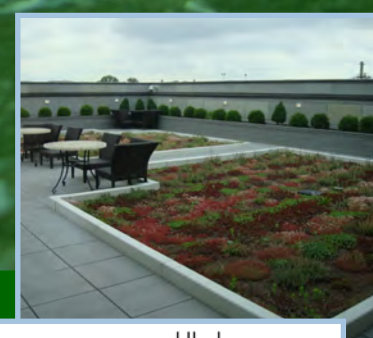
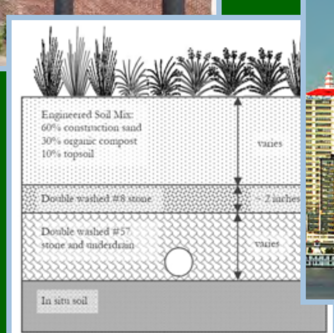
Green Infrastructure Design Manual

Green Management Practices and Design Strategies to Manage Stormwater in our Community





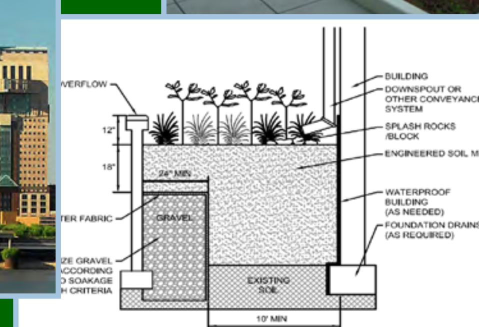


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Table of Contents
Chapter 18: Green Infrastructure

Table of Contents Chapter 18 (Continued)

Louisville and Jefferson County
Metropolitan Sewer District

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18.1 Purpose of this Chapter

Louisville skyline (Photo: Louisville & Jefferson County MSD)

Louisville Metro is promoting green management practices (GMPs) to supplement traditional development methods to encourage environmental sustainability and economic growth. Benefits of GMPs include aesthetics, improvements to quality of life, cleaner water and air, increased property values and increased potential for recreation. Green infrastructure is a method to manage stormwater in a manner that promotes stormwater reduction, reduces sewer treatment costs, reduces gray infrastructure sizing, improves water quality, increases public awareness and economic benefits. The green infrastructure goals for Louisville and Jefferson County MSD are as follows:

- Comply with the Consent Decree
- Eliminate Sanitary Sewer Overflows (SSOs)
- Reduce Combined Sewer Overflows (CSOs)
- Manage stormwater
- Improve water quality
- Beautify the community
- Improve air quality
- Reduce the heat island effect

The purpose of this chapter is to outline for the community the design, development, implementation and maintenance of green infrastructure and to assist with the planning and design of green management practices, referred to in this chapter GMPs. This chapter is divided into six subchapters that includes a summary of regulations and ordinances that should be considered for the implementation of GMPs, the process for selecting GMPs for a site, examples demonstrating the GMP selection process, design strategies, fact sheets, guidance for operation and maintenance and definitions. The design strategies demonstrate various approaches and uses for the GMPs. The fact sheets provide design guidance for GMPs. Chapter 18.7, Operation & Maintenance (O & M), provides guidance for ongoing operation and maintenance activities that are required to maintain GMP functionality.

Chapter Components

The following design strategies are explained in this chapter:

- Green Streets
- Green Intersections
- Stormwater Curb Extensions
- Green Alleys
- Green Parking
- Downspout Disconnection
- Roofs
- Rainwater Harvesting
- Urban Forestry
- No Mow Buffer Zones
- Stream Buffers
- Retrofits for Detention Basins
- Small Parks & Multi-Use Areas
- Residential Neighborhoods

The following series of GMP fact sheets are included in this chapter:

- Bioswales
- Rain Gardens
- Constructed Wetlands
- Green Wet Basins
- Green Dry Basins
- Extensive Green Roofs
- Intensive Green Roofs
- Blue Roofs
- Permeable Pavers
- Pervious Concrete
- Porous Asphalt
- Planters
- Tree Boxes
- Rainwater Harvesting
- Vegetated Buffers
- Vegetated Swales
- Underground Storage
- Catch Basin Inserts
- Proprietary Water Quality Units
- Infiltration Trenches

The goal of each GMP fact sheet is to provide the following information:

- Typical Implementation Areas
- Key Considerations for Purpose and Location
- Relative Cost
- Maintenance Level
- Stormwater Management Benefits
- Advantages/Benefits
- Disadvantages/Limitations
- Application and Site Feasibility
- Physical Requirements
- Design Criteria
- Treatment Trains—Combination and Location in Series with other GMPs
- Education Awareness
- Application and Site Feasibility Criteria Chart
- Step By Step Design Procedures
- Operation and Maintenance

The application of sound engineering and judgment, along with thorough planning using the information in this chapter are necessary for planning, design, construction and maintenance of GMPs. This chapter is not intended to be a detailed design methodology, nor can this chapter address variable and site-specific design challenges that may arise.

Defining Green Infrastructure

The definition for green infrastructure can vary in use and meaning. Green infrastructure has been used to refer to anything from trees in an urban setting to planned, engineered infrastructure in a community. For purposes of this chapter, green infrastructure refers to an adaptable term used to describe an array of materials, technologies and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate and/or recycle stormwater runoff. The Environmental Protection Agency (EPA) defines green infrastructure similarly and recognizes green infrastructure as a means to manage stormwater runoff. Examples of green infrastructure include green roofs, porous pavement, rain gardens and vegetated swales. These systems are planned, designed and managed to mimic natural systems. Green infrastructure can be implemented

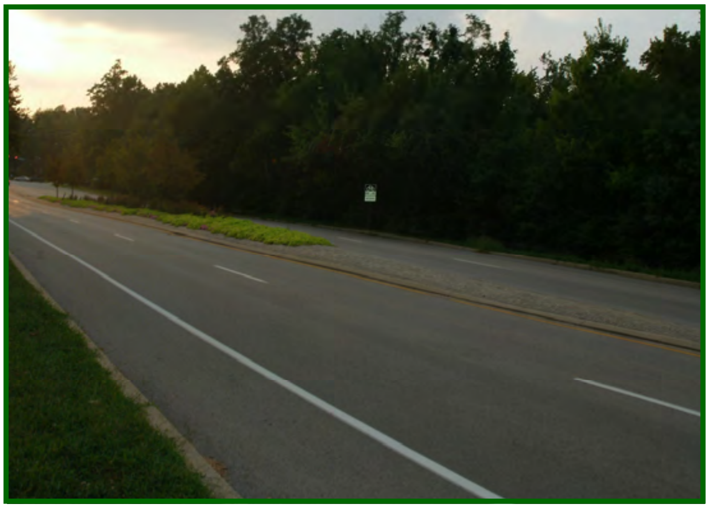
Green roof (Photo: Louisville & Jefferson County MSD)

Defining Green infrastructure Cont.

on scales ranging from statewide, to the local level including local governments and parcel specific green management strategies.

When used as components of a stormwater management system, green infrastructure practices can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands and sequester carbon while also providing communities with aesthetic and natural resource benefits.

Pervious driveway leading to CSO 108
(Photo: Louisville & Jefferson County MSD)



Planted median and grass swale at Lexington Road in Louisville
(Photo: Erin Wagoner, URS Corporation)

Rain barrel (Photo: Louisville & Jefferson County MSD)

Bashford Manor detention basin (Photo: Louisville & Jefferson County MSD)

Green Management Practices (GMPs)

Green infrastructure is a term commonly applied to stormwater BMPs such as pervious pavement, rain gardens and bioswales. These BMPs are designed to infiltrate rain water into the ground rather than it running into MSD's combined sewers or the community's waterways.

BMPs and GMPs can be further categorized as structural and non-structural BMPs and GMPs. Structural GMPs vary from the use of dams, risers, to grading a site to create grass channels or rain gardens. Non-structural GMPs are generally design practices that reduce the amount of impervious area and the impact of impervious cover on the site. Non-structural practices also can include education or public outreach regarding the GMPs on the site.

This sign along banks of the Ohio River informs the public of the location of a potential combined sewer overflow (Photo: Louisville & Jefferson County MSD)

Impacts of Green Infrastructure on Water Quality and Water Quantity

The water quality of many local streams is degraded from pollutants in stormwater runoff that commonly result from large amounts of impervious area in a watershed. Green infrastructure has been demonstrated to reduce the impact of impervious areas by providing a point to infiltrate stormwater runoff. In addition, while green infrastructure cannot in itself serve as a flood control practice, the severity and extent of flood events, including flash flooding, is reduced by green infrastructure.

Natural systems like riparian areas and wetlands provide benefits due to stormwater management, flood control, and the filtration of pollutants. These natural systems are free and highly valuable to local waterways. The loss of these mechanisms can result in increased costs for mitigation efforts, disaster relief, and recovery after a natural disaster. Detailed benefits for Louisville Metro and local waterways include:

- Aesthetically pleasing environment
- Savings for property owners
- Increased property values
- Reduced flooding
- Improvements to water quality
- Reduced costs and discounted stormwater fees
- Increased land values
- Maximized developable property
- Money savings on heating and cooling
- Attractive areas for customers
- Reduced sewer overflows and flooding
- Improved air quality and human health
- Pleasant workplace for employees

The following page contains a map demonstrating some of the projects with GMPs that are implemented, or are under design throughout Louisville Metro. Not only are there site specific projects, regional GMPs are also demonstrated where the Metro area is expanding park land, creating riparian corridors along Floyds Fork and improving connectivity with existing parks.

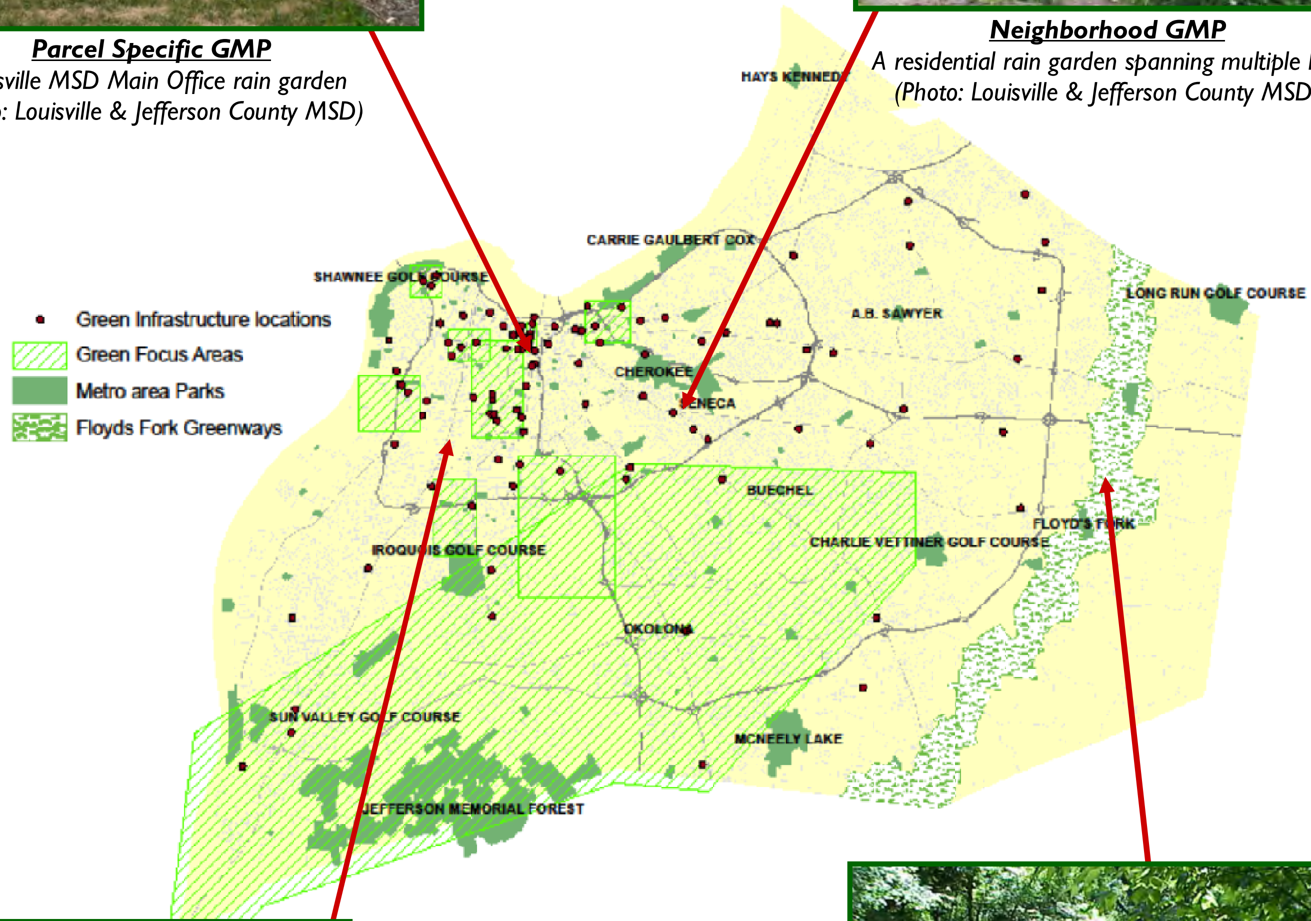
Artist's rendering of a roadway median with green infrastructure, including native plants to assist with drainage and water quality (Concept rendering: Shea Powell, Dropseed Nursery)

Local Examples of Green Infrastructure: Ranging from Site Specific to Regional GMPs

The photos below demonstrate local examples of GMPs, ranging from site specific to regional implementation of green practices.

