2. WHEN CONCENTRATED FLOW IS DIRECTED TO A SMP THROUGH CURB TURNOUTS OR PIPE OUTLETS, A SEDIMENT FOREBAY SHOULD BE USED TO ALLOW MATERIAL TO BE CAPTURED WHERE IT CAN BE EASILY CLEANED.
3. A SEDIMENT FOREBAY SHOULD BE SIZED AND DESIGNED SO THAT IT IS INTEGRATED INTO THE SMP AREA.
4. THE FOREBAY SHOULD BE SIZED TO CONTAIN 10% OF THE OVERALL VOLUME DIRECTED TO THE SMP.
5. IF HIGH RUNOFF VELOCITY IS A POTENTIAL PROBLEM, SOME TYPE OF ENERGY DISSIPATION DEVICE MUST BE INCORPORATED.
6. DIRECT MAINTENANCE ACCESS TO THE FOREBAY MUST BE PROVIDED.
7. EXIT VELOCITIES FROM THE FOREBAY MUST BE NON-EROSIVE.
8. THE BOTTOM OF THE FOREBAY MAY BE PAVED OR LINED WITH A HARDENED MATERIAL OR IMPERMEABLE LINER TO MAKE SEDIMENT REMOVAL EASIER.
9. A FIXED VERTICAL SEDIMENT DEPTH MARKER MUST BE INSTALLED IN THE FOREBAY TO MEASURE SEDIMENT DEPOSITION OVER TIME.
10. SEDIMENT REMOVAL IN THE FOREBAY SHALL OCCUR WHEN IT IS FILLED TO 50% OF CAPACITY.
11. ALL DISTURBED AREAS MUST BE IMMEDIATELY STABILIZED AFTER CONSTRUCTION TO MINIMIZE EROSION.

Stormwater Retrofit Manual ***SMP Design Details***

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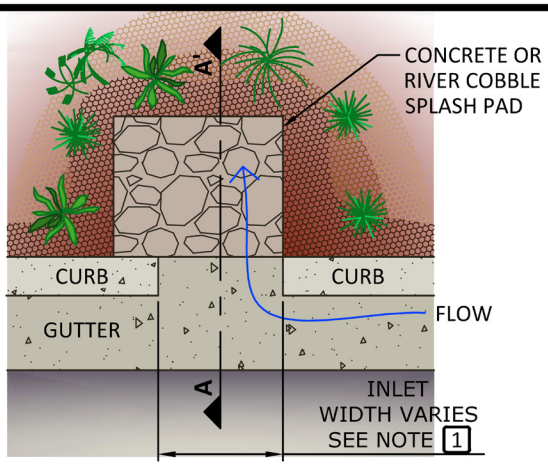
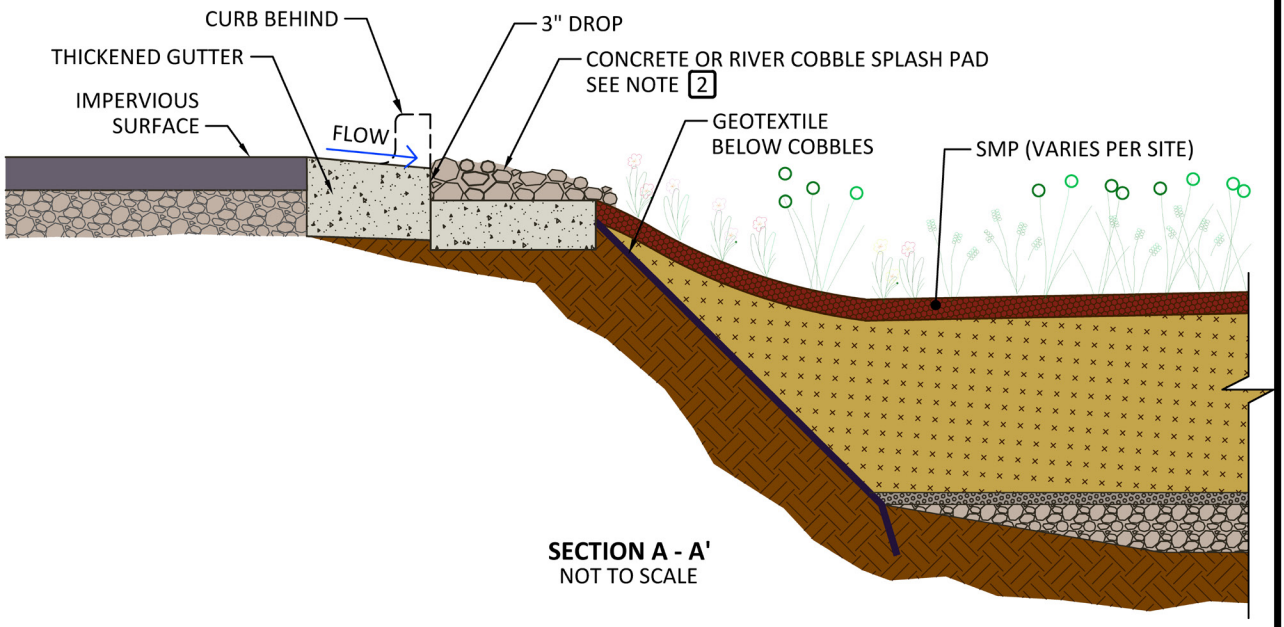
FOREBAY

COM-A.5



PLAN VIEW
NOT TO SCALE



SECTION A - A'
NOT TO SCALE

NOTES

1. SIZE DEPRESSED CURB INLETS TO ACCOMMODATE DESIRED FLOWS.
2. INLETS AND GUTTER MAY BE MODIFIED TO ADJUST FLOW INTO SMP.
3. CONVEYANCE TO AND FROM SMPS SHALL ENSURE NON-EROSIVE CONDITIONS. ENERGY DISSIPATION SHALL BE PROVIDED FOR CONCENTRATED DISCHARGES FROM PAVEMENT CURB TURNOUTS, DOWNSPOUTS, SWALES, PIPE OUTLETS, OR OTHER FLOW CONCENTRATING ELEMENTS, USING A PLUNGE AREA, ROCKS, SPLASH BLOCKS, STONE CHECK DAMS, LEVEL SPREADER, OR OTHER ENERGY DISSIPATION MEASURE.
4. FOR SLOPED APPLICATIONS, A SERIES OF SMPS CAN BE TERRACED TO CONVEY WATER NON-EROSIVELY.

Stormwater Retrofit Manual ***SMP Design Details***

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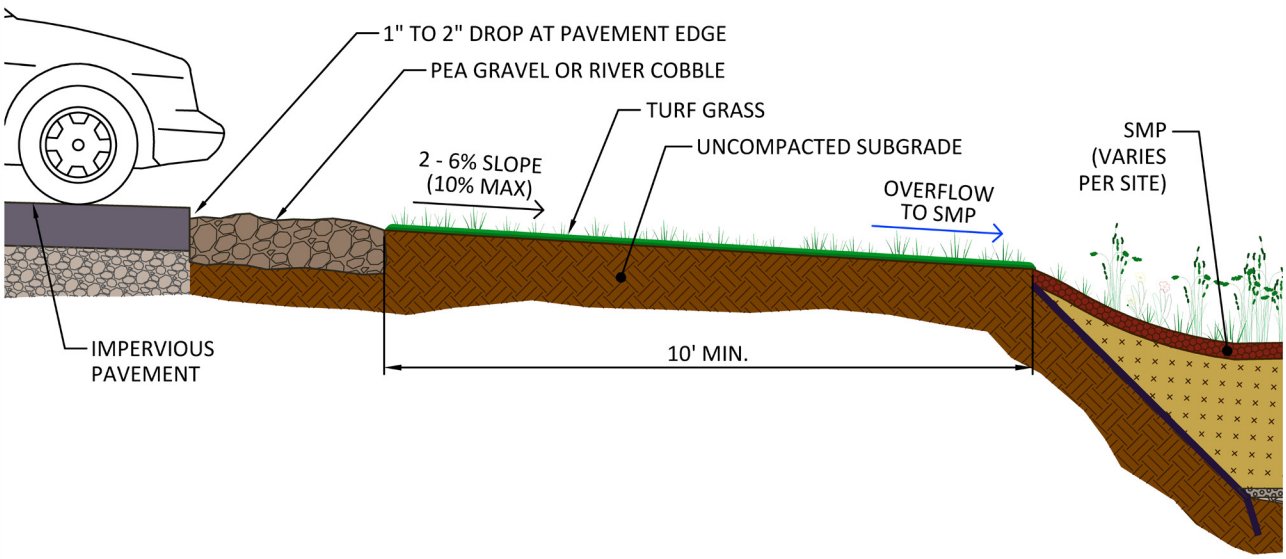
SHEET FLOW OFF
A DEPRESSED CURB
WITH A 3" DROP INLET

COM-A.6



NOTES

1. THE MAIN GOAL OF PRE-TREATMENT FILTERING IS TO CAPTURE FLOATABLES, DEBRIS, GREASE, OILS, SILT AND SEDIMENT WHERE THEY CAN BE EASILY CLEANED AT THE SURFACE OF THE PRE-TREATMENT THROUGH REGULAR MAINTENANCE, AND BEFORE THEY HAVE THE OPPORTUNITY TO CLOG THE SMP.
2. FILTER STRIPS CAN BE USED EFFECTIVELY AS PRE-TREATMENT MEASURES AND CAN PROVIDE ENERGY DISSIPATION WITH THE ADDITION OF A LEVEL SPREADER, CHECK DAMS, OR ROCK DIAPHRAGM.
3. ENSURE THAT FLOWS IN EXCESS OF THE DESIGN FLOW CAN MOVE ACROSS AND AROUND THE FILTER STRIP WITHOUT DAMAGE.
4. THE SLOPE OF THE FILTER STRIP SHOULD BE BETWEEN 2% AND 6% FOR OPTIMUM PERFORMANCE.
5. THE SLOPE OF A FILTER STRIP MUST NOT EXCEED 10%.
6. THE WIDTH OF THE FILTER STRIP SHOULD BE EQUAL TO THE WIDTH OF THE RECEIVING SMP.
7. ALL DISTURBED AREAS MUST BE IMMEDIATELY STABILIZED AFTER CONSTRUCTION TO MINIMIZE EROSION.

Stormwater Retrofit Manual ***SMP Design Details***

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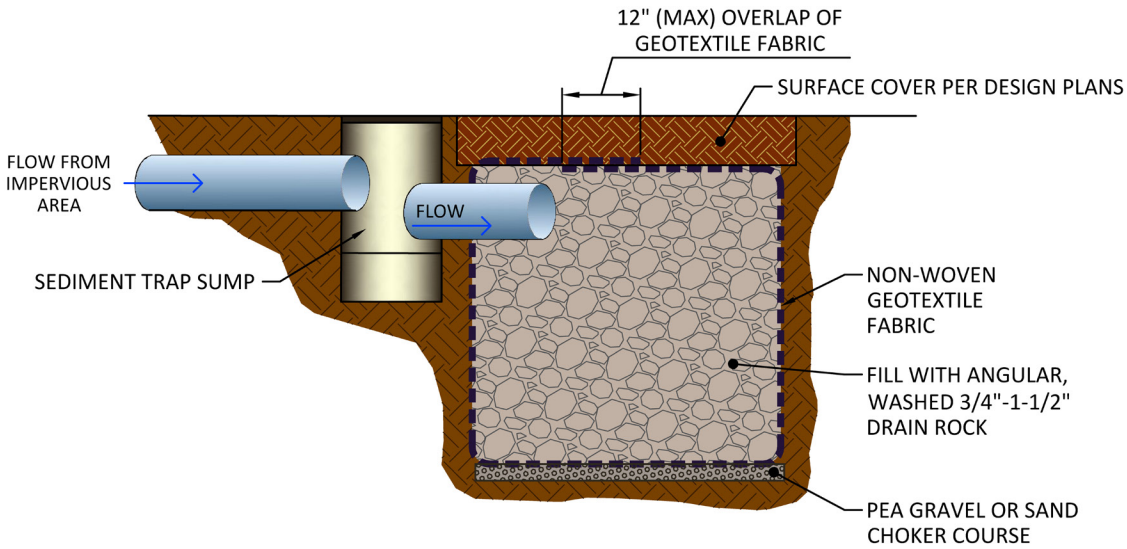
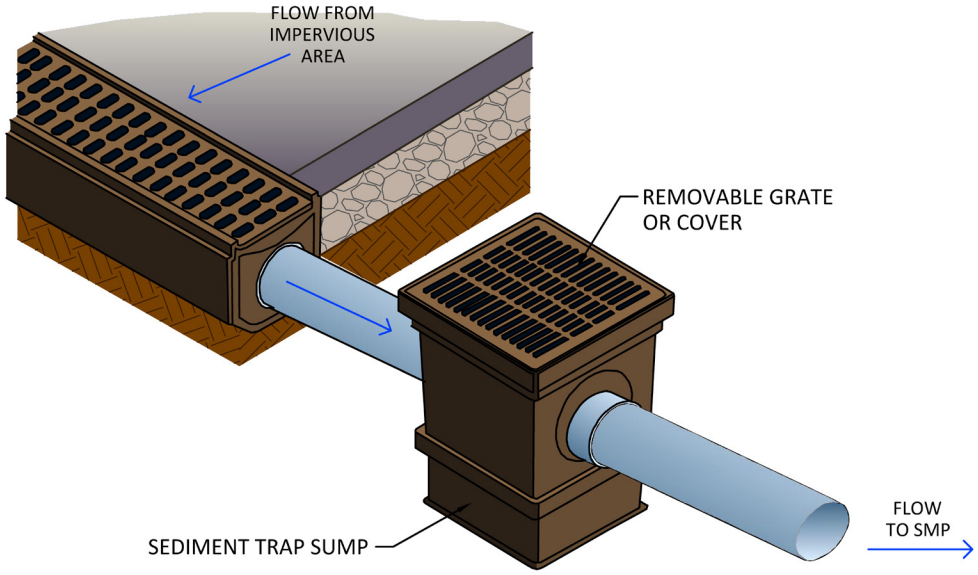
GRASS FILTER STRIP COM-A.7





SUMP INLET IN-LINE PIPE TREATMENT

NOTES

1. INSTALL PRETREATMENT SEDIMENT TRAP WHEN INFILTRATING FLOWS WITH HIGH SEDIMENT LOADS.
2. DESIGN SUMP TO HAVE ONE CUBIC FOOT OF STORAGE FOR EVERY 100 SQUARE FEET OF IMPERVIOUS AREA DRAINING TO SEDIMENT TRAP.
3. SUMP CAN BE PRECAST CONCRETE, PVC, OR HDPE.

Stormwater Retrofit Manual — *SMP Design Details*

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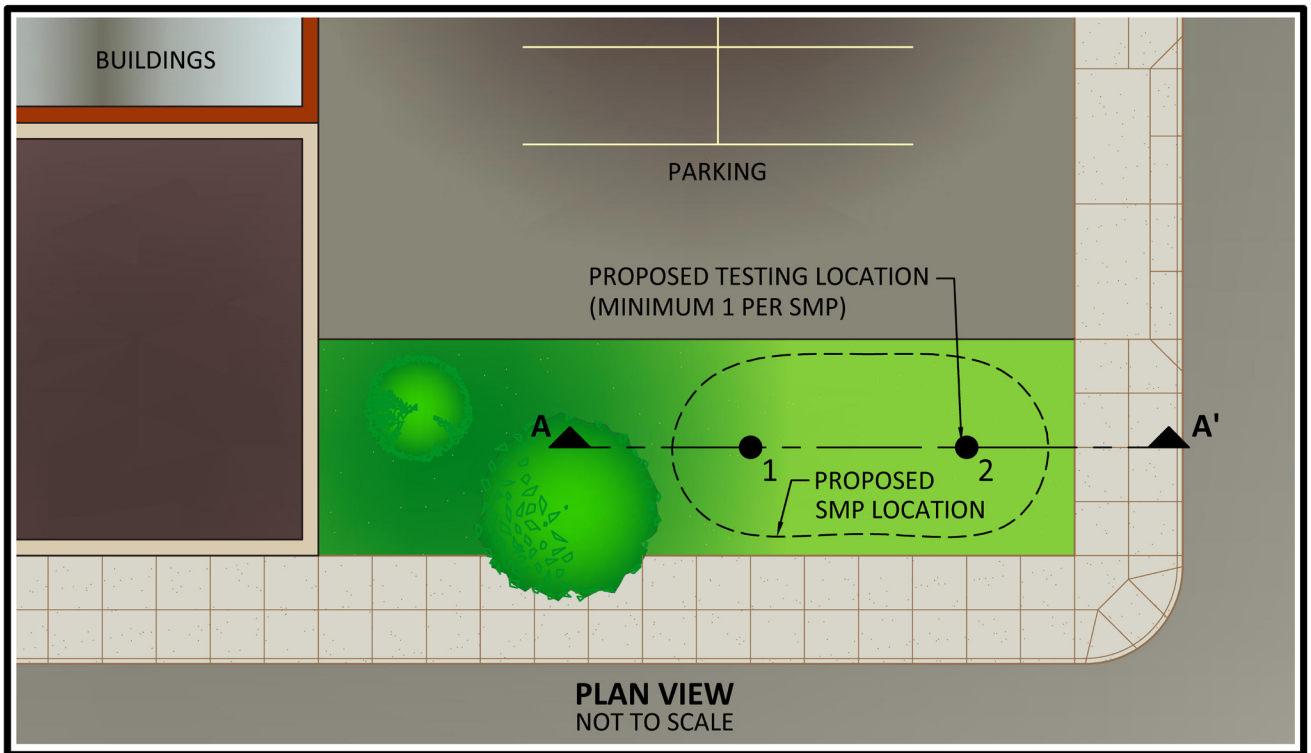
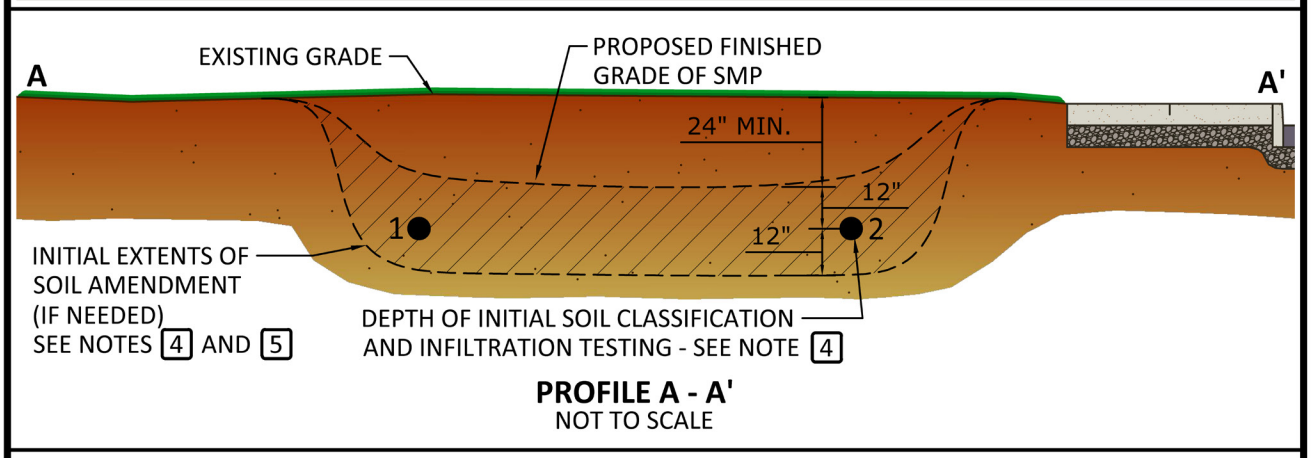
SEDIMENT TRAP SUMP COM-A.8





NOTES

1. ALL INFILTRATION SMPS REQUIRE SOIL INFILTRATION TESTING AND PROFILING / CLASSIFICATION BEFORE CONSTRUCTION. A MINIMUM OF TWO TESTING LOCATIONS ARE REQUIRED FOR EACH SMP.
2. DOUBLE-RING INFILTROMETER TESTING METHODOLOGY IS RECOMMENDED.
3. PROFILING / CLASSIFICATION SHOULD INCLUDE SOIL DESCRIPTIONS, DEPTH TO GROUNDWATER, AND ESTIMATED DEPTH TO SEASONALLY HIGH GROUNDWATER TABLE.
4. INITIAL TESTING SHOULD BE DONE 12" BELOW THE PROPOSED BOTTOM OF THE SMP. IF LOCATIONS 1 AND 2 BOTH SHOW INFILTRATION RATES LESS THAN 0.5 IN/HR OR GREATER THAN 10 IN/HR, SOIL MUST BE AMENDED TO A DEPTH OF 24" BELOW THE PROPOSED BOTTOM OF THE SMP.
5. AFTER SOIL IS AMENDED, TWO ADDITIONAL INFILTRATION TESTS SHOULD BE PERFORMED WITHIN THE AMENDED SOIL LAYER TO CONFIRM RATE IS SUFFICIENT.

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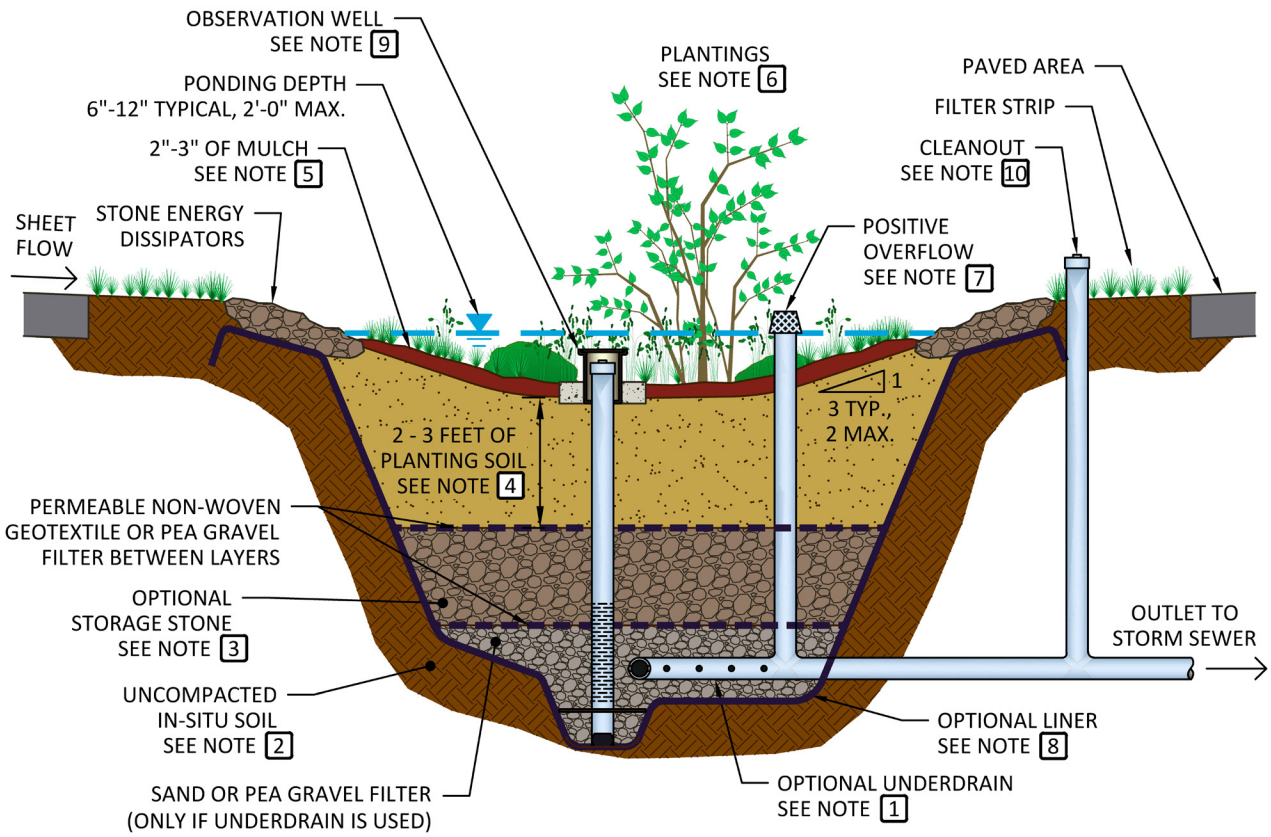
SOIL PROFILING AND INFILTRATION TESTING PROTOCOL

REQ-A.1



NOTES

1. UNDERDRAIN SHOULD BE USED WHEN INFILTRATION IS NOT FEASIBLE OR WHEN A BACKUP SYSTEM IS DESIRED. REFER TO UNDERDRAIN DETAIL SMP-X.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".
2. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE BIORETENTION AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED.
3. STONE MAY BE USED TO INCREASE SUBSURFACE STORAGE VOLUME. IF USED, STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER.
4. PLANTING SOIL MUST COMPLY WITH SWRM SECTION 4.2, "BIORETENTION," SUBSECTION "VEGETATION AND MATERIALS".
5. MULCH SHALL BE ORGANIC AND WEED-FREE. SEE SWRM SECTION 4.1 FOR APPROVED MATERIALS AND ADDITIONAL REQUIREMENTS.
6. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS.
7. A POSITIVE OVERFLOW MUST BE PROVIDED AT THE MAXIMUM PONDING DEPTH FOR LARGER RAIN EVENTS. REFER TO SWRM SECTION 4.1.
8. WHEN INFILTRATION MUST BE AVOIDED, SIDES AND BOTTOM OF THE EXCAVATION SHALL BE LINED WITH AN IMPERMEABLE LINER.
9. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE AT LEAST ONE OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER INFILTRATION PERFORMANCE. REFER TO DETAIL COM-A.1, "OBSERVATION WELL".
10. IF UNDERDRAIN OR OVERFLOW PIPE IS USED, A CLEANOUT MUST BE PROVIDED. REFER TO DETAIL COM-A.2.