Parcel Specific GMP
Louisville MSD Main Office rain garden (Photo: Louisville & Jefferson County MSD)

Neighborhood GMP
A residential rain garden spanning multiple lots (Photo: Louisville & Jefferson County MSD)

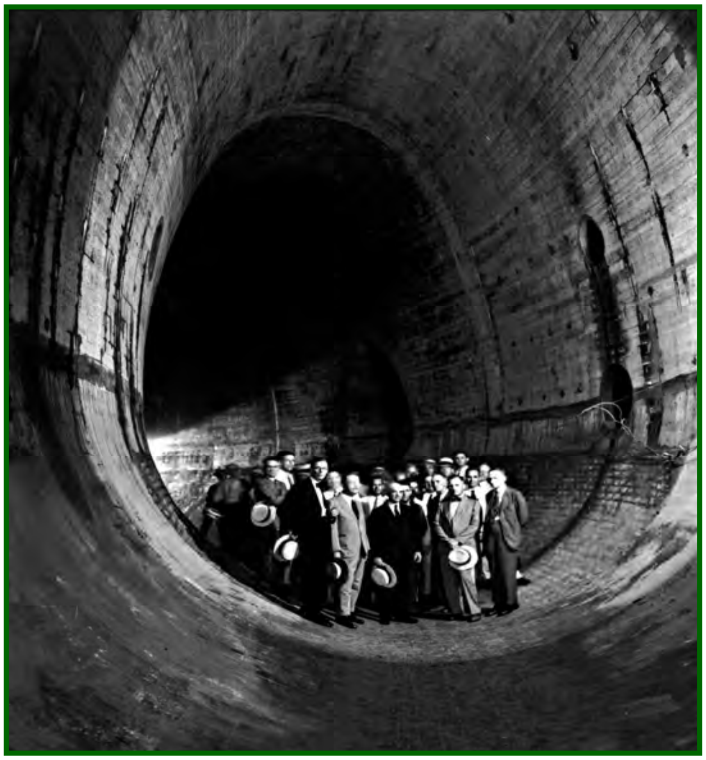


Multiple GMPs
Pervious pavers and planter boxes spanning multiple lots (Concept plan: Louisville & Jefferson County MSD)

Regional GMP
Floyds Fork Greenway (Photo: Louisville & Jefferson County MSD)

Gray infrastructure

Gray infrastructure is the means of moving stormwater and sewage water through a series of pipes, tunnels, cement ditches and wastewater treatment plants. This practice has evolved over the last 100 plus years. Initially, the goal was to move the wastewater into local streams, creeks and ultimately to the Ohio River. In the early 1900s, without a complete understanding of environmental issues and public health practices, streams and creeks were enclosed and wastewater was moved away from the population in sewer pipes and paved structures. As technology improved, wastewater was treated at wastewater treatment plants instead of being sent directly to the Ohio River. As more development occurred, stormwater combined sewer infrastructure was separated from wastewater infrastructure. Researchers also began to understand the implications from increased impervious area (which includes flooding) and started developing better practices for drainage and water quality. These practices include the use of better planning and the implementation of GMPs in developed areas. The pictures on this page are local examples of gray infrastructure.



Combined sewer
(Photo: Louisville & Jefferson County MSD Archives)

River Road drainage improvements
(Photo: Louisville & Jefferson County MSD)

Beechwood Village drainage improvements
(Photo: Louisville & Jefferson County MSD)

Concrete lined drainage way in Louisville Metro
(Photo: Louisville & Jefferson County MSD)

Why is MSD doing this?

By keeping rain water from entering the combined sewer system, pipes become less full and are less likely to result in a CSO. The green infrastructure techniques presented in this chapter help to capture rain water and keep it from overwhelming Louisville's Combined Sewer System (CSS) and Louisville's Municipal Separate Storm Sewer System (MS4).

MSD believes the use of GMPs in urban watersheds will reduce the downstream peak flow rates through urban stream corridors during periods of wet weather and more closely mimic natural, pre-development conditions. By managing stormwater runoff pursuant to the process outlined in Chapter 18.3, the volume of runoff entering traditional gray infrastructure, drainageways and streams will be reduced during wet weather, because the GMPs in this manual promote retaining and infiltrating stormwater runoff on site; and slowing and/or reducing runoff. The base flow of streams can be increased, depending on the GMP selected, and the infiltration capacity of in situ soils and connectivity to the water table. Incorporation of GMPs is recognized by MSD as a critical component in reducing CSOs, MS4 program compliance and meeting flood control objectives.

GMPs are techniques that store, infiltrate or otherwise manage runoff from impervious areas. These GMP improvements will: reduce stream bank erosion, reduce sediment transport through critical flood control structures, reduce nutrient transport and improve the potential for riparian and aquatic habitat.

When strategically selected and sited in CSS sewersheds, the appropriate combination of GMPs and traditional (gray) wastewater engineering solutions will improve the sustainability of urban watersheds by embracing social values, reducing costs to rate payers and the community and improving urban environmental quality. Likewise, GMPs placed in the MS4 watersheds will provide long-lasting benefits to the community. To encourage these opportunities on private property, MSD may offer credits and incentives for the use of GMPs, as funding is available.

MSD's commitment to water quantity and quality measures are also demonstrated through MSD's role in other local programs. MSD maintains many of the Louisville Metro greenway trails and is the administrator of the Louisville Metro Floodplain Management Ordinance.

MSD rain garden at 700 West Liberty Street immediately after installation (Photo: Louisville and Jefferson County MSD)

MSD rain garden at 700 West Liberty Street (Photo: Carolyn Cromer, Dropseed Nursery)

Installation of a new drainage system along Reynolds Avenue (Photo: Louisville & Jefferson County MSD)

18. 2 Overview of Ordinances and Other Requirements

Louisville Metro City Hall (Photo: Kristen Dunaway, URS)

There are a number of federal and local regulatory programs that can impact water quality and quantity. This chapter provides an overview of some of these regulatory programs. The regulatory programs outlined in Chapter 18.2 should not be considered exhaustive, and it should be noted that the requirements of regulatory programs change over time. Therefore, the designer should always consult pertinent statutes and ordinances when developing a green infrastructure project.

Inspections, Permits, and Licenses

Louisville Metro Building Division oversees the implementation and enforcement of the Kentucky Building Code KRS Section 105.1. A permit may be required when an owner or authorized agent intends to construct, enlarge, remodel or change the occupancy of a building, or to erect, convert, or replace any electrical, gas, mechanical or plumbing system. Before any work is to begin, the owner shall first submit an application to a building official and obtain the required permit. Inspections are required pursuant to the Kentucky Revised Statutes (KRS).

Water Quantity

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP). Louisville Metro is a participant in the NFIP and is required to comply with programmatic requirements, including the enforcement of a floodplain development management ordinance. MSD is the administrator of Louisville Metro's Floodplain Management Ordinance. This ordinance should be consulted when developing in or near a floodplain. Specifics regarding the floodplain ordinance can be found in Chapter 3.6 of the MSD Design Manual titled Floodplain Ordinance and in Chapter 10.4 titled Local Regulatory Floodplain and Conveyance Zone. A permit, issued by MSD, is required when developing in the Local Regulatory Floodplain. If a permit is not issued pursuant to local ordinances, development in the floodplain is a violation with the potential for fines. No development is permitted in the conveyance zone. This ordinance also has requirements for buffers along blue line streams.

Application for Permit to Construct Across or Along a Stream from the Kentucky Division of Water (KDOW), Floodplain Management Section is also required, if the drainage area for the impacted stream is one square mile or greater. KDOW should be contacted for more information regarding this permit.

Water Quality

The Clean Water Act is the federal legislation that governs water quality. There are several components of the Clean Water Act that may need to be considered when designing a site.

Section 404– Nationwide Permits from the United States Army Corps of Engineers (USACE) may be required if the project crosses or is in close proximity to waters of the United States (U.S.). The purpose of the 404 program is to regulate the discharge of dredged and fill material into waters of the U.S., which includes streams and wetlands. The Section 404 permitting program is shared by the EPA and the USACE. The EPA develops and defines the criteria used for permit applications, identifies the activities that are exempt from the permit, enforces Section 404 provisions and has the authority to veto USACE permit decisions. The USACE administers the program and approves permit applications. Design engineers must inquire from the USACE whether a project requires a 404 permit.

Section 401– Application for a Water Quality Certificate (WQC) from KDOW, Water Quality Branch may be required if the activities related to a project result in physical disturbance to streams or wetlands.

Total Maximum Daily Loads

Total Maximum Daily Load (TMDL) is the computed pollutant load that a waterbody can receive and still meet water quality standards. TMDLs are allocated to point and nonpoint sources in a watershed. The most common sources of pollutants are sediment, pathogens, nutrients and metals. In the future, as TMDLs are developed and approved for local streams, designers will need to consider these regulatory requirements in the site development.

Municipal Separate Storm Sewer System

Louisville Metro is regulated by the MS4 Program, required by the Clean Water Act, through the Kentucky Pollutant Discharge Elimination System administered through the KDOW. This program mandates that the Louisville Metro enforce stormwater management ordinances. MSD, the City of Anchorage, the City of St. Matthews, the City Jeffersontown, the City of Shively and Louisville Metro are MS4 co-permittees. As a result of this co-permittee relationship, MSD implements and enforces programmatic activities in the MS4 permit.

The MS4 ordinances should be considered when designing, constructing and implementing GMPs. There are three ordinances that are required pursuant to the MS4 program: an erosion prevention and sediment control ordinance (EPSC), a post-construction ordinance, and illicit discharge detection and elimination ordinance. For purposes of this chapter and to aid designers with the implementation of GMPs, the following sections will be explained in more detail: the City of Louisville/Jefferson County Erosion Prevention and Sediment Control Ordinance and when introduced and adopted, the City of Louisville/Jefferson County Post-Construction Ordinance.

Erosion Prevention and Sediment Control Ordinances

The City of Louisville/Jefferson County EPSC, § 159, defines land disturbing requirements at active construction sites. The purpose of the ordinance is to comply with the Clean Water Act by preserving and conserving soils, water, vegetation and wildlife in Louisville Metro. Those involved in qualifying land disturbing activities are required to have an approved EPSC plan and a duly-issued site disturbance permit or an authorized general permit. Land disturbance activities do <u>not</u> include the following:

- Minor land disturbance activities such as home landscaping, repairs and maintenance work
- Installation, maintenance or repair of any underground public utility lines that occurs on a hard surfaced road, street or sidewalk, provided that the land disturbing activity is limited to the area of the road, street or sidewalk
- Septic tank lines or lateral fields unless included in an overall plan for land disturbing activities related to the building to be served by the septic tank system

- Tilling, planting or harvesting of agricultural, horticultural, forest crops or livestock feedlot operations; including soil conservation operations related to agriculture as follows: construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds, ditches, strip cropping, lister furrowing, contour cultivating, contour furrowing, land drainage and irrigation which does not cause an increase in stormwater runoff and does not exacerbate erosion and sedimentation
- Clearing and grading activities that disturb less than 2,000 square feet and are situated no closer than 50 feet to a solid or intermittent blue line stream, and which are not governed under a general permit or site disturbance permit
- Emergency work to ensure health, safety, property and emergency repairs. However, if land disturbance activities would have required an approved EPSC plan, and if the activities were not conducted under emergency circumstances, then the land area will be shaped and stabilized consistent with the City of Louisville/ Jefferson County EPSC ordinance

The following land disturbance activities are exempt from the requirements of the City of Louisville/Jefferson County EPSC ordinance, provided that all exempt activities are undertaken in a manner that presents no significant erosion or sedimentation potential:

- Agriculture operations required to adopt and implement an individual agriculture water quality plan pursuant to the requirements set forth in the Kentucky Agriculture Water Quality Act (KRS 224.71-100 et seq.)
- Usual and customary site investigation and surveying activities that include soil testing, rock coring, test pits, boundary and topographic surveying, monitoring wells and archeological excavations that are conducted prior to the submittal of an application for a preliminary subdivision or development approval, so that the land disturbance is incidental to necessary equipment access and performance of investigation and surveying activities
- Following preliminary subdivision or development approval but prior to site disturbance permit approval and issuance, clearing necessary to provide access for survey work, rock surrounding or other usual and customary site investigations provided that the preliminary site investigations are planned to minimize the amount of the clearing required, clearing will follow the proposed roadway centerlines and will not result in a clear access way of more than 20 feet in width, cleared access ways beyond proposed roadways to assess individual lots will not exceed 12 feet in width and no trees eight inches or greater in diameter measures at breast height (dbh) will be removed without prior approval by the Louisville Metro Division of Planning and Design Services
- Minor land disturbing activities that disturb 2,000 square feet or less of land area and not within 50 feet of a drainageway. This will not apply to land disturbance activities subject to the general permit provisions by utilities or in connection with family home construction.

There are two types of permits granted by MSD to allow land disturbing activities; the Site Disturbance Permit and the General Permit. These permits are distinguished by the land disturbing activity at issue. There are three types of review: Type I, Type II and General Permit. Table 18.2-A, located on the following page, originates from the City of Louisville/Jefferson County EPSC Ordinance and summarizes the review requirements. For a detailed explanation of these ordinances refer to Chapter 12 of the MSD Design Manual.

Permit Requirements for Land-Disturbing Activities in Louisville Metro

Table 18.2-A.

Type of Land-Disturbing Activity	Type of Permit Required See § 159.02(c)(3)		Type of Review Procedure Required See § 159.02(c)(2)			Type of EPSC Required See § 159.02(c)(4)	
	Site Disturbance Permit	General Permit	Type I	Type II	General Permit	Concept EPSC Plan	Detailed EPSC Plan
1. Requires Land Use Approval	X		X			X	X
2. Requires Building Permit Only (Non-Discretionary)	X			X			X
3. Undertaken by Public Utility		X			X	N/A	N/A
4. Single-Lot Residential Construction in an Approved Subdivision		X			X	N/A	N/A
4a. Reserved							
4b. Single-Lot Residential Construction on a "Red-Flagged" Lot	X			X			X (At MSD's Discretion)
5. Excavation, Site Clearing, or Filling of Land (No Building Permit Required)	X			X		X (Only if Type I Review Required)	

Numbers 1-5 below provide additional description regarding the type of land disturbing activities in Table 18.2-A, column 1.