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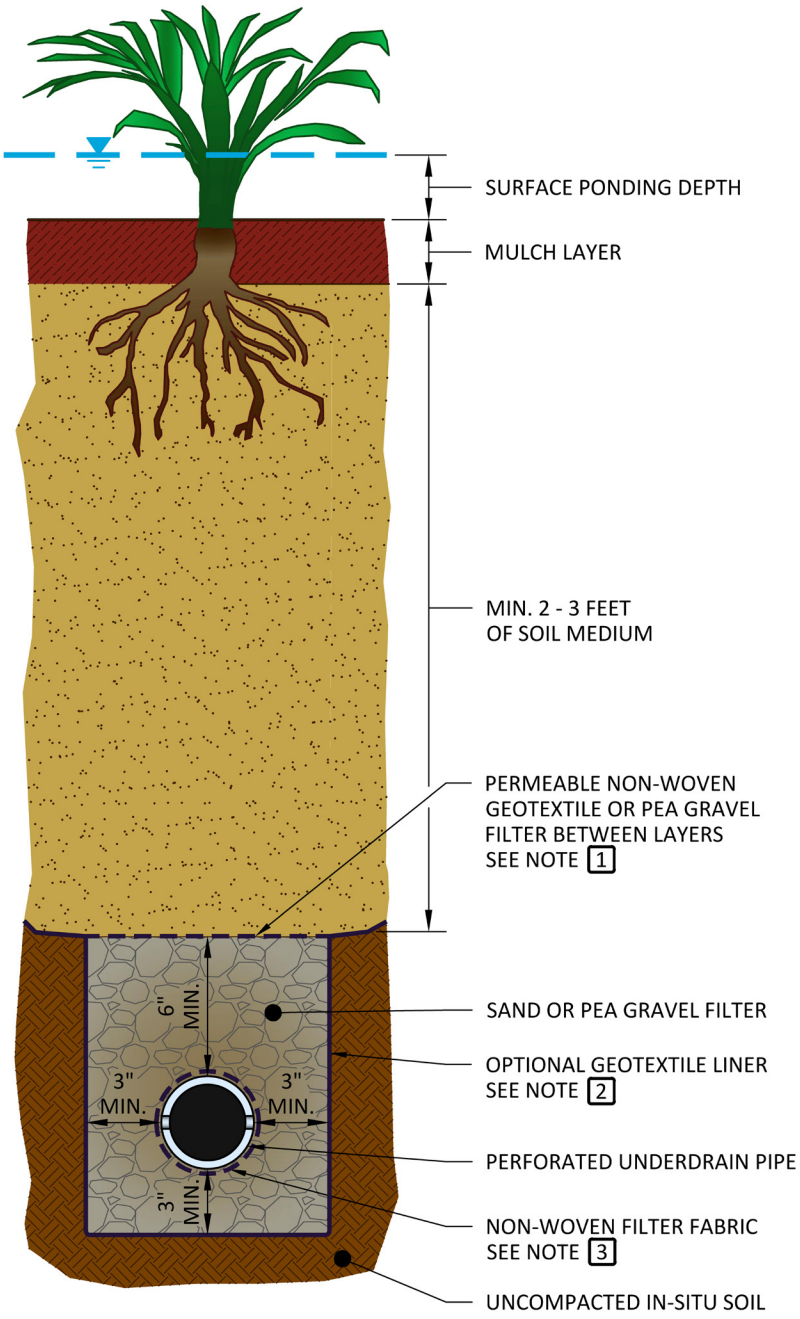
BIORETENTION SMP-4.2.1

NOTES

1. A PERMEABLE NON-WOVEN GEOTEXTILE OR PEA GRAVEL FILTER SHALL BE PLACED ABOVE THE SAND OR GRAVEL FILTER TO MAINTAIN SEPARATION FROM THE LAYER ABOVE.
2. IN AREAS WHERE INFILTRATION IS NOT FEASIBLE OR IS TO BE AVOIDED, AN IMPERVIOUS LINER SHALL BE USED. REFER TO BIORETENTION DETAIL SMP-4.2.1.
3. IF SAND FILTER IS USED, WRAP NON-WOVEN FILTER FABRIC AROUND PIPE TO PREVENT CLOGGING.



Stormwater Retrofit Manual — **SMP Design Details**

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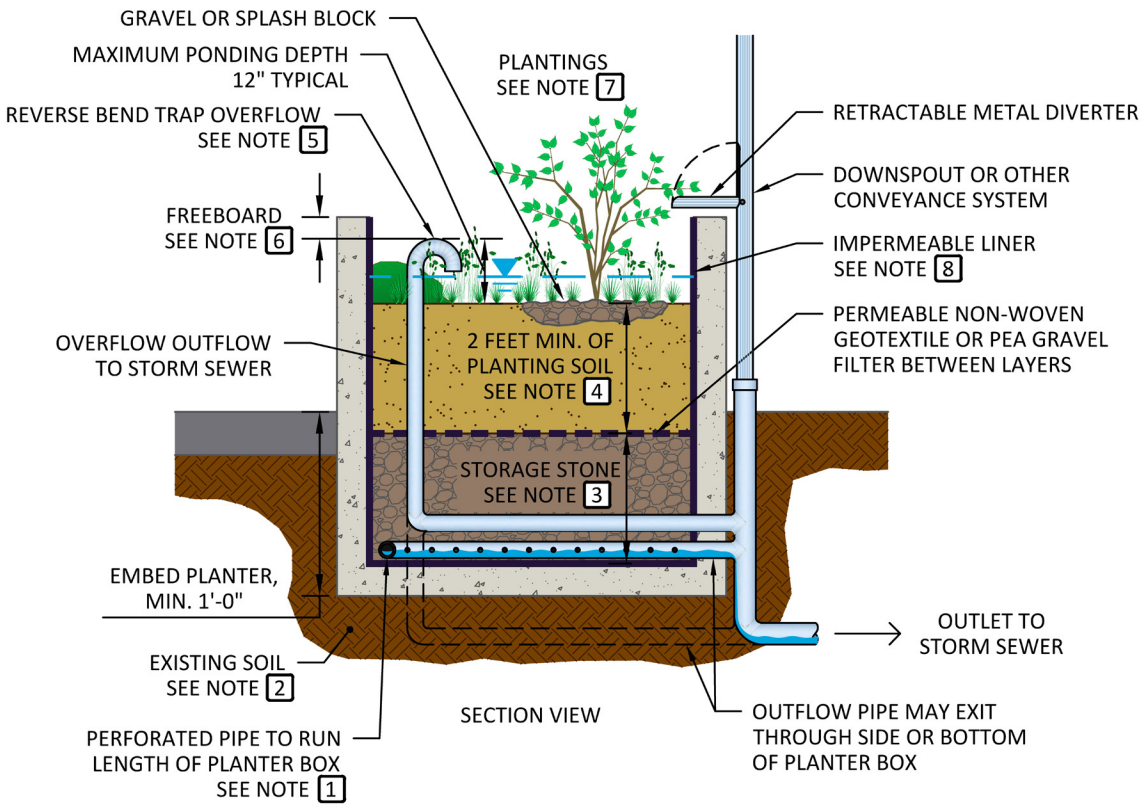
UNDERDRAIN

SMP-4.2.2



NOTES

1. UNDERDRAIN SHOULD BE USED. REFER TO UNDERDRAIN DETAIL SMP-X.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".
2. PLANTER BOX SHOULD BE EMBEDDED A MINIMUM OF 1'-0" BELOW GRADE. MATERIALS BENEATH PLANTER BOX SHOULD BE EVALUATED FOR BEARING CAPACITY, SUSCEPTIBILITY TO FREEZE AND THAW, ETC.
3. STONE MAY BE USED TO INCREASE SUBSURFACE STORAGE VOLUME. IF USED, STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER.
4. PLANTING SOIL MUST COMPLY WITH SWRM SECTION 4.1, "COMMON COMPONENTS".
5. A POSITIVE OVERFLOW MUST BE PROVIDED AT THE MAXIMUM PONDING DEPTH FOR LARGER RAIN EVENTS. REFER TO SWRM SECTION 4.1.
6. PROVIDING FREEBOARD ABOVE THE OVERFLOW TO MINIMIZE OVERTOPPING EVENTS IS A GOOD DESIGN PRACTICE.
7. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS.
8. SIDES AND BOTTOM OF THE PLANTER BOX SHALL BE LINED WITH AN IMPERMEABLE LINER.

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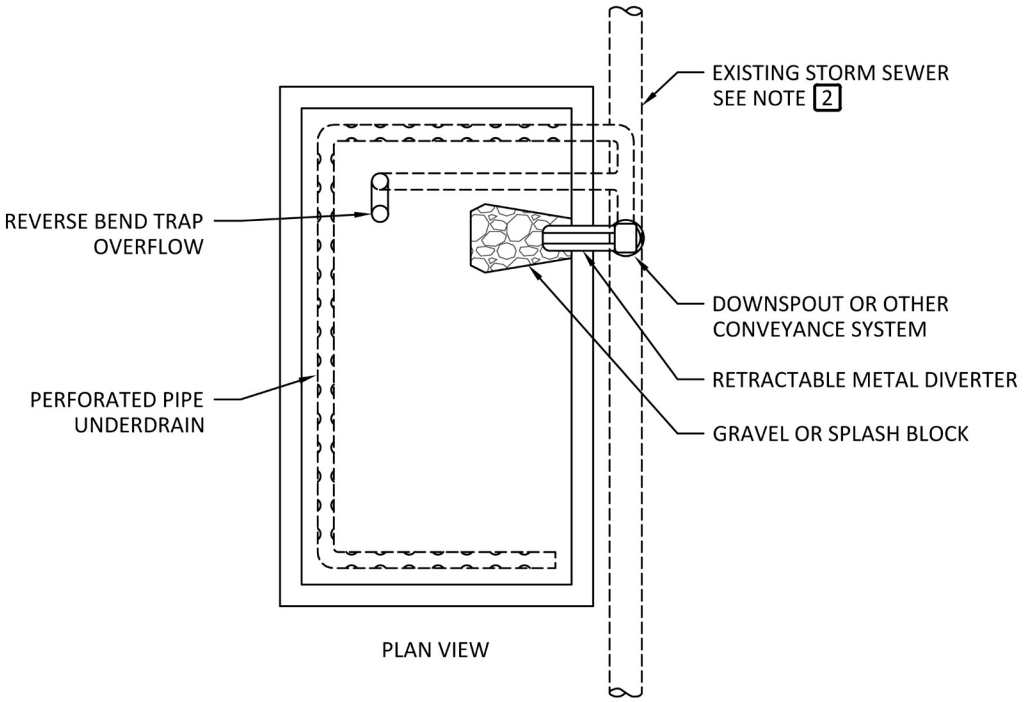
FLOW THROUGH PLANTER
VIEW 1 OF 2

SMP-4.2.3



NOTES

1. PLAN VIEW IS A GENERAL GUIDE TO LAYOUT OF PLANTER BOX. COMPONENT LOCATIONS MAY VARY FROM WHAT IS SHOWN HERE.
2. ATTEMPT TO REUSE EXISTING CONNECTION TO STORM SEWER WHEN POSSIBLE.

Stormwater Retrofit Manual ***SMP Design Details***

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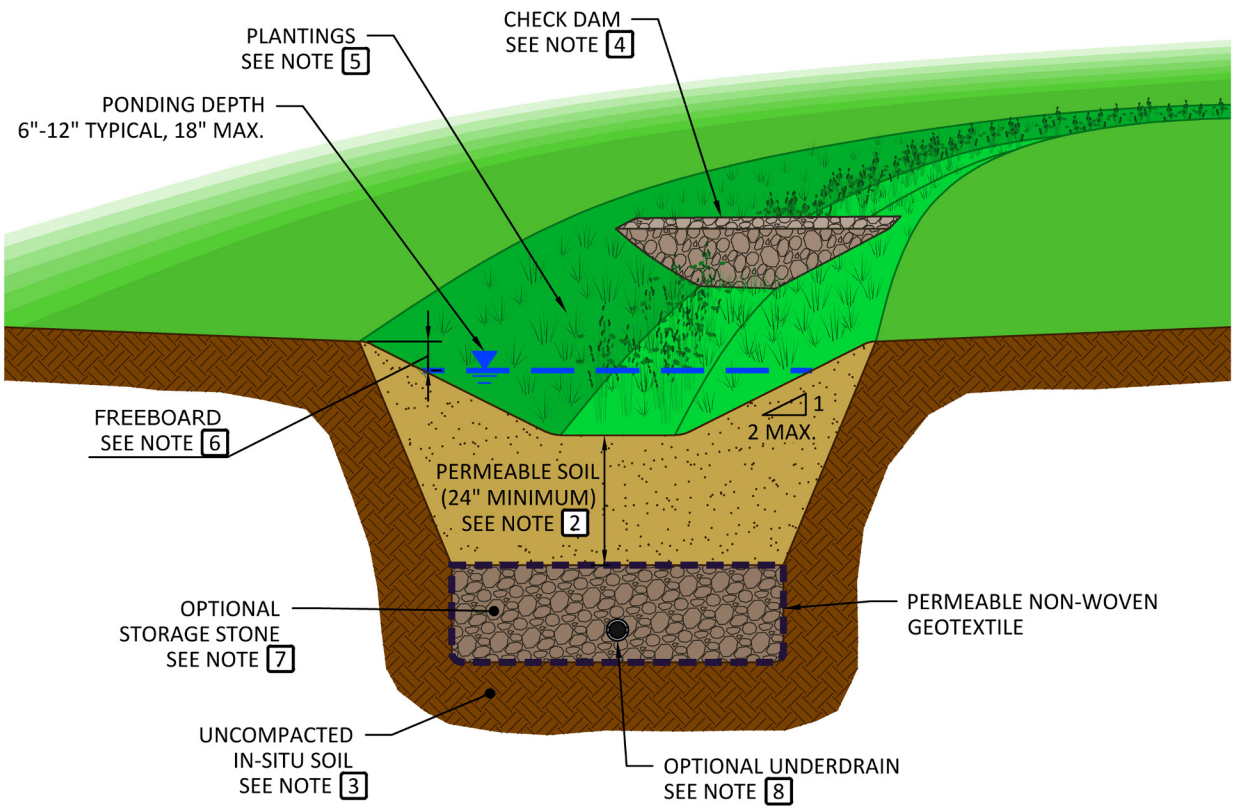
FLOW THROUGH PLANTER
VIEW 2 OF 2

SMP-4.2.4



NOTES

1. THE SLOPE, CROSS SECTION, PLANTINGS, CHECK DAMS (IF USED), AND UNDERDRAIN (IF USED) MUST ALL BE DESIGNED TO ENSURE THAT THE SWALE PERFORMS AS INTENDED. REFER TO SWRM SECTION 4.3, "SWALES", FOR SPECIFIC DESIGN REQUIREMENTS.

2. THE TOP 24 INCHES OF SOIL WITHIN THE SWALE MUST HAVE A MINIMUM INFILTRATION RATE OF 0.5 INCH PER HOUR. THE LEVEL OF ORGANIC MATERIAL MUST BE SUFFICIENT FOR ESTABLISHMENT OF DENSE AND HEALTHY VEGETATION. IF SWALE IS CUT INTO EXISTING SOILS, TOPSOIL SHALL BE ROTOTILLED INTO THE SUBGRADE, AND THE SOIL THEN DISKED PRIOR TO FINAL GRADING OF THE TOPSOIL. ADDITIONAL SOIL AMENDMENTS MAY BE NECESSARY. REFER TO SWRM SECTION 4.3, "SWALES," SUBSECTION "VEGETATION AND MATERIALS".

3. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE SWALE AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED.

4. CHECK DAMS MAY BE USED TO ATTENUATE FLOW VELOCITY, AND TO CREATE PONDING TO ENHANCE INFILTRATION. REFER TO SWRM SECTION 4.3.

5. A BIOSWALE SHOULD SUPPORT A DENSE GROWTH OF NATIVE VEGETATION. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS.

6. IF POSSIBLE, THE SWALE SHOULD BE DESIGNED TO PASS LARGER RAIN EVENTS WITH FREEBOARD REMAINING. PROVIDING A POSITIVE OVERFLOW IS GOOD DESIGN PRACTICE. REFER TO SWRM SECTION 4.1.

7. STONE MAY BE USED TO INCREASE SUBSURFACE STORAGE VOLUME. IF USED, STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER. IT IS PREFERRED FOR THE BOTTOM OF THE STONE BED TO BE FLAT AND LEVEL, BUT A SERIES OF FLAT TERRACES MAY BE USED INSTEAD.

8. UNDERDRAIN SHOULD BE CONSIDERED WITH REFERENCE TO SWALE PERFORMANCE CRITERIA, SUCH AS INFILTRATION RATES AND DEWATERING TIME. REFER TO UNDERDRAIN DETAIL SMP-4.2.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

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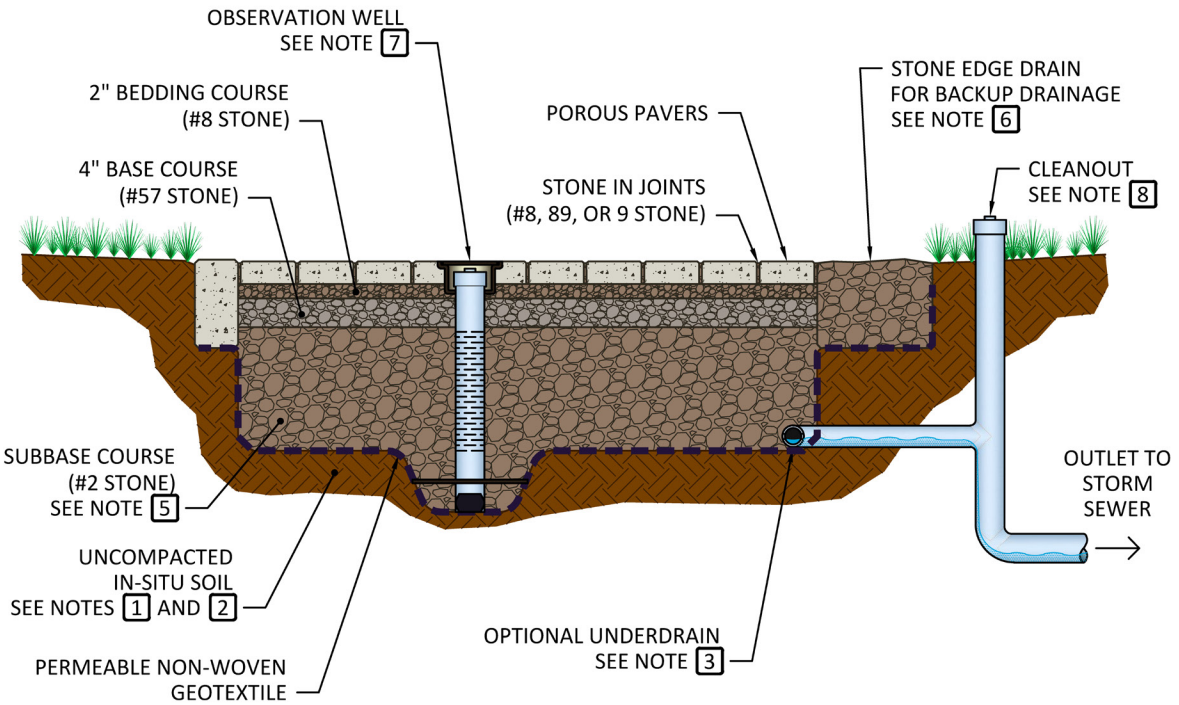
SWALE

SMP-4.3.1



NOTES

1. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE SMP AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED.

2. THE SUBGRADE SHALL BE LEVEL (EXCEPT WHEN UNDERDRAIN IS USED), SMOOTH, AND FREE OF PONDING AND COMPACTION. WHEN UNDERDRAIN IS USED, SUBGRADE SOIL SHOULD BE SLOPED TO DRAIN (1 - 2%). WHEN FINISHED GRADE IS TO BE SLOPED, SUBGRADE MAY BE SHAPED IN FLAT TERRACES ALONG FINISHED GRADE CONTOUR.

3. UNDERDRAIN SHOULD BE USED WHEN INFILTRATION IS NOT FEASIBLE OR WHEN A BACKUP SYSTEM IS DESIRED. REFER TO UNDERDRAIN DETAIL SMP-4.2.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

4. A POSITIVE OVERFLOW MUST BE PROVIDED WHEN THIS SMP MANAGES ADDITIONAL IMPERVIOUS AREA. WATER WITHIN THE SUBSURFACE STONE BED SHOULD NEVER RISE TO THE LEVEL OF THE PAVEMENT SURFACE. REFER TO STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

5. SUBBASE STONE SHALL MEET AASHTO NO. 2 SPECIFICATIONS. MINIMUM THICKNESS IN PEDESTRIAN AREAS SHALL BE 6". IN VEHICLE AREAS, THICKNESS SHALL BE DETERMINED BY PAVEMENT DESIGN. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER. SUBBASE STONE SHOULD BE PLACED IN LIFTS AND LIGHTLY ROLLED IN ACCORDANCE WITH THE SPECIFICATIONS.

6. ALL POROUS PAVEMENT INSTALLATIONS SHOULD HAVE A BACKUP METHOD FOR WATER TO ENTER THE STONE STORAGE BED. IN UNCURBED LOTS, THIS MAY CONSIST OF AN UNPAVED 2 FOOT WIDE STONE EDGE DRAIN CONNECTED DIRECTLY TO THE BED. IN CURBED LOTS, INLETS WITH WATER QUALITY DEVICES MAY BE REQUIRED AT LOW SPOTS.

7. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE AT LEAST ONE OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER INFILTRATION PERFORMANCE. REFER TO DETAIL COM-A.1, "OBSERVATION WELL".

8. IF UNDERDRAIN OR OVERFLOW PIPE IS USED, A CLEANOUT MUST BE PROVIDED. REFER TO DETAIL COM-A.2.

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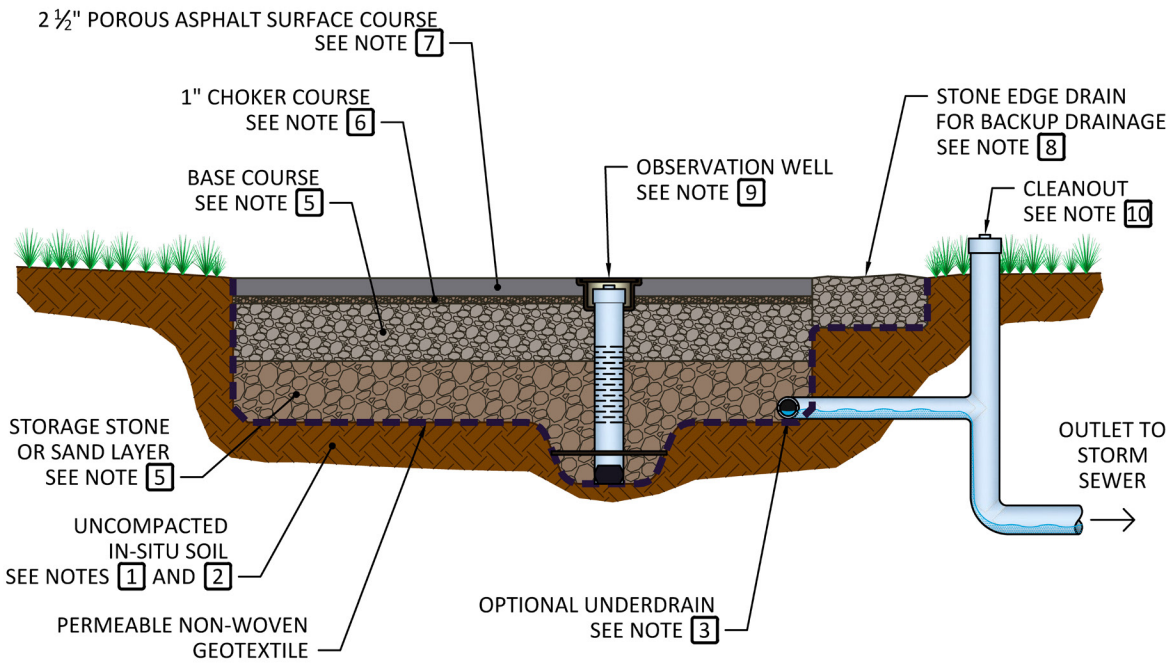
POROUS PAVERS SMP-4.4.1



NOTES

1. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE SMP AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED.

2. THE SUBGRADE SHALL BE LEVEL (EXCEPT WHEN UNDERDRAIN IS USED), SMOOTH, AND FREE OF PONDING AND COMPACTION. WHEN UNDERDRAIN IS USED, SUBGRADE SOIL SHOULD BE SLOPED TO DRAIN (1 - 2%). WHEN FINISHED GRADE IS TO BE SLOPED, SUBGRADE MAY BE EXCAVATED IN FLAT TERRACES ALONG FINISHED GRADE CONTOUR.