1. Includes all land disturbing activities association with specific development proposal subject to discretionary land use or development approvals (e.g. subdivisions, conditional uses, development plan reviews etc.).
2. Includes all land disturbing activities associated with a specific development proposal not subject to discretionary land use or development approvals (e.g., development requiring building permit approval only).
3. Includes land disturbing activities undertaken by a private contractor hired by a utility, includes utility related land disturbing activities such as small trench work service hook-ups to individual structures, general and emergency maintenance and repair work and the like.
4. This category includes only construction of a residence, and/or accessory residential structures on a single lot that is part of a subdivision subject to an EPSC plan approved pursuant to this ordinance. Please see category 4.B in the table for important variations on this general provision.
5. "Red Flagging" refers to a notation on the approved subdivision plan that a particular individual lot shall be subject to additional restrictions or scrutiny prior to construction.

The permittee should consult the City of Louisville/Jefferson County EPSC Ordinance for specific permitting requirements.

Post-Construction Ordinance

A post-construction ordinance will be adopted on or before August 1, 2012. This Chapter will be updated to provide explanation regarding this new ordinance.

Summary of Potential Permitting Requirements for Drainage and Green Infrastructure Projects

The following table provides a summary of permits that are typically required for stormwater drainage and Green Infrastructure projects. Always consult regulations, ordinances and state and federal laws when assessing permit requirements, as requirements change over time. This list is not meant to be exhaustive of the potential permitting requirements.

Potential Permits for Green Infrastructure Projects

Table 18.2-B.

PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
Construction Along a Stream	Application, HEC2 analysis or floodplain verification	KDOW	For any construction along or across a blueline stream, in a floodplain, or when impounding water
Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	USACE	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow ≥ 5 cfs. May require DOW Water Quality Certification
Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	KDOW	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Consult with the USACE and KDOW
Stormwater Discharge Permit	Application/ NOI (Notice of Intent)	KDOW	For all projects disturbing ≥ 1 acre
Water Withdrawal Permit	Application/ Letter	KDOW	When necessary to withdraw more than 10,000 gpd of water from a blueline stream
Encroachment Permit	Application	KYTC	When encroaching on state right-of-way: to be submitted at 80% design stage
Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: To be submitted at 80% design stage
Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way
Building Permit for Temporary Office	Site Plan	Louisville Metro – Code Enforcement or City of Louisville Public Works	For any temporary office/trailer
Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic
Planning Commission Approval	Site Plan(s)	Louisville Metro – Planning Commission	For all projects
MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects
Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept. of Public Works	For any project which requires obstruction of a roadway
Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and USACE	When encroaching on the floodwall right-of-way

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.3 Green Infrastructure Plan Development Standards and Selection Process

Traditional Stormwater Design

Green Infrastructure Design

The sketches above demonstrate the different design approaches for a traditional stormwater drainage design and a green infrastructure design. The green infrastructure design promotes infiltration into pervious areas on the site. (Adapted from Brad Lancaster www.rainwaterharvesting.com)

Introduction

The purpose of this chapter is to provide the guidance for managing the water quality requirements on a project site. The primary goals of a GMP is to provide both water quantity reduction and water quality improvements before leaving a site. Although the process for selecting GMPs is the same, the selected GMPs will vary from site to site. There are many factors that may contribute to the effectiveness of a specific GMP. It is important for the design professional to consider and assess numerous factors, including but not limited to: site characteristics, the water quality volume (WQv) required to be managed on a site, site design, constructability of GMP, and long-term operation and maintenance of GMPs. Chapter 18.3 provides the process for selecting green infrastructure design components for a site, but is not intended to address every site planning or design variable that a designer may encounter. The application of sound engineering, planning and surveying principles and judgment apply. Approval of plans pursuant to this process does not relieve the designer from required compliance with the other sections of the MSD Design Manual and applicable standards.

The GMPs in the MSD Design Manual should be considered as a list of tools and should be implemented based on the site conditions and stormwater management needs to comply with Clean Water Act, post-construction stormwater water quality and quantity requirements. Furthermore, appropriate site planning will result in GMPs that are potentially less expensive and more effective for the intended purpose, and will play a role in enhancing new development and urban spaces in Louisville Metro.

Chapter 18.3 provides a summary of the general considerations for design. These steps can also be referenced in the flow chart, Figure 18.3-1, on page 5. Later sections of this chapter will provide more specific guidelines for the design of each GMP. Last, examples are provided in Chapter 18.3 to demonstrate the process for selecting GMPs.

In general, the following steps should be followed to incorporate green infrastructure design components:

1. Implement Site Planning Recommendations, including conserving natural areas and reducing impervious cover
2. Determine Required Water Quality Rain Event (RE_{WQV})
3. Calculate Required WQv
4. Select GMPs with Runoff Reduction Abilities
5. Determine Managed Water Quality Volume (MWQ_V)
6. Calculate Remaining Water Quality Volume (RWQ_V), as needed
7. Select Alternative GMPs to Treat the RWQ_V
8. Provide O & M Documentation

The Impacts of Stormwater Management

The purpose of stormwater management is to mitigate the impact on the hydrologic cycle that results from alterations to land surfaces. As land is developed, the hydrologic cycle is impacted by reducing the natural storage and infiltration capabilities of natural pervious areas, including grasslands and forests. With urbanization, naturally occurring pervious areas are reduced and replaced with impervious surfaces. By reducing natural vegetation and increasing impervious areas, the quantity of runoff entering drainage systems and streams increases significantly. Even green areas in older developments often contain compacted soils, causing an increase in stormwater runoff.

Urbanization also increases the types and amounts of pollutants that enter local streams and drainage ways. Some of the increased pollutant runoff is due to the increased stormwater runoff volume. Research indicates that small frequently occurring rain events account for a significant amount of the pollutants generated from stormwater runoff. Therefore, designing GMPs that treat the volumes generated by smaller rain events is the approach utilized in this manual. Pollutants typically found in stormwater runoff include the following:

- Nutrients
- Bacteria and pathogens
- Petrochemical products
- Heavy metals
- Pesticides and herbicides
- Thermal pollution
- Sediments
- Deicers
- Floatables

Many of these pollutants have the potential to enter the local waterways. A summary of the potential pollutants including pollutant sources and pollutant impacts is provided in the following paragraphs.

Nutrients Phosphorous and nitrogen enter waterways from fertilizers, both natural and manmade. Fertilizers are typically used on lawns, golf courses, parks and construction sites to promote vegetative growth. These chemicals can disrupt the aquatic ecosystem through increased vegetative and algal growth, resulting in lower dissolved oxygen (DO) levels, taste and odor problems. Lower DO levels are caused by the decomposition of organic materials in stormwater or algal respiration. The resulting lower DO levels can lead to fish kills and the loss of sensitive aquatic species.

Bacteria and Pathogens Bacteria and pathogens can impact human health when they enter the body through ingestion or open wounds. Coliform bacteria originate from human and animal waste, including wildlife and domestic animals. Leaking sewer systems, failing septic systems, SSOs and CSOs are also potential sources of these pollutants.

Heavy Metals Heavy metals originate from such sources as preserved wood, paint and metals from automobile tires and brake liners. These enter the waterways through corrosion, flaking, dissolving, decaying or leaching. Heavy metals are toxic to aquatic animals, can be bioaccumulative and can contaminate drinking water supplies.

Pesticides and Herbicides	Pesticides and herbicides have the potential to be used improperly or excessively for residential and commercial purposes, and as a result have the potential to runoff into water sources. Both can be toxic to aquatic life, as well as the general public.
Thermal Pollution	The change of ambient water temperature can affect the level of DO in the water and the life cycle of some aquatic species. Water temperature can be increased by cooling waters used by power plants, as well as urban runoff. With an increase in temperature, a decrease of DO levels occurs in the water, which is harmful to aquatic animals.
Sediments	The amount of particulate matter in water is usually measured by total suspended solids, which is the amount of solids suspended in the water column, or turbidity. Turbidity is the discoloration of the water. The impacts from excessive sediment include: stream warming, transportation of other pollutants during rain events, destruction of stream habitats, declines in mussels and darters, and decreased flow capacity of pipes and channels, which leads to localized flooding. Water that is too turbid does not allow sunlight to penetrate the water and grow phytoplankton, which is the foundation for the aquatic food chain.
Deicers	Deicers are used to melt snow from roadways and walkways. Deicers can harm aquatic life because of high salt levels and increased conductivity of the stormwater runoff.
Floatables	Floatables include trash and organic materials such as leaves, grass or other yard wastes floating on the water surface. Floatables are unsightly and can damage aquatic habitats. As organic floatables decompose, they deplete the level of DO needed by fish and other organisms.

GMP Benefits to Water Quantity and Quality

Pollutant loadings to the local waterways can be decreased by treating and reducing the volume of stormwater runoff. Management of the WQv must be provided at all developments where stormwater management is required, either due to the receipt of credits or incentives through the MSD Rates, Rentals and Charges Policy or as a result of the Louisville Metro Post -Construction Ordinance, which is anticipated to be adopted one year from the issuance of the MS4 permit.

Table 18.3-A contains a summary of the relative pollutant treatment and stormwater management benefits that can be provided by well-maintained GMPs. Table 18.3-A was derived from the stormwater benefits that are identified on each of the GMP fact sheets located in Chapter 18.5. The intent of this table is to provide a brief summary of the potential benefits of the GMPs recommended including: pollution reduction, hydrologic characteristics and runoff volume reduction potentials.

Green Management Practices Summary

Table 18.3-A

■ Significant Benefit; ◪ Partial Benefit; □ Low or Unknown Benefit		Pollution Reduction								Hydrologic Charateristics					Runoff Volume Reduction		
		Sediment	Phosphorous	Nitrogen	Metals	Pathogens	Floatables	Oil and Grease	Dissolved Pollutants	Surface Flow Reduction	Infiltration	Stormwater Conveyance	Stream Channel Protection	Peak Flow Control	Runoff Capture	Maintenance	Cost
18.5.1	Bioswales	■	◪	◪	◪	□	◪	◪	◪	◪	◪	◪	◪	□	◪	Low	Low
18.5.2	Rain Gardens	■	◪	◪	◪	◪	◪	◪	◪	◪	◪	□	◪	◪	■	Low	Low
18.5.3	Constructed Wetlands	■	◪	◪	◪	◪	◪	◪	◪	◪	□	□	◪	◪	◪	Medium	Medium
18.5.4	Green Wet Basin	■	◪	◪	◪	◪	◪	◪	◪	◪	□	□	◪	◪	◪	Low	Medium
18.5.5	Green Dry Basin	■	◪	◪	◪	□	◪	◪	□	◪	□	□	◪	◪	◪	Low-Medium	Low-Medium
18.5.6	Extensive Green Roof	□	□	□	□	□	□	□	□	■	□	□	◪	■	■	Low	High
18.5.7	Intensive Green Roof	□	□	□	□	□	□	□	□	■	□	□	◪	■	■	Medium	High
18.5.8	Blue Roofs	□	□	□	□	□	□	□	□	□	□	□	◪	◪	■	Low	Medium
18.5.9	Permeable Pavers	◪	□	□	◪	□	□	□	□	■	■	□	◪	□	■	High	High
18.5.10	Pervious Concrete	◪	□	□	◪	□	□	□	□	■	■	□	◪	□	■	Medium	Medium
18.5.11	Porous Asphalt	◪	□	□	◪	□	□	□	□	■	■	□	◪	□	■	Medium	Medium
18.5.12	Planters	■	◪	◪	◪	□	◪	◪	◪	◪	◪	◪	□	□	◪	Low	Medium
18.5.13	Tree Boxes	■	◪	◪	◪	□	◪	◪	◪	◪	◪	◪	□	□	◪	Low	Medium
18.5.14	Rainwater Harvesting Cisterns	□	□	□	□	□	□	□	□	■	□	□	◪	□	■	Medium-High	Medium-High
18.5.15	Vegetative Buffers	◪	◪	◪	◪	□	◪	□	□	◪	◪	◪	□	□	◪	Low	Low-Medium
18.5.16	Vegetated Swales	◪	□	□	□	□	◪	□	□	□	◪	■	□	□	◪	Low	Low
18.5.17	Underground Storage	◪	□	□	□	□	◪	□	□	□	□	□	◪	□	■	Medium	Medium-High
18.5.18	Catch Basin Inserts	◪	□	□	◪	□	◪	◪	□	□	□	□	□	□	◪	Medium-High	Low-Medium
18.5.19	Proprietary Water Quality Units	*varies by technology*								□	□	◪	□	□	◪	Medium	Medium-High
18.5.20	Infiltration Trenches	■	■	■	■	◪	◪	◪	◪	■	■	■	◪	◪	■	Medium-High	Medium

Green Management Practice Selection Process

Developing a green infrastructure project involves incorporating GMPs throughout the life of the project, from the concept stage through the final design and subsequent operation and maintenance. Figure 18.3-A is a flow chart that depicts the steps in developing a green infrastructure project. Each of these steps are discussed in more detail in this section.