3. UNDERDRAIN SHOULD BE USED WHEN INFILTRATION IS NOT FEASIBLE OR WHEN A BACKUP SYSTEM IS DESIRED. REFER TO UNDERDRAIN DETAIL SMP-4.2.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

4. A POSITIVE OVERFLOW MUST BE PROVIDED WHEN THIS SMP MANAGES ADDITIONAL DCIA. WATER WITHIN THE SUBSURFACE STONE BED SHOULD NEVER RISE TO THE LEVEL OF THE PAVEMENT SURFACE. REFER TO STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

5. STORAGE STONE OR SAND LAYER AND BASE COURSE MATERIALS MUST BE COMPATIBLE WITH PAVEMENT DESIGN. STORAGE STONE OR SAND LAYER SHALL HAVE A MINIMUM THICKNESS OF 6". IF A STONE LAYER IS THICKER THAN 6", STONE SHOULD BE PLACED IN LIFTS AND LIGHTLY ROLLED IN ACCORDANCE WITH THE SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER.

6. CHOKER COURSE SHALL BE OF AGGREGATE PER SPECIFICATIONS, INSTALLED AND COMPACTED EVENLY TO ALLOW EVEN PLACEMENT OF ASPHALT. CHOKER COURSE SHOULD NOT EXCEED 1" IN THICKNESS.

7. POROUS ASPHALT SURFACE COURSE SHALL BE LAID IN ONE LIFT AND COMPACTED TO A 2 ½" FINISHED THICKNESS. VEHICLES TRANSPORTING ASPHALT MIX TO THE SITE MUST HAVE SMOOTH, CLEAN DUMP BEDS. COVER ASPHALT MIX TO CONTROL COOLING. ASPHALT MUST NOT BE STORED FOR MORE THAN 90 MINUTES BEFORE PLACEMENT. ASPHALT SHALL BE COMPACTED AFTER THE SURFACE HAS COOLED ENOUGH TO RESIST A 10-TON ROLLER. USE ONLY 1 OR TWO PASSES TO AVOID EXCESSIVE COMPACTION. PREVENT VEHICULAR TRAFFIC UNTIL ASPHALT IS FULLY COOLED AND HARDENED (MINIMUM 48 HOURS).

8. ALL POROUS PAVEMENT INSTALLATIONS SHOULD HAVE A BACKUP METHOD FOR WATER TO ENTER THE STONE STORAGE BED. IN UNCURBED LOTS, THIS MAY CONSIST OF AN UNPAVED 2 FOOT WIDE STONE EDGE DRAIN CONNECTED DIRECTLY TO THE BED. IN CURBED LOTS, INLETS WITH WATER QUALITY DEVICES MAY BE REQUIRED AT LOW SPOTS.

9. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE AT LEAST ONE OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER INFILTRATION PERFORMANCE. REFER TO DETAIL COM-A.1, "OBSERVATION WELL."

10. IF UNDERDRAIN OR OVERFLOW PIPE IS USED, A CLEANOUT MUST BE PROVIDED. REFER TO DETAIL COM-A.2.

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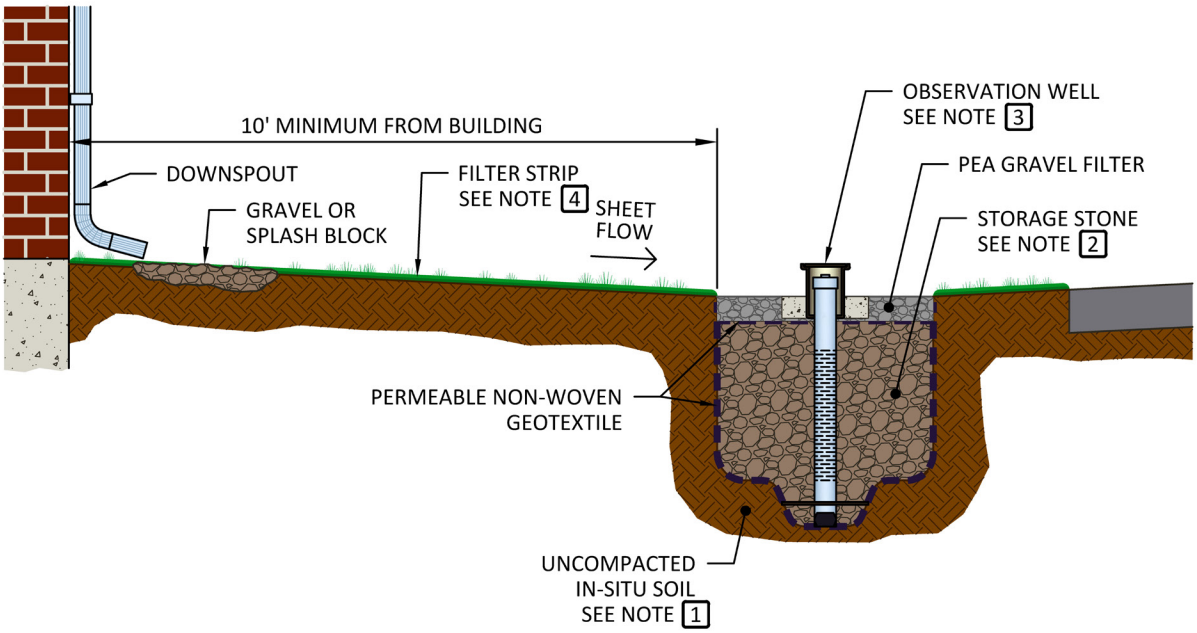
POROUS ASPHALT **SMP-4.4.2**



NOTES

1. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE BIORETENTION AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHOULD BE USED.

2. STORAGE STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER.

3. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE AT LEAST ONE OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER INFILTRATION PERFORMANCE. REFER TO DETAIL COM-A.1, "OBSERVATION WELL".

4. THE FILTER STRIP MUST BE ABLE TO WITHSTAND THE VELOCITY AND QUANTITY OF RUNOFF THAT WILL BE DIRECTED ACROSS IT. SLOPE AND PLANTING SEED MIX SHOULD BE SELECTED TO PREVENT EROSION.

5. REFER TO CITY OF PHILADELPHIA GREEN STREETS DESIGN MANUAL FOR MORE INTENSIVE STORMWATER DRAINAGE WELL DESIGN. SEE CHAPTER 2, P. 36, AND APPENDIX 6.1, DETAIL DW-01.

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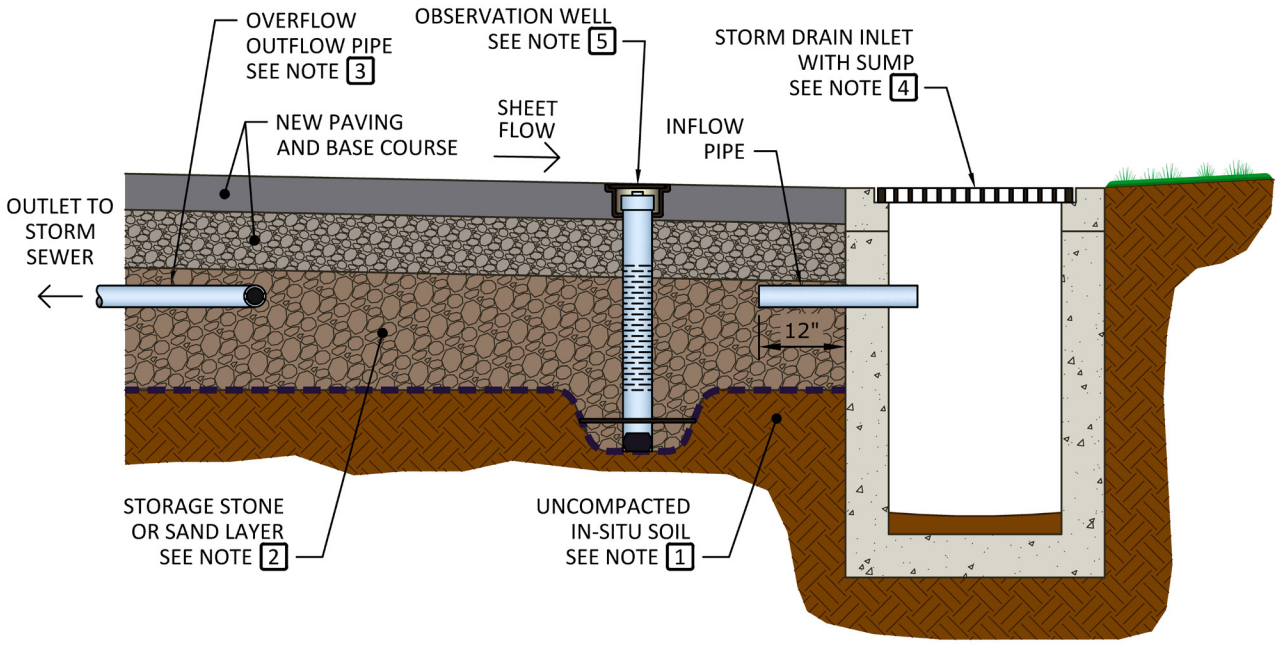
DRY WELL

SMP-4.5.1



NOTES

1. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE SMP AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED. THE SUBGRADE SHALL BE LEVEL (EXCEPT WHEN UNDERDRAIN IS USED), SMOOTH, AND FREE OF PONDING AND COMPACTION.

2. STORAGE STONE OR SAND LAYER SHALL HAVE A MINIMUM THICKNESS OF 6" AND BE COMPATIBLE WITH PAVEMENT DESIGN. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER. IF LAYER IS THICKER THAN 6", SUBBASE STONE SHOULD BE PLACED IN LIFTS AND LIGHTLY ROLLED IN ACCORDANCE WITH THE SPECIFICATIONS.

3. ALL SUBSURFACE INFILTRATION INSTALLATIONS SHOULD BE DESIGNED WITH AN OVERFLOW SYSTEM. WATER WITHIN THE SUBSURFACE STONE BED SHOULD NEVER RISE TO THE LEVEL OF THE PAVEMENT SURFACE. REFER TO STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".

4. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE PRETREATMENT IF ADDITIONAL WATER IS CONVEYED TO THE INFILTRATION BED. SOME SEDIMENT REMOVAL IS PROVIDED BY A SUMP BELOW THE INVERT OF THE PIPE LEADING TO THE INFILTRATION BED. AN INLET FILTER MAY BE CONSIDERED IN LIEU OF A SUMP. IF SITE CONDITIONS PERMIT, SURFACE RUNOFF SHOULD FLOW THROUGH A BIORETENTION AREA OR SIMILAR SMP BEFORE ENTERING THE STORM DRAIN INLET.

5. ALL SUBSURFACE INFILTRATION INSTALLATIONS REQUIRE AT LEAST ONE OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER INFILTRATION PERFORMANCE. REFER TO DETAIL COM-A.1, "OBSERVATION WELL."