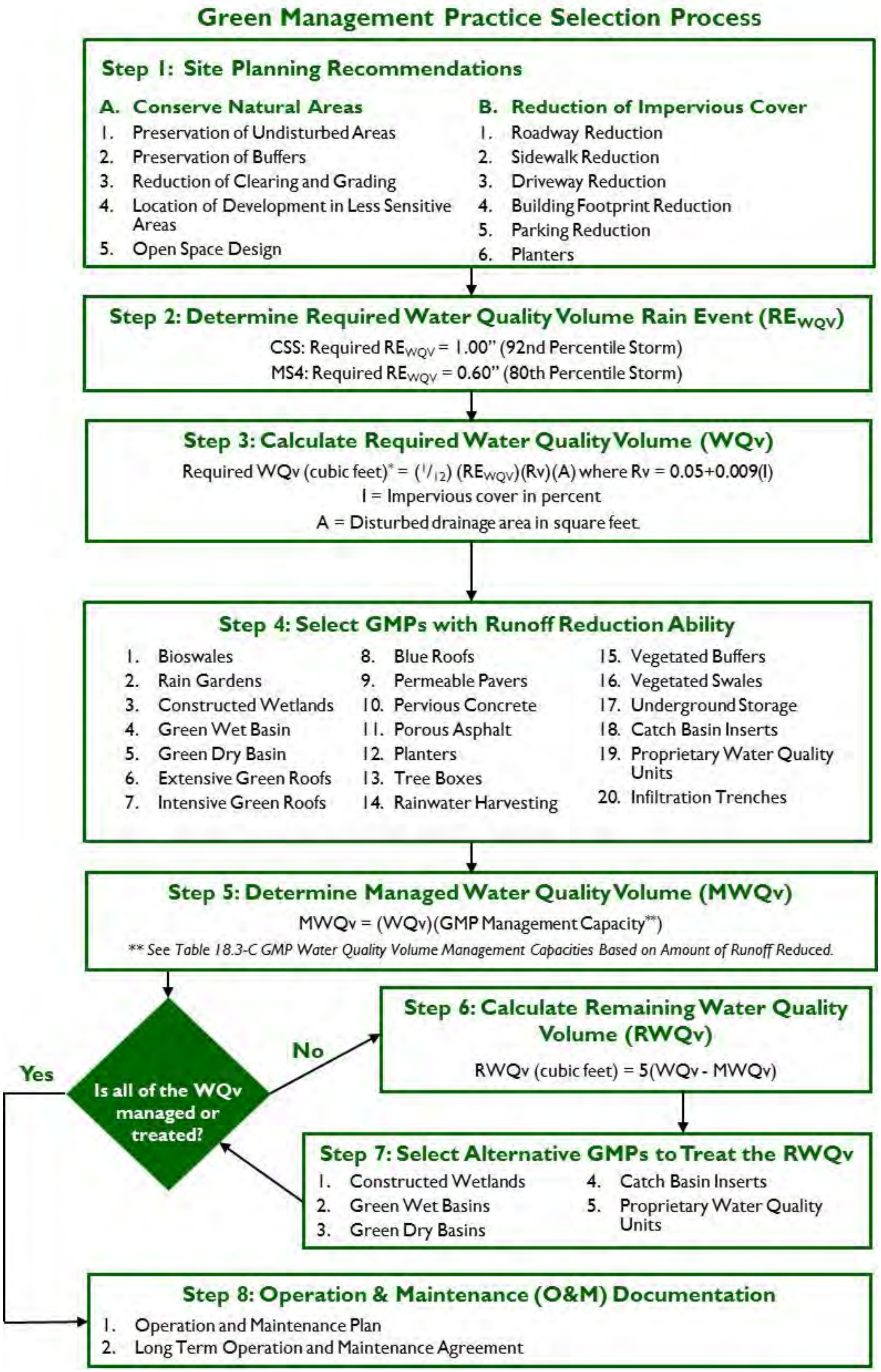


Figure 18.3-A. Green Management Practice Selection Process

Step 1: Site Planning Recommendations

During the first step of selecting GMPs for a project, consideration should be given to preserving the natural features of a project site, often referred to as conservation design. As discussed in Chapter 18.1 green infrastructure can range from natural features on a property that treat runoff to manmade structures that treat stormwater before entering the drainage system. Research indicates that it is more effective to treat stormwater at its source. Therefore, preserving the natural features on a site can be a cost effective means for stormwater management by reducing impervious areas and reducing the WQv that must be treated. The first step of the selection process is to understand the site characteristics, including the following:

Development Features Development features include the natural and manmade features of the site. Utilities, park areas, waterfront areas, landscaping, conservation areas, roads and sidewalks are examples of development features that should be considered during the site assessment and planning phase.

Natural Features Natural features are grasslands, wooded areas and streams or ponds on the site. Attention should be given to preserving existing drainage features and to promote the conservation of natural areas, which reduces the amount of stormwater runoff leaving the site.

Manmade Features Manmade features include existing structures, roads, sidewalks and utilities on the site.

Watershed Factors Watershed factors to consider include pollutants of concern in the watershed, water quality concerns, sources of water pollution and location of the property within the watershed.

Aesthetic and Habitat Related Issues Aesthetic and habitat related issues can include whether the site is located near impaired waters or sensitive areas and whether there are threatened and/or endangered species identified on the site.

Topography The topography will impact the location and types of GMPs that are suitable for the site; it is important to try to utilize the natural topography to the best extent possible.

Karst Area Karst areas consist of limestone terrain with caverns, sinkholes and underground streams. GMPs that impound water can be problematic in karst areas by causing these underground caverns and sinkholes to expand and open at the surface. Liners may be a solution to this design impediment; however, the conveyance to the GMP and the conveyance from the GMP to the downstream location must be considered because the overall volume of runoff is increasing and potentially being transported to areas that may not have received runoff previously. Furthermore, in karst topographies, there is a risk that stormwater runoff can enter the water table with little to no pollutant treatment. This is why appropriate GMP selection is critical in these areas. GMPs that infiltrate, should not be used in karst topographies.

High Water Tables High water tables can impact the functioning of a GMP. High infiltration GMPs are prohibited in these areas, since high water tables will prevent the percolation of stormwater into the subsoils. In addition, special geotechnical considerations may be necessary in these areas, especially for embankment or impoundment facilities.

Wind Exposure Wind exposure can impact the planting selections for green roofs and other GMPs that require landscaping.

Vegetation Vegetation on a site can both enhance and impede the effectiveness of a GMP. For example, deciduous trees near pervious pavement can clog the GMP with their leaves, but reduce stormwater runoff by rainfall interception and evapotranspiration. In spite of these challenges, appropriately selected vegetation in GMPs can improve their performance.

Existing Development and Steep Slopes

One of the goals for stormwater management is to recharge groundwater. This process also has the potential to impact adjacent ground during and after storm events. Saturating the soils on steep slopes (6 to 10 percent or greater) can cause the failure of the slope and adjacent structures.

Costs

Costs for GMPs can include planning, design, construction and O & M.

Credits

Credits are reductions applied to the stormwater user fees in exchange for the implementation of GMPs on a site. The requirements for these credits vary and as a result, the designer should consult MSD policy and the availability of credits.

Local Planning and Regulatory Requirements

Federal, state and/or local regulatory requirements may prohibit or require certain GMPs to meet specific requirements. The designer should consult all applicable ordinances and regulatory requirements. Planning and regulatory requirements could impact the design process, the selection criteria, operation and maintenance and possibly the cost of the GMPs. Some of the planning and regulatory aspects to consider when planning GMPs for the site are CSO mitigation, TMDL requirements, MS4 permitting, 401/404 permitting, floodplain permitting, and MSD credits/ incentives. Review local ordinances and zoning codes to verify that potential GMPs comply with local codes and ordinances and that there are not any regulatory impediments to the GMPs proposed for the site. Regulatory programs and local ordinances are discussed in more detail in Chapters 2.5, Chapter 10 and 18.2 of the MSD Design Manual.

Operation and Maintenance

The operation and maintenance schedule and costs may impact the decision to use a GMP. Some GMPs require more maintenance than others. Information regarding O & M is in Chapter 18.7.

Designated Land Use

The designated land use is a factor to consider since some GMPs are better suited for specific land uses. A summary of the most applicable land uses can be found on the first page of each GMP fact sheet shown in Chapter 18.5.

Contributing Drainage Area Size

The applicability of some GMPs will be limited due to the size of the contributing drainage area and the functionality of GMPs. The maximum and minimum contributing drainage area sizes shown on the GMP fact sheets are guidelines. However, when incorporating water quality proprietary units into a site design, design criteria should be modified only by the manufacturer.

Hotspots

Hotspots are a land use or activity that generate higher concentrations of pollutants, including but not limited to hydrocarbons, sediments and trace metals that are found in stormwater near the land use. Due to the potential for groundwater contamination, the use of some GMPs near hotspots is prohibited. Separation from the groundwater table or an impermeable liner for impoundment structures should be considered for hotspots.

Hotspot locations include:

- Gas/fueling stations
- Vehicle washing /steam cleaning
- Auto salvage yards/auto recycling facilities
- Outdoor material storage areas
- Outdoor loading and transfer areas
- Landfills
- Construction sites
- Facilities that store or generate hazardous materials
- Industrial sites
- Industrial rooftops

Treatment Trains

A treatment train is the use of multiple GMPs in series on a site to meet the WQv requirement for stormwater management. Treatment trains can include structural and non-structural GMPs. When assessed and planned, a treatment train consists of all of the design concepts and GMPs that work to accomplish the site requirements. The general approach for treatment trains should consider:

1. Avoiding additional stormwater runoff volume.
2. Managing stormwater runoff as close to the source as possible.
3. As appropriate, infiltrating as much of the stormwater runoff as possible.

Two examples of treatment trains for residential and commercial developments are provided in Figures 18.3-B and 18.3-C.

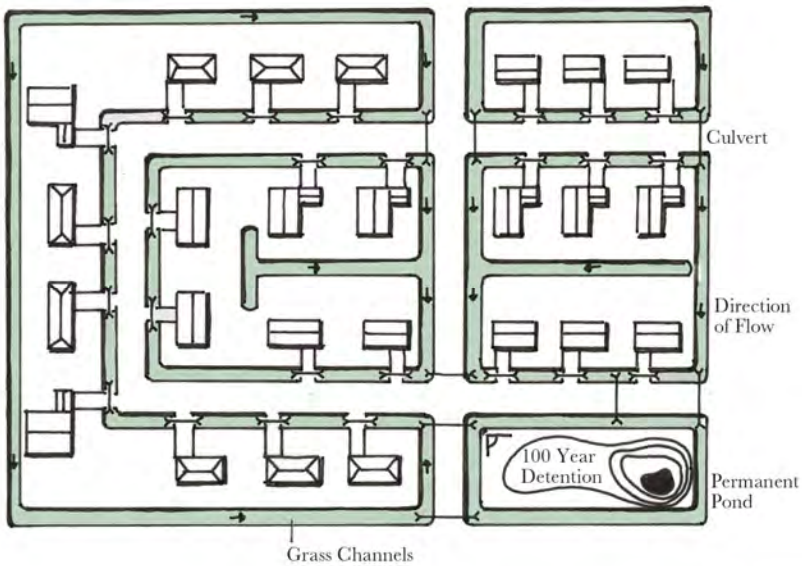


Figure 18.3-B. Multiple GMPs are used in a residential setting. The use of vegetated swales and a green detention basin are used in combination to manage the stormwater runoff. (Sketch: Shea Powell, Dropseed Nursery; Source: Atlanta Regional Council and Georgia Stormwater Design Manual)

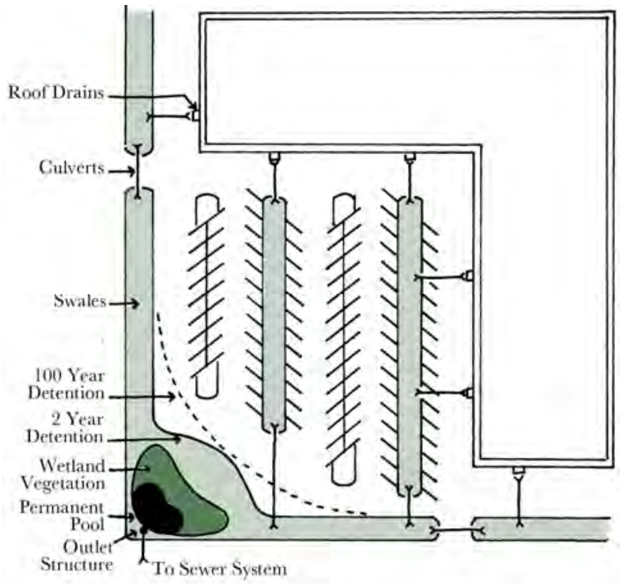


Figure 18.3-C. Multiple GMPs used in a commercial development, including directing roof drains to grass swales to a wetland system. (Sketch: Shea Powell, Dropseed Nursery; Source: Atlanta Regional Council, 2001)

Questions to consider when developing a treatment train include the following:

- Do management GMPs cost effectively help manage stormwater runoff?
- Can existing GMPs be retrofitted to increase their effectiveness?
- Does one structural GMP cost effectively help manage stormwater runoff?
- Do multiple structural GMPs cost effectively help manage stormwater runoff?

Evaluate Site Conditions

By defining the site characteristics and learning the opportunities and limitations of the site, the designer can select GMPs that are more effective and reduce the stormwater management costs for the site.

Opportunities on a site may include:

- Existing overhead utility easements that can double as a GMP area
- Open spaces and preservation areas that can serve as GMPs while also providing multi-use areas such as parks, playgrounds, walking and hiking areas, and water recreational areas.

Limitations on a site may include:

- Regulatory restrictions
- Limitations due to soil types
- High water table
- Land use
- Existing utilities
- Local acceptance of particular GMPs

Consideration should be given to preserving the natural features of the property. Conservation design is a means of development to preserve the natural features that can protect water resources, natural habitat, and sensitive areas. These practices provide significant benefit for reducing imperviousness and as a result the amount of stormwater leaving the site. Table 18.3-B contains recommended conservation design practices.

Conservation Design Practices

Table 18.3-B.

Practice	Description
Minimization of Disturbed Areas	Minimization of disturbed areas includes maintaining undisturbed forests, native vegetative areas, riparian corridors, wetlands and natural terrains to preserve natural drainage characteristics of the area.
Preservation of Buffer Areas	The preservation of riparian buffers along streams, rivers and wetland areas provides water quality benefits by allowing pollutants to filter from the stormwater runoff before entering these aquatic areas. Buffers also protect stream channels, wetlands and existing vegetation and habitat.
Reduction of Clearing and Grading	Reducing plan grading and clearing to the minimum amount needed for structures, roads, driveways and utilities can minimize the amount of impervious cover on the site and as a result reduce the required WQv for the site.
Minimization of Development Impacts to the Site	Preserve the natural drainage patterns and topography of the land by incorporating the natural features into the site design. This can result in lower costs for stormwater management.
Identification of Less Sensitive Areas for Development	Identifying less sensitive areas for development can reduce the impacts on water quality. Sensitive areas include highly erosive soil, steep topography, streams, wetlands and buffers. The designer should also reference federal, state and local laws for floodplain development and permitting regulated by the Clean Water Act in these areas.

Figure 18.3-E. Conservation design is used to preserve open space and natural site characteristics. This approach can reduce the WQv that must be managed on a site.

Figure 18.3-F. This residential street in a development using conservation and open space design uses narrower streets than traditional practices. (Photo Sabak, Wilson and Lingo Inc.)

Practice	Description
Promotion of Open Space Design	Open space design includes the use of stormwater controls in areas that are set aside as open space for the development. Inclusion of these practices in areas that were already set aside as open space or landscaping areas can improve drainage and reduce development and management costs.
Minimization of Impacts to Soil Permeability	Unaltered soils with high organic material infiltrate and store larger quantities of rainfall, as opposed to altered and compacted soils. When top soils are removed during development and compacted subsoils with a high clay content and little organic material remain, stormwater is more likely to flow to streams and wetlands with little natural water quality treatment. Many of the GMPs in the MSD Green Infrastructure Design Manual have specific soil permeability requirements.
Reduction of Impervious Cover	The reduction of impervious cover includes the following practices: roadway reduction, sidewalk reduction, driveway reduction, building footprint reduction, parking reduction and the installation of planter boxes. By implementing these practices impervious area can be reduced on a site and thus the associated WQv that must be treated on-site.
Additional Aspects to Consider	• Managing stormwater as a resource and not a waste product • Managing stormwater at its source

Below is an example of a conceptual green site plan. As demonstrated in Figure 18.3-D the designer has preserved conservation areas on the property including ponds and forested areas.

Figure 18.3-C. Conceptual Green Site Plan (Sabak, Wilson and Lingo, Inc.)

Step 2: Determine the Required Water Quality Volume Rain Event

The second step of the process to select GMPs for a project site requires determining the appropriate water quality rain event (RE_{WQV}). There are two RE_{WQV} to consider, the 92nd percentile storm and the 80th percentile storm. The selection of the RE_{WQV} is dependent upon the location of the project site. If the site is in the MS4 area, then the 80th percentile storm is used. If the site is located in the combined sewers system area, then the 92nd percentile storm is used to calculate the required WQv.

Determine Required Water Quality Volume Rain Event (RE_{WQV})

CSS: Required RE_{WQV} = 1.00 inch (92nd Percentile Storm)
MS4: Required RE_{WQV} = 0.60 inches (80th Percentile Storm)

Step 3: Calculate Required Water Quality Volume (WQv)

The third step of the process to select GMPs for a project site requires calculating the Required Water Quality Volume (WQv). The WQv for a site is the volume of runoff from the site for the Required RE_{WQV}.

The equation for the Required WQv is as follows: Required WQv (ft^3) = (RE_{WQV})(Rv)(A/12).

- RE_{WQV} is the required water quality volume rain event, discussed in Step 2
- R_V is the volumetric runoff coefficient, $R_V = 0.05 + 0.009(I)$, where I is the impervious percentage
- A is the site area in square feet

Step 4: Select the GMPs with Runoff Reduction Abilities

During the fourth step consideration should be given to selecting GMPs with Runoff Reduction Abilities. The designer should experiment with various GMPs or combinations of GMPs with runoff reduction abilities on the site until the required WQv is managed and/or treated. In each scenario, the designer estimates the drainage area contributing to each GMP, calculates the size of the GMP needed to manage the Required WQv, and attempts to footprint the GMP in the design. Runoff from at least 90% of the site is required to be managed or treated. This allows for flow from discharges at property lines or locations with little to no setback to be accommodated. In addition, any GMP can be sized greater than the WQv for the area draining to it, but not more than 110% of the GMP WQv can be used for calculating the managed water quality volume.

The GMP Water Quality Volume Management (MWQv) Capacities for each of the GMPs are listed in Figure 18.3-C labeled "GMP Management Capacity". By applying a combination of GMPs with water quality volume reduction abilities, the designer should manage 100% of the WQv calculated in Step 3. If the MWQv provided by the designed GMPs calculated in this step is greater than or equal to the WQv calculated in Step 3, the designer has met the requirements. When compliance cannot be achieved on the first try, the designer should return to prior steps to see if different GMPs, GMP sizes, or the combination of GMPs can be applied or whether the site can be redesigned to minimize the impervious area to achieve compliance with the sizing criteria in Step 4.

Step 5: Determine Managed Water Quality Volume (MWQ_V)

The fifth step requires calculating the managed portion of the WQv. Each GMP has a management capacity shown in Table 18.3-C, on the following page. The MWQ_V for a GMP is the WQv provided by the GMP management capacity multiplied by the GMP management capacity. The sum of the MWQ_V provided by the GMPs is then compared to the Required WQv. If the MWQ_V is greater than or equal to the WQv, then the designer can move to Step 8. If it is not, then the designer should revisit the site planning recommendations to reduce the impervious area and/or consider alternatives and/or additional GMPs with runoff reduction ability. If the designer cannot manage the WQv for the site with these options, then the designer must provide justification in the plan that evaluates each of the GMP calculations, limitations to reducing the impervious area, and any additional site limitations that make application of the technique(s) infeasible.

GMP Water Quality Volume Management Capacities Based on Amount of Runoff Reduced

Table 18.3-C.

GMP	GMP Management Capacity as a % of the WQv
Bioswales	• 100%, if entire WQv is stored within practice, including forebay, check dams and soils, and no underdrain is provided • 50%, if entire WQv is stored within practice, including forebay, check dams and soils, and underdrain is provided
Rain Gardens/Bioretention Areas	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the stone or soil media • 60%, if underdrain is below the water level of the WQv stored in the stone or soil media and drains in 24 to 48 hours • 30%, if underdrain is below the water level of the WQv stored in the stone or soil media and drains in less than 24 hours
Constructed Wetlands	0%
Green Wet Basin	0%
Green Dry Basin	0%
Extensive Green Roof	70%
Intensive Green Roof	90%
Blue Roof	• 100%, if rainfall is stored and beneficially used later • 60%, if rainfall is only temporarily detained
Permeable Pavers	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate
Pervious Concrete	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate
Porous Asphalt	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the aggregate • 60%, if underdrain is below the water level of the WQv stored in the aggregate

GMP Water Quality Volume Management Capacities Based on Amount of Runoff Reduced (Cont.)

Table 18.3-C.

GMP	GMP Management Capacity as a % of the WQv
Planters	• 100%, if no underdrain • 60%, if underdrain is below the water level of the WQv stored in the planter media and it drains in 24 to 48 hours • 30%, if underdrain is below the water level of the WQv stored in the planter media and it drains in less than 24 hours
Tree Boxes	• 100%, if no underdrain or underdrain is above the water level of the WQv stored in the tree box media • 60%, if underdrain is below the water level of the WQv stored in the tree box media and drains in 24-48 hours • 30%, if underdrain is below the water level of the WQv stored in the tree box media and it drains in less than 24 hours
Rainwater Harvesting - Cisterns	• 100%, if the rainfall is stored and beneficially used* later • 60%, if the rainfall is only temporarily detained
Vegetated Swale	• 25%, if infiltration rate of top 12 inches of soil is 2 inches/hr. or greater • 10%, if infiltration rate of top 12 inches of soil is less than 2 inches/hr.
Vegetated Buffer	• 90%, if infiltration rate of top 12 inches of soil is 2 inches/hr. or greater • 50%, if infiltration rate of top 12 inches of soil is less than 2 inches/hr.
Infiltration Trench	• 100%
Underground Storage	• 100%, if the collected rainfall runoff is infiltrated • 60%, if the collected rainfall runoff is only temporarily detained
Catch Basin Inserts	0%
Proprietary Water Quality Units	• TBD, if infiltration mechanism is provided • 0%, if infiltration mechanism is not provided

To promote the practice of proper site planning, while acknowledging the limitations of poorly draining soils, the following table, 18.3-D, contains the minimum MWQv for soil types are required for a site.

Table 18.3-D. **Minimum MWQv for Soil Groups**

Hydrologic Soils Group (HSG)	Minimum MWQv/WQv (%)
A	80
B	65
C	50
D	40

Step 6: Calculate Remaining Water Quality Volume (RWQ_V)

The sixth step of the GMP selection process is only necessary if the MWQ_V provided by the design and the selected GMPs is less than the WQv. In step 6, RWQv must be calculated based on the following formula:

RWQ_V (cubic feet) = 5(WQv - MWQ_V)

When this volume is calculated, the designer should proceed to Step 7 to identify alternative GMPs to treat the RWQ_V.

Step 7: Select Alternative GMPs to Treat the RWQ_V

The following GMPs may be used to treat the RWQ_V calculated in Step 6:

- Constructed wetlands
- Green wet basins
- Green dry basins
- Catch basin inserts
- Proprietary water quality units

After selection of the GMPs from this list, the designer should verify that the RWQ_V is met. If it is not, then the designer should revisit earlier steps until the WQv requirements for the site are met.

Step 8: Operation and Maintenance Documentation

During step 8 of the selection process for GMPs consideration should be given to O & M of GMPs, including documentation requirements. A critical aspect of proper functioning of a GMP is its maintenance. As part of the maintenance program, sites with GMPs that receive credits and/or stipends are required to enter into long-term operation and maintenance agreements with MSD regarding the inspection and maintenance requirements for the GMPs. For more information regarding the level of service, MSD access to the GMPs, maintenance requirements, maintenance schedules, inspections and compliance mechanisms, owners should consult the long-term maintenance and operation agreement and MSD policy.

Examples of maintenance issues include the following, but vary from GMP to GMP:

- Clogged or broken pipes
- Missing or broken parts
- Cracked concrete
- Erosion
- Landscaping care and replacement
- Mowing
- Weeding and the removal of invasive plants
- Watering
- Litter removal

Monitoring is also an important element of GMP operation and maintenance. The monitoring results should be documented and reviewed at least annually, as a means to assess the effectiveness of the GMP.

After Plan Submittal

After the GMPs are designed the following aspects should be considered: GMP construction, long-term operation and maintenance agreements, inspection requirements, enforcement and education awareness.

GMP Construction

GMPs require care during construction and installation for optimal performance. Special care shall be given not to compact native soils with construction equipment during construction. Knowledgeable personnel should provide construction oversight of the GMPs.

Long-Term Operation and Maintenance Agreements

The terms and conditions regarding the long-term O & M of each GMP shall be defined by the agreement between the GMP owner and MSD. Operation includes but is not limited to the following: start up, validation that the device is meeting its intended purpose and record keeping for the life of the GMP. Maintenance includes but is not limited to the following: cleaning, pumping, disposing of waste, pruning, mowing, weeding and record keeping.

Inspection Requirements

The GMP owner is required to make routine inspections to ensure that the GMP is operating properly and that maintenance is being conducted as needed to maintain proper function of the GMP. The GMP owner is required to maintain records of installation and maintenance activities. These records will be made available to MSD or Louisville Metro government upon request. An annual report shall to be submitted to MSD.

Enforcement

Enforcement is vital to public health and safety. Enforcement measures shall be consistent with local ordinances and MSD policies.

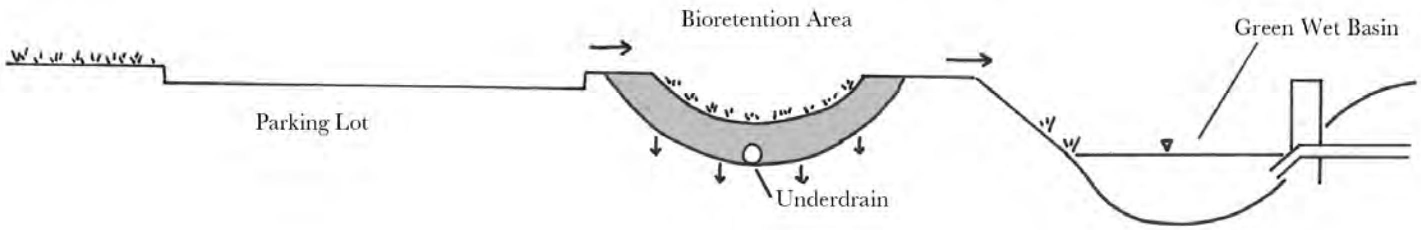
Education Awareness

Outreach opportunities are an important aspect of GMPs. Education and outreach is key to the success of the GMP and can compliment the GMP through behavior changes. Educational programs are a means to promote proper operation and maintenance of GMPs. Employees or residents that benefit from a GMP at their place of employment or near their homes should be informed of the benefits of the GMP and actions that can impact the functionality of the GMP. Behaviors such as mowing and landscaping, pesticide and herbicide use, improper disposal of motor oil and litter can impact the effectiveness of a GMP. Therefore, making information available as to how the GMP functions and behaviors that can promote the effectiveness of the GMP are encouraged. Employees can be given reoccurring training, including ready access to the MSD Green Infrastructure Design Manual, regarding best management practices for maintenance and operation of the GMP. An example of an outreach opportunity includes providing education and outreach information to residents living near a no mow buffer zone surrounding a detention basin, that explains the benefits of the no mow buffer as well as information encouraging residents not to mow the buffer will likely preserve the no mow buffer.

GREEN MANAGEMENT PRACTICE (GMP) SELECTION PROCESS EXAMPLES

Example 1 – Bioretention Area Site Confirmation

An area in the combined sewer system is being developed (see illustration below). In this example, the developer wants to use bioretention to manage the stormwater runoff from 12,200 square feet that is 85% impervious. The proposed bioretention area is 600 square feet, has 30 inches of soil media that has a porosity of 0.4, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 6 inches. Will this bioretention area provide the required Runoff Reduction Volume (RRv) in accordance with the GMP Manual? The following steps show how to use the selection process to determine the GMP RRv.