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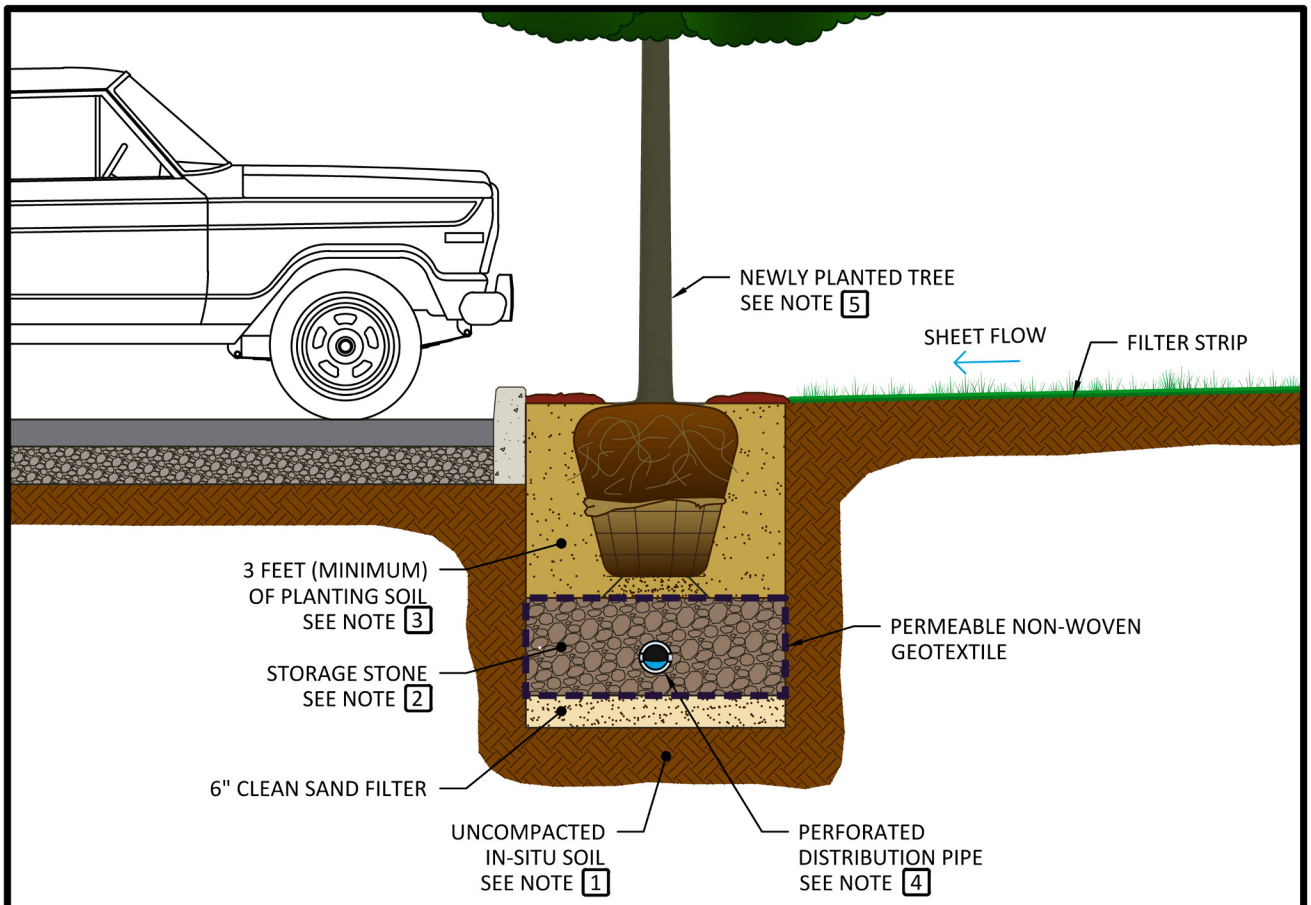
SUBSURFACE INFILTRATION AREA

SMP-4.5.2



NOTES

1. HEAVY EQUIPMENT SHALL NOT BE USED WITHIN THE TREE TRENCH AREA. IF CONSTRUCTION CANNOT BE COMPLETED WITH HAND TOOLS, LOW IMPACT EQUIPMENT SHALL BE USED.
2. STONE MAY BE USED TO INCREASE SUBSURFACE STORAGE VOLUME. IF USED, STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC OR A PEA GRAVEL FILTER.
3. PLANTING SOIL MUST COMPLY WITH SWRM SECTION 4.1, "COMMON COMPONENTS".
4. RUNOFF FROM ANOTHER SMP PROVIDING FILTRATION MAY BE CONVEYED INTO THE TREE TRENCH BY A PERFORATED DISTRIBUTION PIPE. PIPE SHOULD BE LEVEL AND RUN THE LENGTH OF THE TRENCH. REFER TO UNDERDRAIN DETAIL SMP-4.2.2 AND STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.1, "COMMON COMPONENTS".
5. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS.

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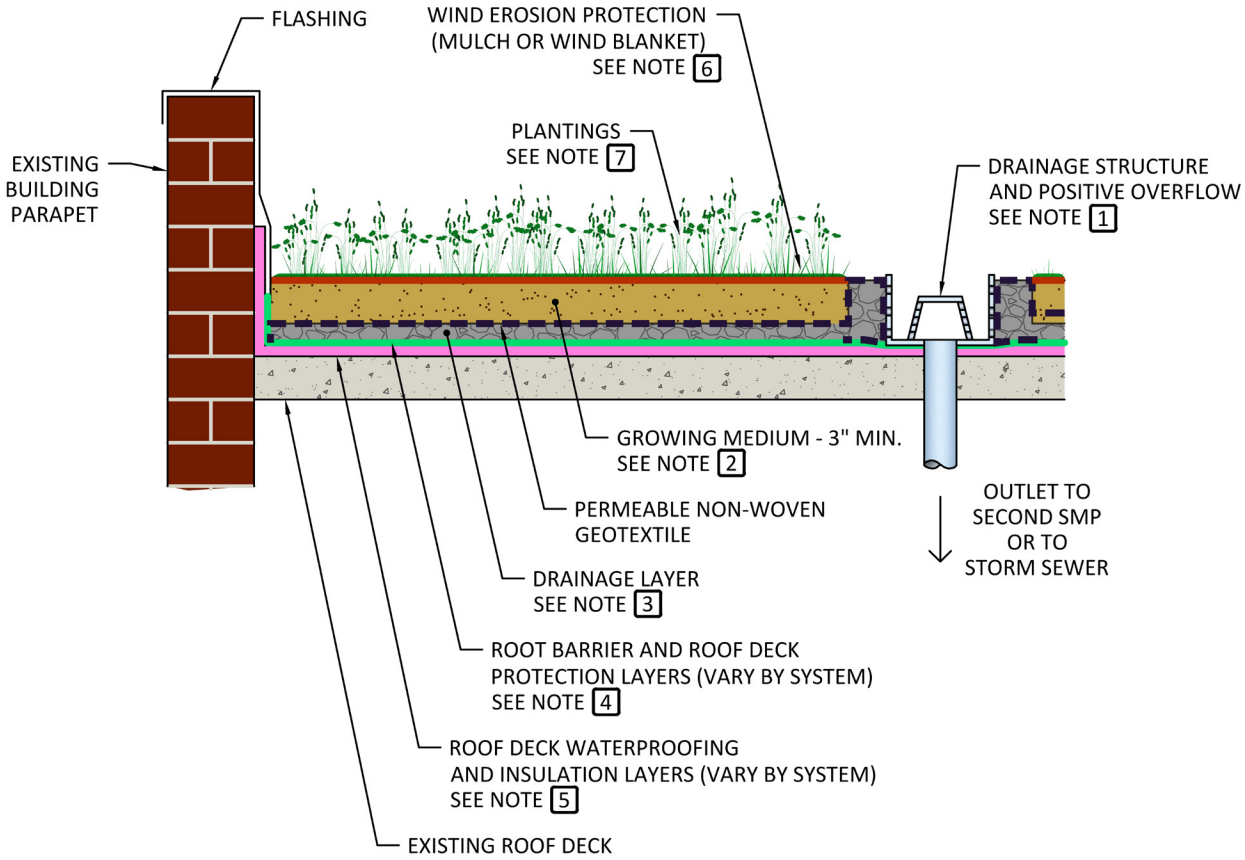
TREE TRENCH SMP-4.7.1



NOTES

1. A POSITIVE OVERFLOW MUST BE PROVIDED FOR LARGER RAIN EVENTS. REFER TO SWRM SECTION 4.1.

2. GROWING MEDIUM MUST COMPLY WITH SWRM SECTION 4.8, "GREEN ROOFS", SUBSECTION "VEGETATION AND MATERIALS".

3. DRAINAGE LAYER STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 8 SPECIFICATIONS. STONE MUST BE SEPARATED FROM SOIL BY A NON-WOVEN FILTER FABRIC.

4. A ROOT BARRIER IS TYPICALLY REQUIRED TO PROTECT WATERPROOFING MEMBRANE FROM ROOT PENETRATION. A SEPARATE PROTECTION LAYER MAY BE REQUIRED TO PROTECT AGAINST PUNCTURES AND ABRASION. CONSULT MANUFACTURER OF GREEN ROOF SYSTEM FOR SPECIFIC REQUIREMENTS.

5. THE WATERPROOFING MEMBRANE IS CRITICALLY IMPORTANT. IT MUST BE COMPLETELY WATERPROOF AND HAVE A LIFE SPAN AT LEAST AS LONG AS THE OTHER GREEN ROOF COMPONENTS. WATERPROOFING MEMBRANE MUST BE PROTECTED FROM DAMAGE DURING TRANSPORT AND INSTALLATION. AFTER INSTALLATION, MEMBRANE MUST BE FULLY INSPECTED AND LEAK TESTED. MEMBRANE MUST BE PROTECTED DURING PLACEMENT OF SUBSEQUENT LAYERS OF THE GREEN ROOF SYSTEM. AFTER GREEN ROOF CONSTRUCTION IS COMPLETE, THE COMPLETE SYSTEM MUST BE RE-TESTED FOR LEAKS. CONSULT MANUFACTURER OF GREEN ROOF SYSTEM FOR SPECIFIC SYSTEM REQUIREMENTS.

6. WIND EROSION PROTECTION IS REQUIRED TO PREVENT LOSS OF GROWING MEDIUM AND PLANTS BEFORE VEGETATIVE COVER IS FULLY ESTABLISHED. A LAYER OF MULCH OR A WIND BLANKET MAY BE USED.

7. ONLY CERTAIN PLANTINGS ARE APPROPRIATE FOR EXTENSIVE GREEN ROOF SYSTEMS. TYPICAL PLANTINGS INCLUDE SEDUM, HERBS, AND PERENNIALS. CONSULT MANUFACTURER OF GREEN ROOF SYSTEM FOR SPECIFIC SYSTEM REQUIREMENTS.

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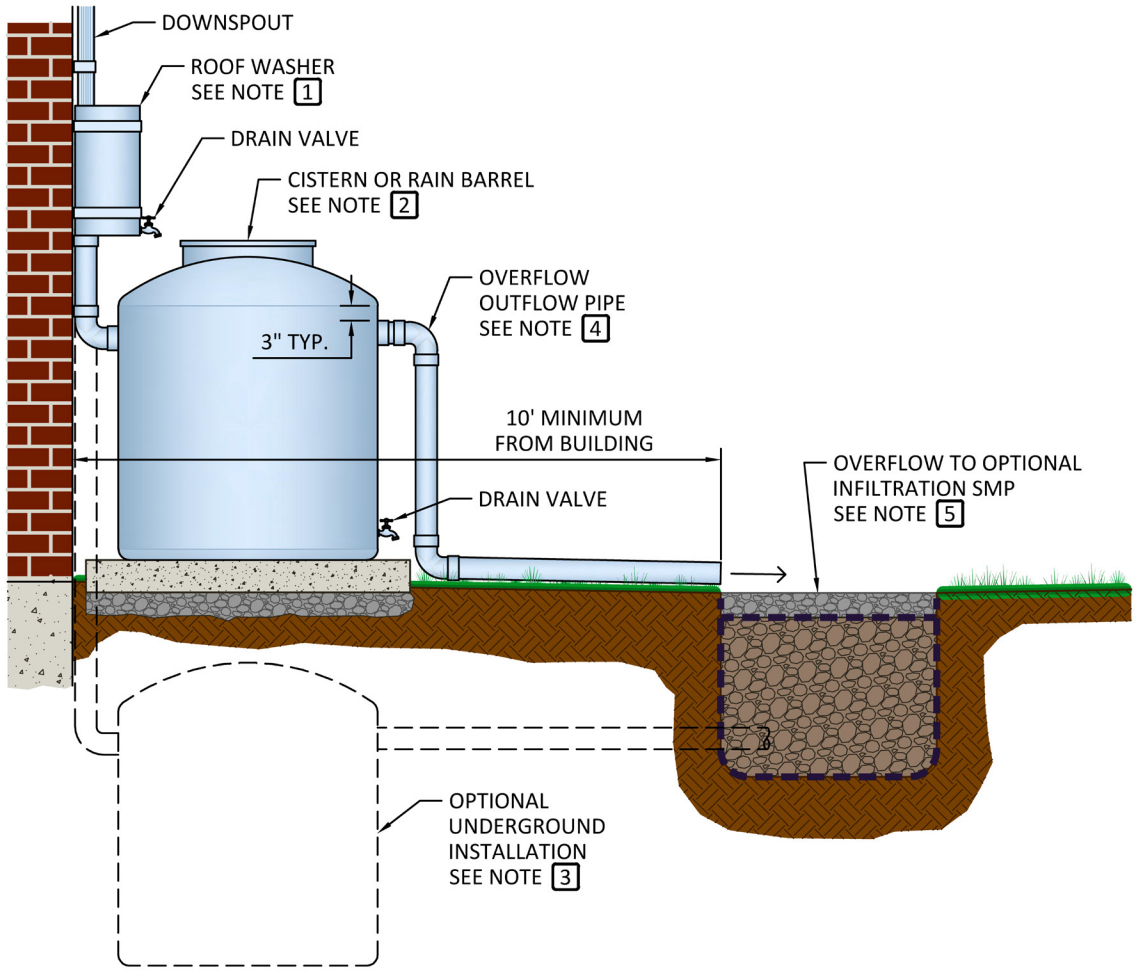
GREEN ROOF - EXTENSIVE **SMP-4.8**



NOTES

1. A ROOF WASHER IS REQUIRED IN ORDER TO DIVERT AND CAPTURE THE FIRST FLUSH OF ROOF RUNOFF, AND TO FILTER THE SUBSEQUENT RUNOFF THAT WILL ENTER THE CISTERN. A ROOF WASHER SHOULD PROVIDE APPROXIMATELY 10 GALLONS OF HOLDING CAPACITY FOR EACH 1,000 SQUARE FEET OF CATCHMENT AREA.