Example 1 – Redevelopment Site *(Continued)*

Step 1: Site Planning Recommendation

The developer has tried to minimize impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (RE_{WQV})

Because the project is in the combined sewer system, the required WQv rain event (RE_{WQV}) is 1.00 inches.

Step 3: Calculate the Required Water Quality Volume (WQv)

$WQv = (^1/_{12})(RE_{WQV})(Rv)(A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 85%. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(1.00)[0.05 + 0.009(85\%)]12{,}200 = 829$ cubic feet

Step 4: Select GMPs with Runoff Reduction ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(600)(2.5)(0.4) + (600)(0.5)] = 900 cubic feet

Step 5: Determine Managed Water Quality Volume (MWQv)

Since the bioretention area has an underdrain below the water level of the WQv stored in the media, the management capacity is only 60%. Therefore, the MWQv is:

900(0.6) = 540 cubic feet

Is all of the WQv managed or treated?

No →

The MWQv is 540 cubic feet, while the required WQv is 900 cubic feet, so this GMP does <u>not</u> manage all of the WQv.

(Proceed to Step 6, next page.)

Example 1 – Redevelopment Site *(Continued)*

Suppose the developer cannot provide any other GMPs to manage the WQv. What is the required remaining WQv that he will need to treat?

Step 6: Calculate the Required Remaining Water Quality Volume (RWQv)

Required RWQv = 5(WQv – MWQv)

Adding the values into the equation yields the following:

Required RWQv = 5(829 - 540) = 1445 cubic feet, which must be treated by an alternate GMP.

Step 7: Select Alternate GMPs to Treat RWQv

1. Constructed Wetlands
2. Green Wet Basin
3. Green Dry Basin
4. Catch Basin Inserts
5. Proprietary Water Quality Units

The developer chooses to use a **green wet basin** to treat the required RWQv. The developer must modify the site plan, while still maintaining the percent impervious, to allow for the green wet basin. The green wet basin must be designed to treat a WQv of 1445 cubic feet.

Is all of the WQv managed or treated?

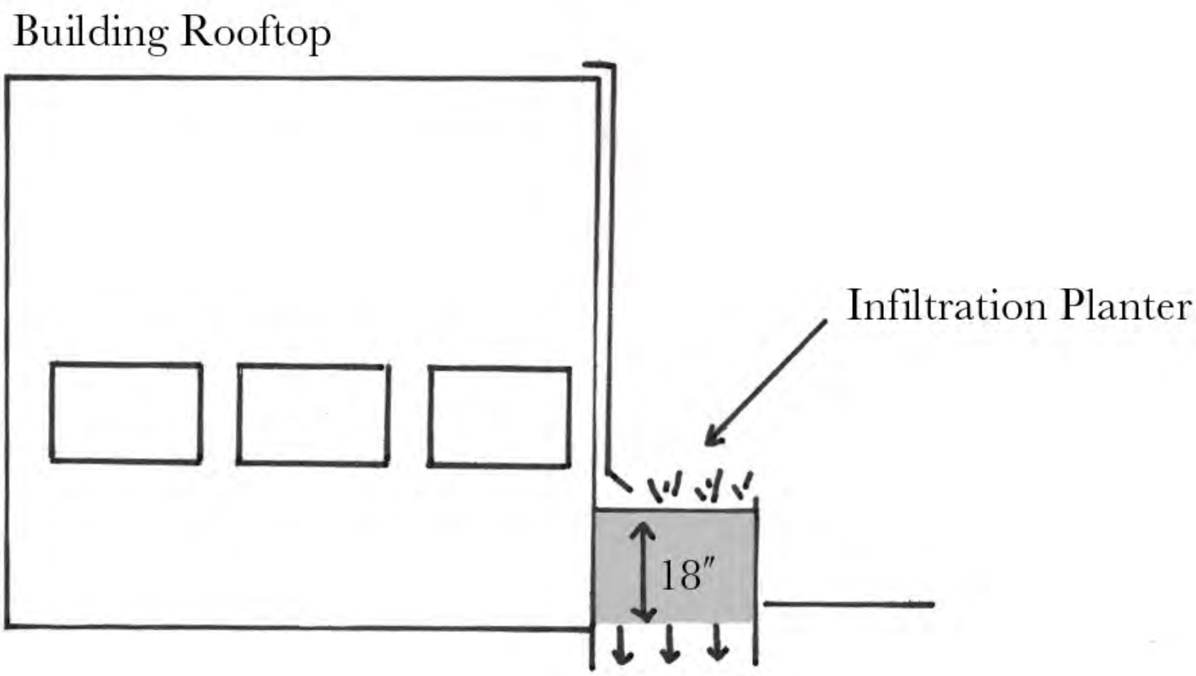
Yes

Step 8: O&M Documentation

Complete O&M documentation.

Example 2 – Size an Infiltration Planter

A new development is proposed in the MS4 area (see illustration below). The developer wants to use an infiltration planter with no underdrain to manage the stormwater runoff from 3,000 square feet of rooftop that is 100% impervious. The proposed infiltration planter has 18 inches of soil media, a porosity of the soil media of 0.3 and has a ponding depth of 6 inches. What is the area of planter needed to manage the WQv in accordance with the Green Infrastructure Design Manual? The following steps show how to use the selection process to determine the GMP RRv.



Example 2 – Size an Infiltration Planter (*Continued*)

Step 1: Site Planning Recommendation

The developer has conserved natural areas as possible and minimized impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (RE_{WQV})

Because the project is in the MS4 area, the required WQv rain event (RE_{WQV}) is 0.60 inches.

Step 3: Calculate the Required Water Quality Volume (WQv)

$WQv = (^1/_{12})(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 100%. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(100\%)]3{,}000 = 142$ cubic feet

Step 4: Select GMPs with Runoff Reduction Ability

The developer selected an infiltration planter box.

Step 5: Determine Managed Water Quality Volume (MWQv)

From the GMP Management Capacity Table, an infiltration planter with no underdrain has a management capacity equal to 100% of the WQv provided.

$A\ required = WQv/[d(p) + h]$ *Adding the values to the equation yields the following:*

$A\ required = 143/[1.5(0.3) + (0.5)] = 150$ square feet

Use an infiltration planter that is 3 feet wide by 50 feet long.

$WQv = (3 \times 50)[1.5(0.3) + 0.5)] = 142$ cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv (142 cubic feet) is equal to the required (142 cubic feet) WQv, so **YES**

Step 6: O&M Documentation

Complete O&M documentation.

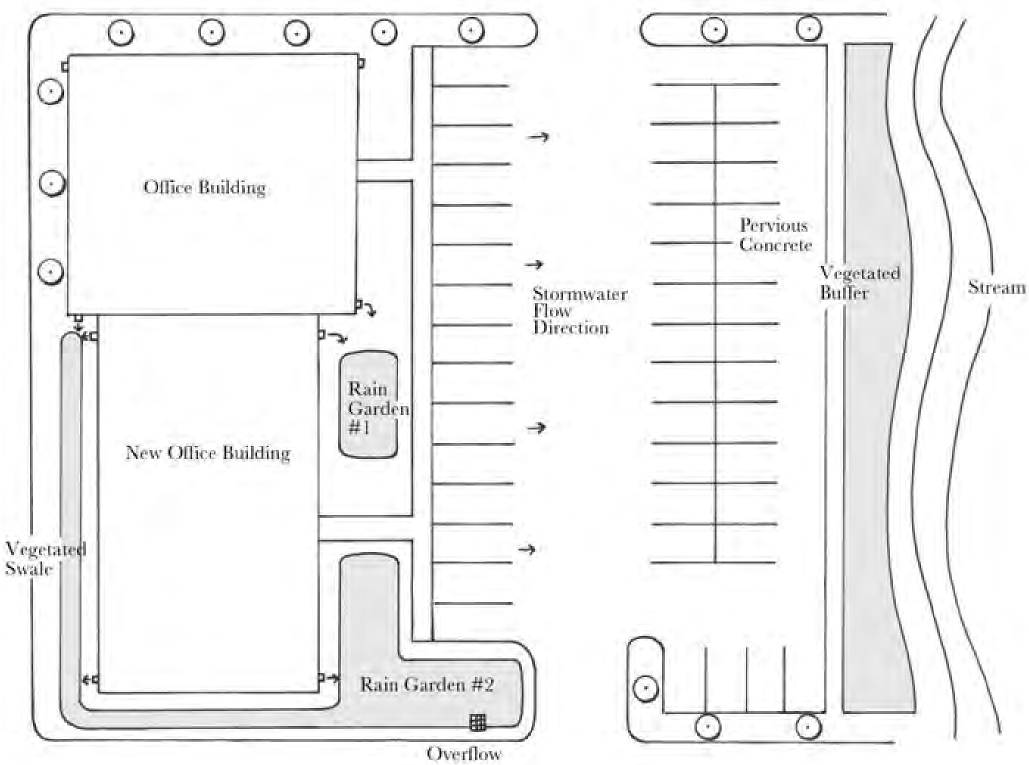
Example 3 – Expanded Office Building

A developer is expanding his office building and adding parking in the MS4 area. The new 2,000 square foot office building will manage stormwater runoff with a vegetated swale and two rain gardens. The new parking area will be pervious concrete with a vegetated buffer around the downhill side of the parking area. Project specifics are as follows:

- Project Disturbed Area: 5,000 square feet
- Rain Garden #1: The proposed Rain Garden #1 has a contributing area of 1,000 square feet (500 square feet from the old office building) that is 95% impervious. The rain garden is 45 square feet, has 30 inches of soil media that has a porosity of 0.2, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 6 inches. The rain garden drains in 18 hours.
- Vegetated Swale: The vegetated swale is 90 feet long, has a 2% slope, 2 foot wide bottom slope width with 3:1 side slopes, has a peak flow rate at the WQv rain event of 3 cfs and n = 0.03.
- Rain Garden #2: The proposed Rain Garden #2 has a contributing area 2,500 square feet (500 square feet from an old office building) that is 90% impervious. The rain garden is 125 square feet, has 30 inches of soil media that has a porosity of 0.3, has an underdrain system that is below the water level of the WQv stored in the media and has a ponding depth of 6 inches. The rain garden drains in 25 hours.
- Pervious Concrete: The proposed pervious concrete has a contributing area of 4,500 square feet that is 98% impervious with a water level that is 2.5 feet below ground elevation. The pervious concrete is 2,000 square feet and consists of a gravel layer with a porosity of 0.35, a concrete layer with a porosity of 0.18, depth of gravel layer of 1 foot, depth of concrete layer of 3 inches and an underdrain below the water level of the WQv stored in the gravel.
- Vegetative Buffer: The vegetated buffer varies between 10 feet to 50 feet wide at a 2% slope and is located downgrade of the pervious concrete.

Rain garden #1, vegetated swale and rain garden #2 are discharged to the same point, while the pervious concrete and vegetative buffer share a discharge point. All GMPs used on-site are part of the same stream or tributary network.

Will these multiple GMPs provide the RE_{WQv} in accordance with the Green Infrastructure Design Manual? The following steps show how to use the selection process to determine the GMP RRv.



Example 3 – Expanded Office Building *(Continued)*

Step 1: Site Planning Recommendation

The developer has tried to conserve natural areas and limit impervious cover.

Step 2: Determine Required Water Quality Volume Rain Event (WQv)

Because the project is in the MS4 area, the RE_{WQV} is 0.60 inches.
(Continue to step 3, next page.)

Step 3 (Rain Garden #1): Calculate the Required Water Quality Volume (WQv)

$WQv = (^1/_{12})(RE_{WQV})(Rv)\ (A)$ where $Rv = 0.05 + 0.009(I)$.

From the project information I, imperviousness, is 95%. The WQv requirements only apply to the newly disturbed portion of the site so A = 500 square feet. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(95\%)]500 = 23$ cubic feet

Step 4 (Rain Garden #1): Select GMPs with Runoff Reduction Ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(45)(2.5)(0.2) + (45)(0.5)] = 45 cubic feet

Step 5 (Rain Garden #1): Determine Managed Water Quality Volume (MWQv)

Since rain garden #1 has an underdrain and drains in less than 24 hours, the management capacity is only 30%. Therefore, the MWQv is:

45(0.3) = 14 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 14 cubic feet, while the required WQv is 23 cubic feet, so this GMP does <u>not</u> manage all of the WQv. There is a deficit of 9 cubic feet.
(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)

Example 3 – Expanded Office Building *(Continued)*

Step 4 (Vegetated Swale) Select GMPs with Runoff Reduction Ability

Calculate the flow depth during the peak flow rate.

$D = \{n(Q)/[1.49W(s)^{1/2}]\}^{3/5}$

Adding the values to the equation yields the following:

$D = \{0.3(3)/[1.49W(s)^{1/2}]\}^{3/5} = 0.40$ feet

Calculate the velocity, $v = Q/[W(D)]$ Adding the values to the equation yields the following:

$V = 3/[2(0.40)] = 3.8$ fps

Calculate the residence time, $R = L/[60(v)]$. Adding the values to the equation yields the following:

$R = 90/[60(3.8)] = 0.4$ minutes

Step 5 (Vegetated Buffer): Determine Managed Water Quality Volume (MWQv)

Does the vegetated buffer meet the minimum requirements.

Is $V \leq 1$ fps? No

Is $L \geq 100$ ft? No

Is $R \geq 5$ minutes? No

Is all of the WQv managed or treated?

No

The vegetated swale does not meet any of the minimum requirements so no credit can be offered.

(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)

Example 3 – Expanded Office Building *(Continued)*

Step 3 (Rain Garden #2): Calculate the Required Water Quality Volume (WQv)

WQv = $({}^{1}/_{12})(RE_{WQV})$(Rv) (A) where Rv = 0.05 + 0.009(I).

From the project information I, imperviousness, is 90%. Adding the values to the equation yields the following:

WQv = $({}^{1}/_{12})$(0.60)[0.05 + 0.009(90%)]2,500 = 108 cubic feet

↓

Step 4 (Rain Garden #1): Select GMPs with Runoff Reduction Ability

WQv provided = [(A)(Depth of Media)(Porosity of Media) + (A)(Ponding Depth)]

Adding the values to the equation yields the following:

WQv provided = [(125)(2.5)(0.3) + (125)(0.5)] = 157 cubic feet

↓

Step 5 (Rain Garden #2): Determine Managed Water Quality Volume (MWQv)

Since rain garden #1 has an underdrain below the water level of the WQv stored in the media and it drains in greater than 24 hours the management capacity is only 60%. Therefore, the MWQv is:

157(0.6) = 95 cubic feet

↓

Is all of the WQv managed or treated?

No →

The MWQv is 95 cubic feet, while the required WQv is 108 cubic feet, so this GMP does not manage all of the WQv. There is deficit of 13 of WQv.

(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)

Example 3 – Expanded Office Building *(Continued)*

Step 3 (Pervious Concrete): Calculate the Required Water Quality Volume (WQv)

WQv = ($^{1}/_{12}$)(RE_{WQV})(Rv) (A) where Rv = 0.05 + 0.009(I).

From the project information I, imperviousness, is 98%. Adding the values to the equation yields the following:

WQv = ($^{1}/_{12}$)(0.60)[0.05 + 0.009(98%)]4,500 = 210 cubic feet

Step 4 (Pervious Concrete): Select GMPs with Runoff Reduction ability

WQv provided = (A) [(Porosity of Aggregate Layer)(Depth of Aggregate Layer)]

Adding the values to the equation yields the following:

WQv provided = 2000[(0.35)(1)] = 700 cubic feet

Step 5 (Pervious Concrete): Determine Managed Water Quality Volume (MWQv)

Since the pervious concrete has an underdrain below the water level of the WQv stored in the media, the management capacity is only 60%. Therefore, the MWQv is:

700(0.6) = 420 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv is 420 cubic feet, which is in excess of the required WQv of 210 cubic feet, so this GMP does manage all of the WQv.
(Proceed to step 6, next page.)

Example 3 – Expanded Office Building *(Continued)*

Will these multiple GMPs manage all of the required WQv in accordance with the GMP Manual?

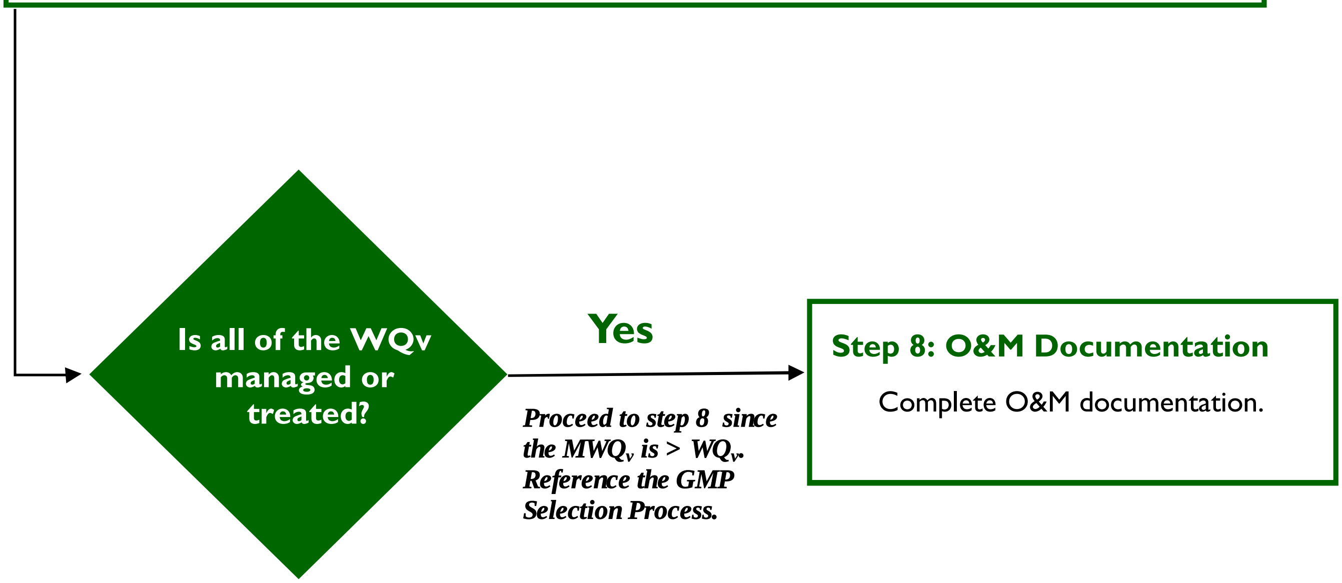
Step 5 (Total) : Determine the Managed Water Quality Volume (MWQv)

Is MWQv total ≥ WQv total?

14 + 0 + 95 + 420 > 23 + 0 + 108 + 210

529 cubic feet > 341cubic feet

Yes



Design Strategies Key

Louisville and Jefferson County MSD logo and address

MSD
Metropolitan Sewer District

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Infrastructure Design Strategies

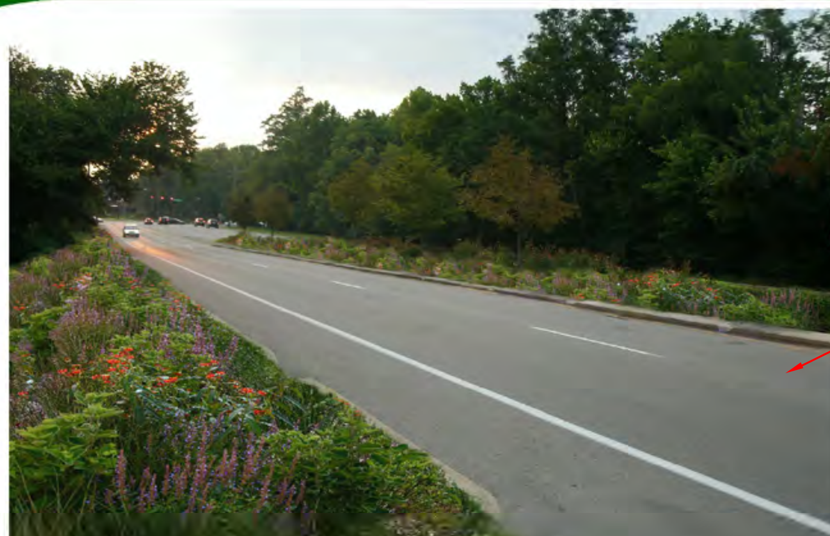
18.4.1 Green Streets

Chapter and section number and the design strategy name

Bulletted items list potential GMPs that can be used as part of this design strategy; several of these options are outlined in photos and descriptions on subsequent pages of each design strategy

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Infiltration Planters
- ☑ Rain Gardens
- ☑ Bioswales



Conceptual Green Streetscape
(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Photo/illustration of a typical implementation or schematic of the design strategy

General description of the design strategy

Description:

Green streets use linear landscape and hardscape GMPs to capture and reduce runoff from the street and adjacent properties. Green streets provide multiple benefits that are not limited to stormwater management including: reducing stormwater volume, replenishing ground water, improving air quality, encouraging economic development and improving the overall aesthetics in a community. There are several GMP options to use as a component of green street design including: pervious pavement, tree boxes, infiltration planters, rain gardens and bioswales.

Typical areas to implement a design strategy

Suitable Applications:

Green streets are suitable for a wide variety of land uses ranging from mid densities to high densities, including residential and commercial areas as well as parkways.

Items to consider before implementing a design strategy

Special Considerations:

- Design consistency with local and state ordinances/regulations
- Minimum widths for service trucks and emergency response vehicles
- Curb extension compatibility with narrow street widths
- Soil permeability
- Use of curb extensions for rain gardens, tree boxes and bioswales
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)

Effective:

Effective date

18.4.1 - 1

Page number

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.1 Green Streets

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Planters
- ☑ Rain Gardens
- ☑ Bioswales

Conceptual Green Streetscape
(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Green streets use linear landscape and hardscape GMPs to capture and reduce runoff from the street and adjacent properties. Green streets provide multiple benefits that are not limited to stormwater management including: reducing stormwater volume, replenishing ground water, improving air quality, encouraging economic development and improving the overall aesthetics in a community. There are several GMP options to use as a component of green street design including: pervious pavement, tree boxes, infiltration planters, rain gardens and bioswales.

Suitable Applications:

Green streets are suitable for a wide variety of land uses ranging from mid densities to high densities, including residential and commercial areas as well as parkways.

Special Considerations:

- Design consistency with local and state ordinances/regulations (see Table 18.2-B)
- Minimum widths for service trucks and emergency response vehicles
- Curb extension compatibility with narrow street widths
- Soil permeability
- Use of curb extensions for rain gardens, tree boxes and bioswales
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)

Concept Neighborhood and Parkway Uses

Multiple GMPs can be used as part of the design strategy for green streets as demonstrated in the following pictures.

Existing: Traditional Curb and Gutter with Catch Basins in a Residential Development ➔

A traditional street with catch basins and curbing is shown in the picture to the right.

(Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Traditional Curb and Gutter Parkway with Island ➔

An arterial road with traditional curb and gutter drainage and a center island provides aesthetic benefits.

(Concept Rendering: Shea Powell, Dropseed Nursery)

(Photo: Erin Wagoner, URS)

🡐 Green Option: Rain Garden, Pervious Pavers and Trees are Used in Residential Neighborhood

In residential neighborhoods existing catch basins can be incorporated into curb cuts that capture street runoff and direct it to rain gardens (demonstrated in the picture to the left), bioswales and filter strips. The use of pervious pavers reduces the runoff from the street. These GMPs provide environmental benefits, as well as aesthetic and economic benefits.

(Photo: Erin Wagoner, URS)

🡐 Green Option: Parkway with Center Bioswale Incorporating Urban Forestry and Rain Garden

A rain garden with curb cuts has replaced the traditional curb and gutter along the side of the street, allowing stormwater runoff to drain to the rain garden. A bioswale has been added to the center island. These practices add aesthetic and stormwater management benefits.

Concept Residential and Urban Uses

Green streets can utilize various GMPs to manage drainage and improve water quality. These practices can be used in residential and non-residential areas.

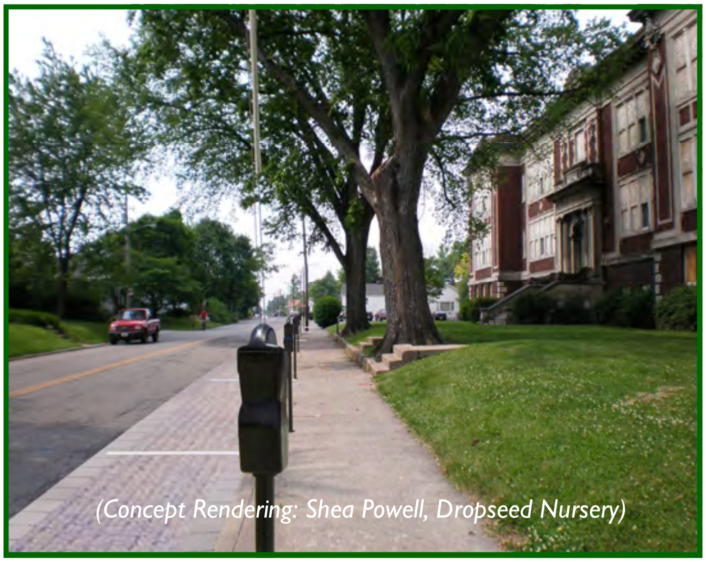
Existing: Street Parking with Traditional Curb and Gutter ➔

Traditional gray infrastructure, with curb and gutter stormwater management is a common practice.

(Photo Erin Wagoner, Concept Rendering: Shea Powell, Dropseed Nursery)

🡐 Green Option: Pervious Pavers Used in a Parking Area

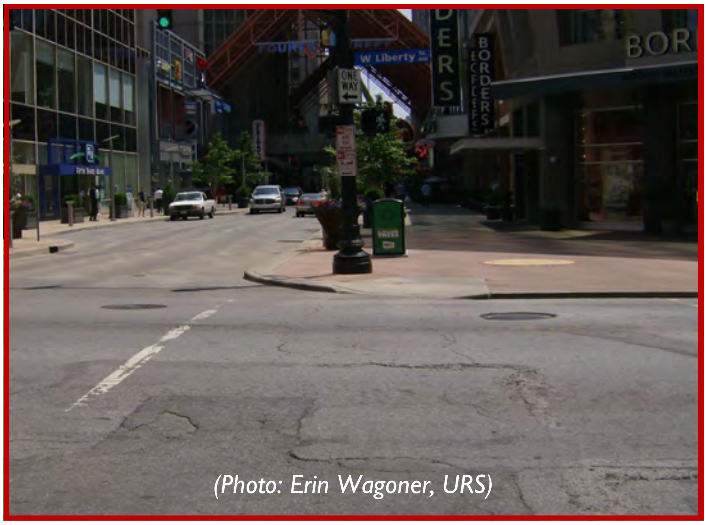
In this concept rendering, on-street parking has been converted from impervious pavement to permeable pavers.



(Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Traditional Curb and Gutter Used Along an Urban Street ➔

Existing conditions contain the use of curb and gutter in an ultra-urban area.



(Photo: Erin Wagoner, URS)

🡐 Green Option: Tree Box with Curb Cuts

The design strategy to the right demonstrates the use of curb cuts with tree boxes to treat stormwater. Permeable pavers are incorporated into this design, adding both stormwater management and aesthetic benefits.