2. ROOF RUNOFF COLLECTION CISTERNS MAY VARY IN SIZE FROM RAIN BARRELS TO LARGE TANKS. SIZING WILL BE INFLUENCED BY THE SIZE OF THE ROOF CATCHMENT AREA, AS WELL AS THE POTENTIAL DEMAND FOR REUSE OF THE CAPTURED RUNOFF. FOUNDATION PAD MAY BE REQUIRED BASED ON THE SIZE OF THE CISTERN. INSTALLATION MUST COMPLY WITH MANUFACTURER'S SPECIFICATIONS. CISTERNS MUST HAVE TIGHT-FITTING COVERS TO EXCLUDE DEBRIS AND DISCOURAGE INSECT BREEDING.

3. CISTERNS MAY BE INSTALLED BELOW GRADE, IF A CISTERN DESIGNED FOR UNDERGROUND USE IS SELECTED. SPECIAL INSTALLATION REQUIREMENTS APPLY. INSTALLATION MUST COMPLY WITH MANUFACTURER'S SPECIFICATIONS.

4. AN OVERFLOW MUST BE PROVIDED FOR LARGER RAIN EVENTS. REFER TO SWRM SECTION 4.1.

5. OVERFLOW FROM THE CISTERN MAY BE DIRECTED TO SUPPLEMENTAL STORAGE TANKS, TO INFILTRATION SMPS, OR TO THE SEWER SYSTEM.

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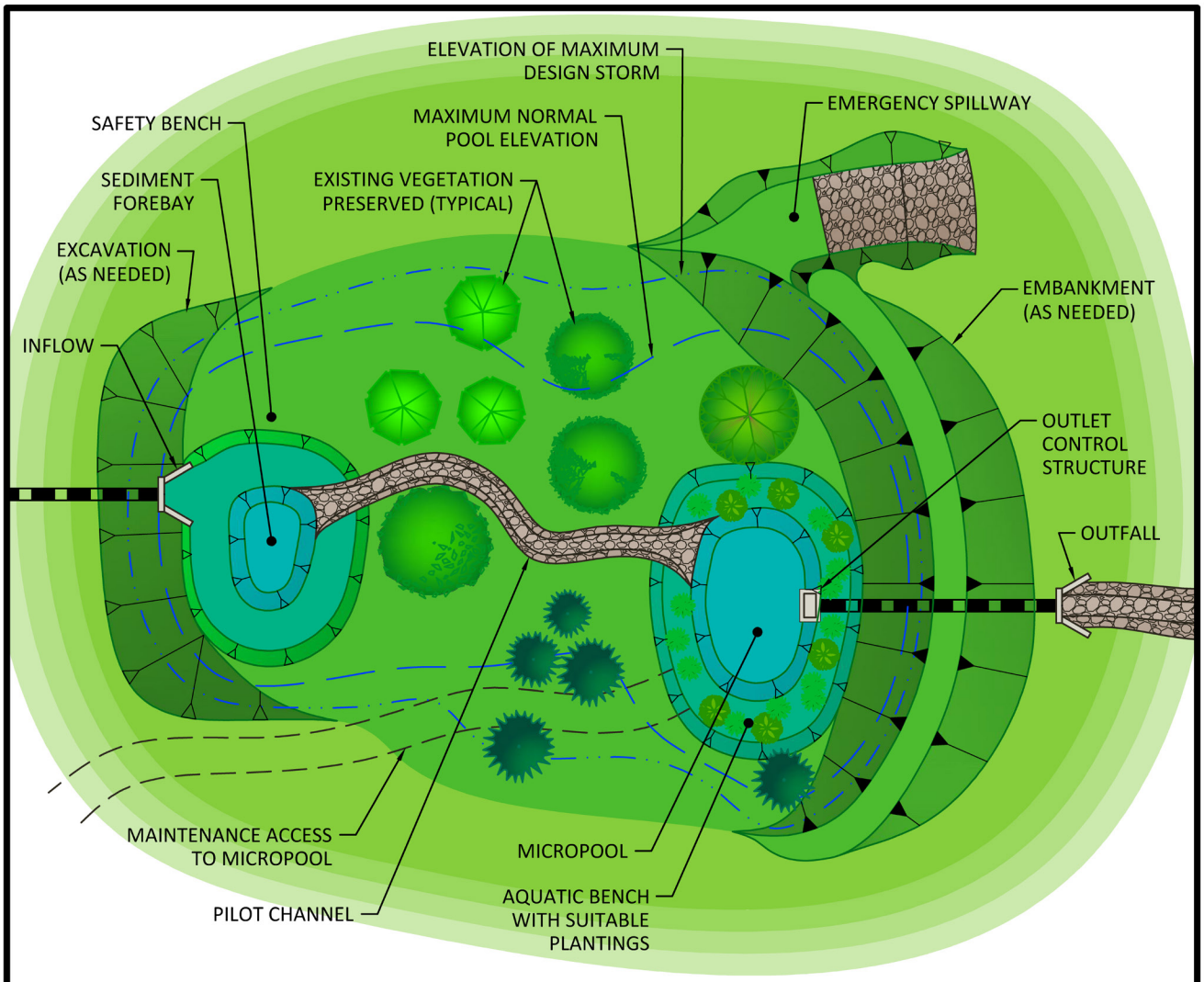
ROOF RUNOFF COLLECTION CISTERN

SMP-4.9.1



NOTES

1. THE EXTENDED DETENTION BASIN CAN BE CONSTRUCTED BY IMPOUNDING A NATURAL DEPRESSION (WITH A FILL EMBANKMENT) OR BY EXCAVATION OF EXISTING SOIL. EARTH DISTURBANCE SHOULD BE LIMITED TO THE MINIMUM EXTENT PRACTICABLE. AVOID COMPACTION OF EXISTING SOIL BY USING LOW-IMPACT EQUIPMENT. IF SOIL BECOMES COMPACTED, IT SHOULD BE RESTORED BY APPROPRIATE AMENDMENT.
2. EXISTING VEGETATION SHOULD BE PRESERVED TO THE MAXIMUM EXTENT PRACTICABLE. IT IS RECOMMENDED TO ADD DIVERSE NATIVE PLANTINGS TO SUPPLEMENT EXISTING VEGETATION. PLANTINGS SHOULD BE MOISTURE-TOLERANT. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS. DO NOT USE FERTILIZERS AND PESTICIDES WHEN PLANTING.
3. SEDIMENT FOREBAY OR EQUIVALENT UPSTREAM PRETREATMENT IS RECOMMENDED.
4. A MICROPOOL STORAGE AREA SHOULD BE PROVIDED WHERE FEASIBLE FOR ADDITIONAL WATER QUALITY IMPROVEMENT AND BIODIVERSITY.
5. FLOW PATHS FROM INFLOW TO OUTLET SHOULD BE MAXIMIZED.
6. OUTFALL AND EMERGENCY SPILLWAY MUST BE PROVIDED WITH SUFFICIENT PROTECTION AGAINST EROSION. REFER TO SECTION 4.1, "COMMON COMPONENTS".
7. SUBSURFACE EXTENDED DETENTION IS OPTIONAL FOR HIGHLY URBAN SITES. REFER TO SECTION 4.10.

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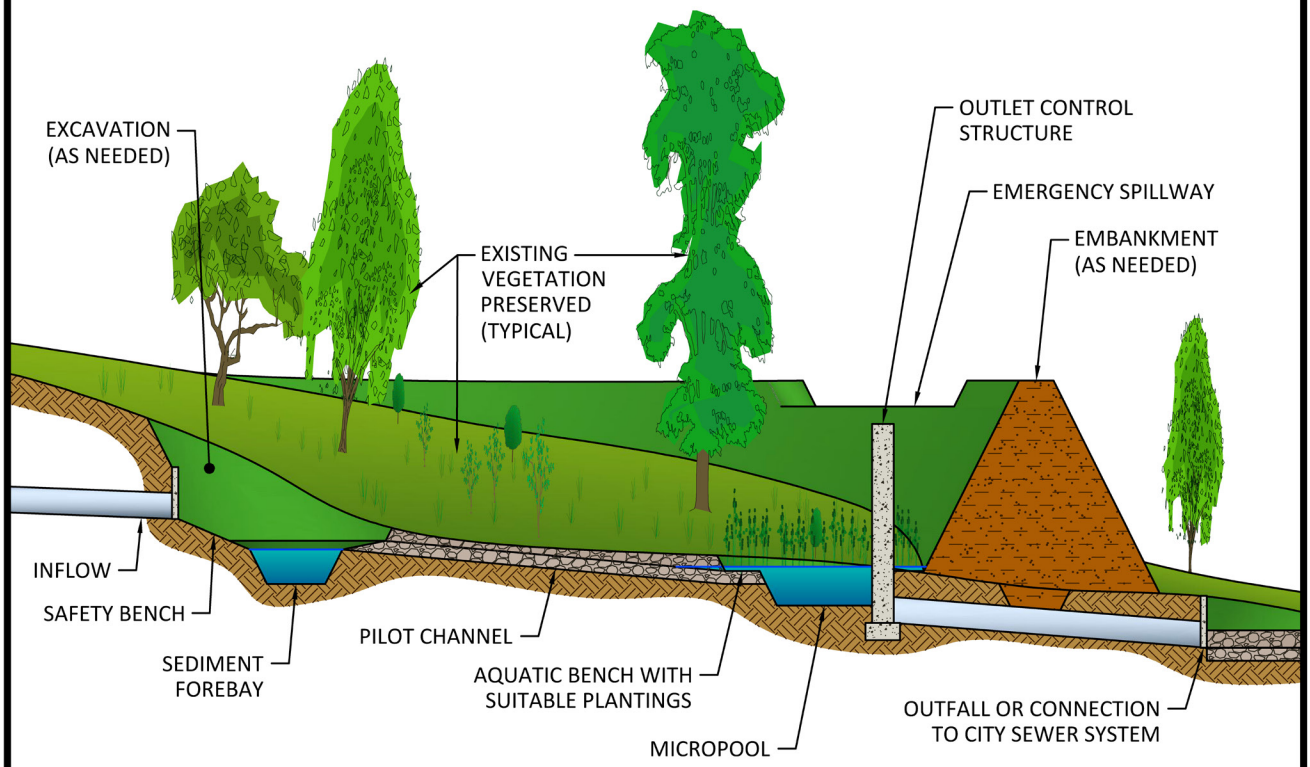
EXTENDED DETENTION BASIN - PLAN VIEW

SMP-4.10.1



PROFILE VIEW (VERTICALLY EXAGGERATED)

NOTES

1. THE EXTENDED DETENTION BASIN CAN BE CONSTRUCTED BY IMPOUNDING A NATURAL DEPRESSION (WITH A FILL EMBANKMENT) OR BY EXCAVATION OF EXISTING SOIL. EARTH DISTURBANCE SHOULD BE LIMITED TO THE MINIMUM EXTENT PRACTICABLE. AVOID COMPACTION OF EXISTING SOIL BY USING LOW-IMPACT EQUIPMENT. IF SOIL BECOMES COMPACTED, IT SHOULD BE RESTORED BY APPROPRIATE AMENDMENT.
2. EXISTING VEGETATION SHOULD BE PRESERVED TO THE MAXIMUM EXTENT PRACTICABLE. IT IS RECOMMENDED TO ADD DIVERSE NATIVE PLANTINGS TO SUPPLEMENT EXISTING VEGETATION. PLANTINGS SHOULD BE MOISTURE-TOLERANT. REFER TO SWRM SECTION 4.1 AND APPENDIX 2 FOR PLANTING REQUIREMENTS. DO NOT USE FERTILIZERS AND PESTICIDES WHEN PLANTING.
3. SEDIMENT FOREBAY OR EQUIVALENT UPSTREAM PRETREATMENT IS RECOMMENDED.
4. A MICROPOOL STORAGE AREA SHOULD BE PROVIDED WHERE FEASIBLE FOR ADDITIONAL WATER QUALITY IMPROVEMENT AND BIODIVERSITY.
5. FLOW PATHS FROM INFLOW TO OUTLET SHOULD BE MAXIMIZED.
6. OUTFALL AND EMERGENCY SPILLWAY MUST BE PROVIDED WITH SUFFICIENT PROTECTION AGAINST EROSION. REFER TO SECTION 4.1, "COMMON COMPONENTS".
7. SUBSURFACE EXTENDED DETENTION IS OPTIONAL FOR HIGHLY URBAN SITES. REFER TO SECTION 4.10.

Stormwater Retrofit Manual ***SMP Design Details***

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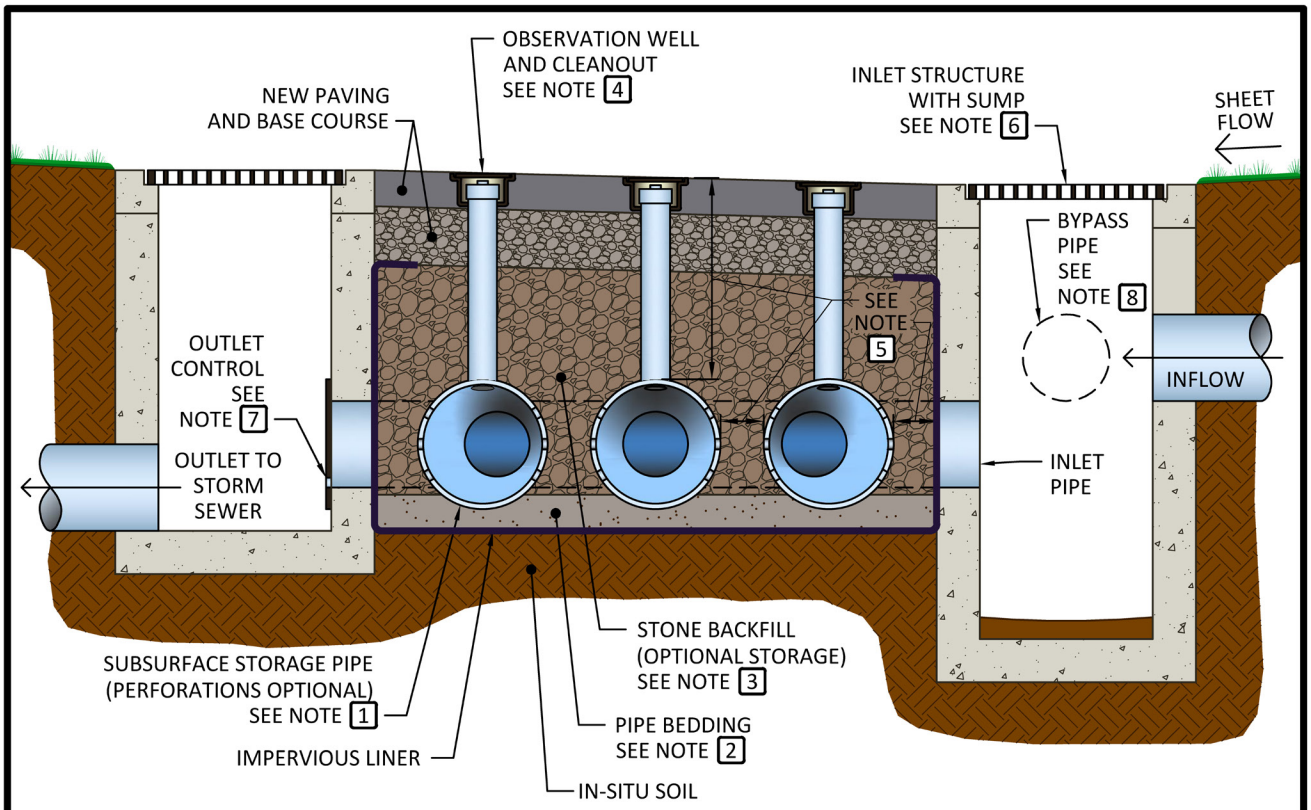
EXTENDED DETENTION BASIN - PROFILE VIEW

SMP-4.10.2



NOTES

1. SUBSURFACE DETENTION VOLUME MAY BE PROVIDED BY ROUND PIPES, ARCHED PIPES, MODULAR CHAMBER SYSTEMS, OR OTHER APPROVED METHODS. REFER TO STORMWATER RETROFIT MANUAL (SWRM) SECTION 4.10. THE SYSTEM MAY BE SEALED AGAINST SURROUNDING BACKFILL, OR MAY HAVE PERFORATIONS TO ALLOW SURROUNDING BACKFILL TO BE USED FOR ADDITIONAL DETENTION VOLUME.

2. PIPE BEDDING SHALL BE OF COMPACTED SAND OR OTHER APPROVED GRANULAR MATERIAL. REFER TO PIPE MANUFACTURER'S RECOMMENDATIONS TO ENSURE COMPATIBILITY WITH PIPE.

3. BACKFILL MATERIAL MAY OPTIONALLY BE USED TO PROVIDE ADDITIONAL DETENTION VOLUME / STORAGE. IF USED, STONE SHALL BE UNIFORMLY GRADED, CRUSHED, WASHED STONE MEETING AASHTO NO. 3 OR NO. 5 SPECIFICATIONS. REFER TO PIPE MANUFACTURER'S RECOMMENDATIONS TO ENSURE COMPATIBILITY WITH PIPE.

4. ALL SUBSURFACE DETENTION PIPES MUST BE SERVED BY A CLEANOUT. THIS CLEANOUT CAN ALSO SERVE AS AN OBSERVATION WELL. THE WELL WILL ALLOW PERIODIC INSPECTION TO ENSURE PROPER PERFORMANCE. REFER TO DETAILS COM-A.1, "OBSERVATION WELL" AND COM-A.2, "CLEANOUT".

5. THE REQUIRED PIPE COVER AND SPACING BETWEEN PIPES SHALL BE DETERMINED BY PIPE SIZE AND MATERIAL. THE USE AND LOADING OF PAVEMENT ABOVE THE PIPES SHALL BE CONSIDERED WHEN DETERMINING THE REQUIRED COVER.

6. ALL SUBSURFACE DETENTION INSTALLATIONS REQUIRE PRETREATMENT. SOME SEDIMENT REMOVAL IS PROVIDED BY A SUMP BELOW THE INVERT OF THE PIPE LEADING TO THE DETENTION BED. AN INLET FILTER MAY BE CONSIDERED IN LIEU OF A SUMP. IF SITE CONDITIONS PERMIT, SURFACE RUNOFF SHOULD FLOW THROUGH A BIORETENTION AREA OR SIMILAR SMP BEFORE ENTERING THE STORM DRAIN INLET.

7. OUTLET CONTROL SHALL BE DESIGNED TO ALLOW THE SUBSURFACE DETENTION AREA TO DEWATER IN THE REQUIRED TIME. REFER TO SECTION 4.1, "COMMON COMPONENTS".

8. A BYPASS PIPE SHALL BE PROVIDED TO PASS LARGER RAIN EVENTS.

Stormwater Retrofit Manual ***SMP Design Details***

Philadelphia PWD Water Department

SUBSURFACE DETENTION

SMP-4.10.3

Definitions

DEFINITIONS

Applicant: A property owner, developer, or other person who has filed an application to with PWD for a retrofit project in the City of Philadelphia.

Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

Conceptual Stormwater Management Plan: A preliminary stormwater management plan.

Condominium Parcel: Real estate, portions of which are designated for separate ownership, and the remainder of which is designated for common ownership by the owners of those portions.

Condominium Properties: Real estate, portions of which are designated for separate ownership and the remainder of which is designated for common ownership by the owners of those portions.

Current Rates and Charges: The current rates and charges in the tariffs for water, sewer, and stormwater services provided by the Philadelphia Water Department.

Customer: An owner, Tenant or occupant who, by operation of law or agreement, is responsible for payment of the charges for water/sewer/stormwater service at a Residential, Non-residential or Condominium Property.

Demolition: To tear down, raze, or remove an existing structure or impervious surface, whether in whole or in part.

Department: The Philadelphia Water Department is the operating department of the City of Philadelphia with the duties, powers and obligations set forth in the Home Rule Charter and the Philadelphia Code. For all purposes related to the Rate Change Proceeding, the Department shall be considered to include the Water Revenue Bureau of the Revenue Department. Nothing in these Regulations shall be construed to change, alter, or modify the functions, powers, responsibilities or authority of the Water Revenue Bureau or the Department under the Home Rule Charter or the ordinances of the City of Philadelphia.

Design Storm: The magnitude and temporal distribution of precipitation from a storm event defined by probability of occurrence (e.g., five-year storm) and duration (e.g., 24 hours), used in the design and evaluation of stormwater management systems.

Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land Development project prior to issuance of the Certificate of Occupancy.

Development Site: The specific tract of land where any Development activities are planned, conducted, or maintained. It refers to a contiguous area of disturbance including across streets and other rights-of-way, regardless of individual parcel ownership, where lots are developed as one common project.

Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

Directly Connected Impervious Area (DCIA): An impervious or impermeable surface that is directly connected to the drainage system as defined in the Manual.

Earth Disturbance: A construction or other human activity which disturbs the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling or storing of soil, rock or earth materials.

Erosion and Sediment Control Plan: A site-specific plan consisting of both drawings and a narrative that identifies measures to minimize accelerated erosion and sedimentation before, during and after Earth Disturbance.

Gross Area (GA): All of the parcel area within the legally described boundaries except streets, medians and sidewalks in the public right-of-way.

Groundwater Recharge: The replenishment of existing natural undergroundwatersuppliesfromprecipitationoroverlandflowwithout degrading groundwater quality.

Impervious Area (IA): A surface which is compacted or is covered with material that restricts infiltration of water, including semi-pervious surfaces such as compacted clay, most conventionally hard-scaped surfaces such as streets, driveways, roofs, sidewalks, parking lots, attached and detached structures, and other similar surfaces.

Impervious Area Managed: Impervious area that directs runoff to surface water bodies or to approved Stormwater Management Practices (SMPs).

Impervious Area Reduction: Impervious area that is directed to pervious area on a property or, based on the type of cover, has characteristics similar to pervious area. Impervious Area Reductions include the following disconnection categories: rooftop and pavement areas that are directed to pervious areas

on the same property; tree canopy cover that overhangs onsite impervious areas; green roofs used in place of typical roofing; and porous pavement used in place of typical imperious pavement materials.

Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. A Development Site located in more than one Management District shall conform to the requirements of the district into which the site discharges.

Municipal Stormwater System: City-owned and maintained real property, infrastructure or natural feature used and/or constructed for purposes of transporting, conveying, retaining, detaining or discharging stormwater runoff.

New Development: Development project on an unimproved tract of land where structures or impervious surfaces were removed before January 1, 1970.

Non-Residential Parcel: Real estate which cannot be classified as either Residential or Condominium.

Non-residential Property: Real estate which cannot be classified as either Residential or Condominium. Real estate used exclusively as a cemetery shall not be considered Non-residential property.

Open Space: The pervious area on a parcel that is calculated as the Gross Area minus the Impervious Area.

Operations & Maintenance Agreement (O&M Agreement): Agreement between the Property Owner and the City which outlines the maintenance requirements associated with the Post-Construction Stormwater Management Plan.

Post-Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan as described in the Philadelphia Stormwater Regulations, the Stormwater Management Guidance Manual, and in these Regulations.

Predevelopment Condition: For New Development and Redevelopment, Predevelopment shall be defined according to the procedures found in the Manual.

Property: Any parcel of real estate identified in the records of the Philadelphia Department of Records.

Property Owner: The owner of the particular parcel of real estate identified in the records of the Philadelphia Department of Records, or the grantee in a land transfer of record.

PWD Stormwater Regulations: Chapter Six of the Philadelphia Water Department Regulations, available at www.phila.gov/water.

Record Drawings: Construction drawings revised to represent the as-built conditions.

Redevelopment: Development improved tract of land that includes, but is not limited to, the demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970.

Residential Property: Real estate used exclusively for residential purposes with at least one and no more than four Dwelling Units. Property adjacent to Residential Property owned and utilized exclusively by the Residential Property owner for residential uses. Upon proof submitted to the Department, said properties shall be deemed by the Department to form one Residential parcel comprised of the Property and the Residential Property.

Stormwater Management Guidance Manual: The Philadelphia Water Department's comprehensive technical guide to stormwater management, available at www.pwdplanreview.org.

Stormwater Management Practice (SMP): Any man-made structure that is designed and constructed to convey, store, detain, infiltrate, or otherwise control stormwater runoff quality, rate, or quantity.

Stormwater Pretreatment: Techniques employed to remove pollutants before they enter the SMP, including, but not limited to, the techniques defined and listed as pretreatment in the Manual.

Stormwater Retrofit: The voluntary rehabilitation and/or installation of SMPs on a property to better manage stormwater runoff.

Surface Discharge: The discharge of stormwater runoff from a property to an adjacent surface water body, without the use of City infrastructure.

Undeveloped Property: Property classified by the Board of Revision of Taxes as SB, SC, SI, SR, or SS; Undeveloped refers to the status of the property as having no structures and is not related to whether the property has ever been developed.