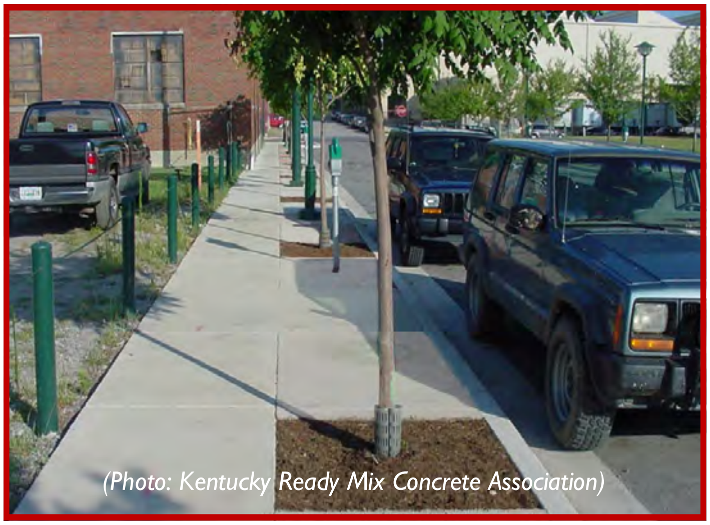
(Concept Rendering: Shea Powell, Dropseed Nursery)

Concept Residential and Urban Uses (Cont.)

Green streets can utilize various GMPs to manage drainage and improve water quality. These practices can be used in residential and non-residential areas.

Existing: Traditional Tree Box with Impervious Concrete ➔

Surrounding a tree box with impervious concrete is a common practice.



(Photo: Kentucky Ready Mix Concrete Association)

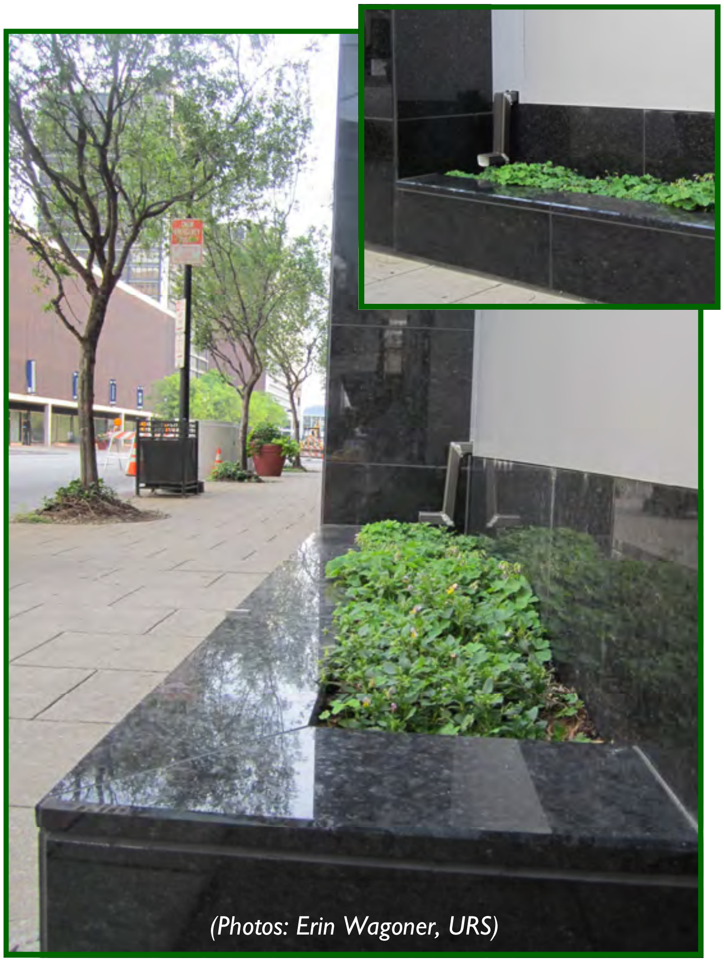
🡐 Green Option: Pervious Concrete Surrounding Tree Boxes

In this concept rendering, pervious concrete has been added adjacent to existing trees.

(Concept Rendering: Shea Powell, Dropseed Nursery)

Flow-Through Planter Box Along Downtown Storefront ➔

These photos along 4th Street show a small flow-through planter with flowering annual plants. The downspout is routed from inside the building to the planter box.



(Photos: Erin Wagoner, URS)

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18.4.2 Green Intersections

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Porous Asphalt
- ☑ Permeable Pavers
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales

Green Intersection Concept (Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Green intersections use landscape and hardscape GMPs to capture and treat stormwater. GMPs vary depending on the area and goals for the intersection. In some circumstances, it could be beneficial to use rain gardens.

Suitable Applications:

Green intersections are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Location and size of the intersection
- Minimum widths for service or emergency response vehicles
- Soil permeability
- Curb breaks can be retrofitted to route stormwater to GMPs prior to draining to catch basins
- Design consistency with local and state ordinances/regulations
- Surrounding land uses
- Pedestrian walking area, lighting and trash receptacles locations

Concept Corner Beautification

Green intersection GMPs can vary depending on the location of the intersection and the type of development near the intersection as demonstrated in the following pictures.

Existing: Traditional Asphalt Paving ➔

Traditional asphalt paving used for a park entrance near high traffic intersection.

(Photo: Erin Wagoner, URS)

(Concept Rendering Shea Powell, Dropseed Nursery)

← Green Option #1: Rain Garden is Incorporated into Park Access Entrance

This green intersection was designed with porous asphalt that spans the full width of the walkway and includes a rain garden and bioswale near the street. Stormwater from adjacent sidewalks and residential developments is intercepted by these facilities.

Green Option #2: Pervious Pavers are Used ➔

Permeable pavers are installed along the alley centerline and rain gardens and bioswales are installed along the street in this design. Stormwater from adjacent sidewalks and residential developments is intercepted by these facilities.

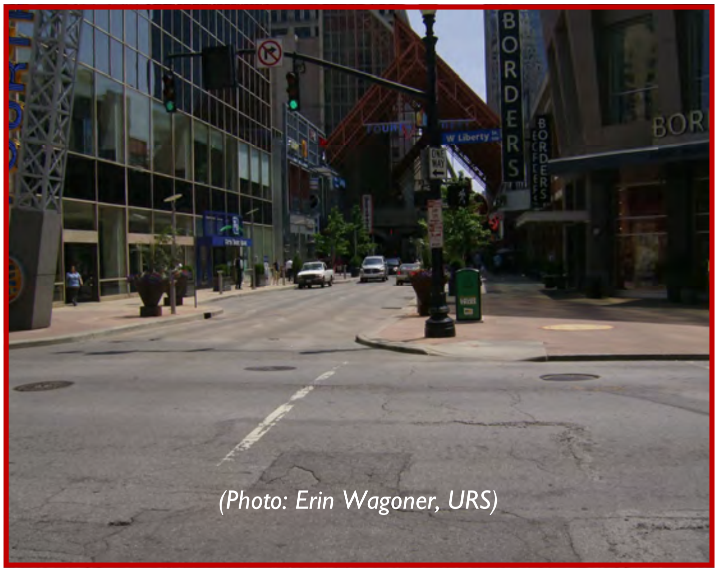
(URS Concept Rendering: Shea Powell ,Dropseed Nursery)

Concept Pervious Crosswalks

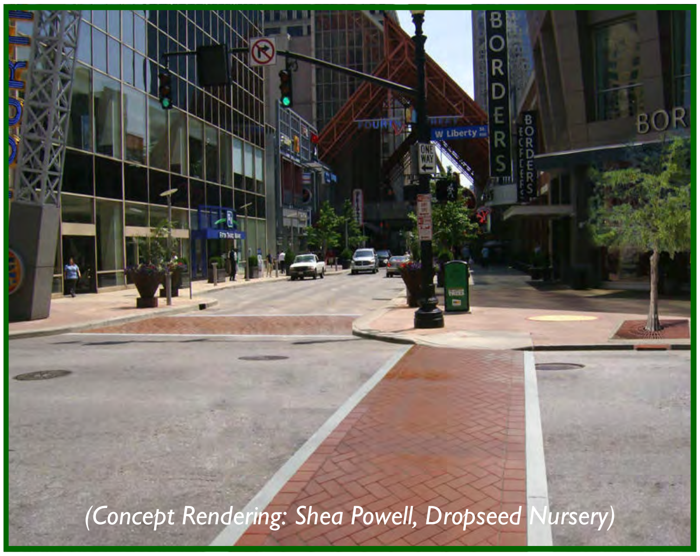
Green intersection GMPs can vary depending on the location of the intersection and the type of development near the intersection as demonstrated in the following pictures.

Existing: Intersection in Urban Area with Traditional Infrastructure ➔

An urban intersection is shown with a large amount of impervious area.



(Photo: Erin Wagoner, URS)



(Concept Rendering: Shea Powell, Dropseed Nursery)

➔ Green Option #1: Tree Boxes and Pavers Add Stormwater as well as Aesthetic Benefits

Pavers replace traditional asphalt along the street crosswalk. Tree boxes capture runoff from the street. Pervious concrete and porous asphalt can be substituted for pavers where appropriate.

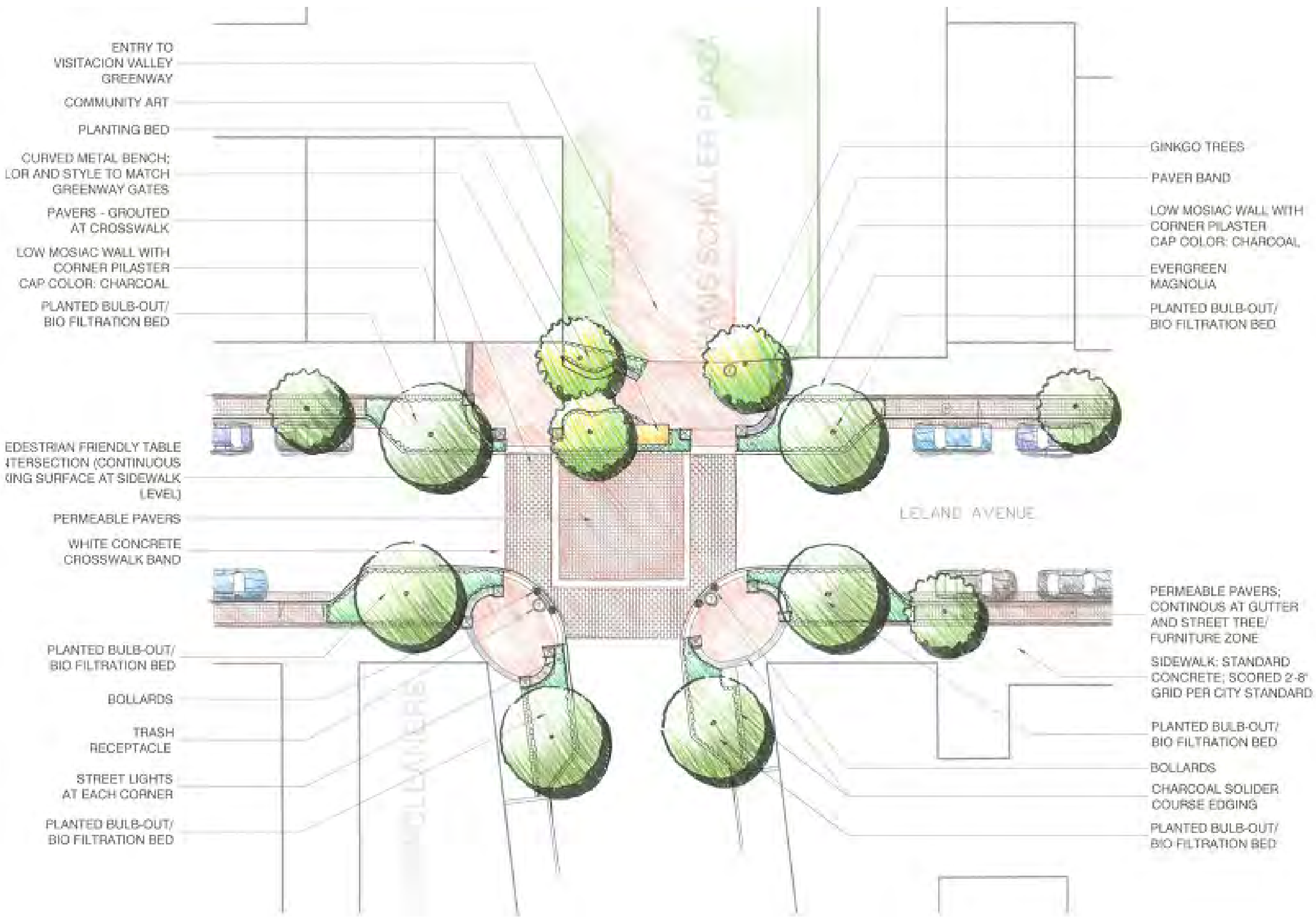
Green Option: #2: Use of Multiple GMPs ➔

This intersection includes the use of a curb cuts to collect stormwater from the street and direct it to a tree box, where it can filter though the soil medium. In this design, overflow and underdrain pipes prevent stormwater from collecting in the street.

(Concept Rendering: Shea Powell, Dropseed Nursery)

Concept Intersection Green Planning

Green intersection GMPs can vary depending on the location of the intersection and the type of development as demonstrated in the following green intersection design.



Example of a green intersection design in San Francisco (Courtesy of http://sf.streetsblog.org)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.3 Stormwater Curb Extensions

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales

Stormwater Curb Extension Concept (Concept Rendering: Shea Powell, Dropseed Nursery)

Description:

Stormwater curb extensions, like traditional curb extensions, are traffic calming measures that can extend the length of the sidewalk and reduce the crossing distance for pedestrians. Stormwater curb extensions utilize breaks in the curb and the space created inside the curb for infiltration GMPs including rain gardens, tree boxes or bioswales. Stormwater curb extensions capture, infiltrate and treat stormwater runoff through various GMPs.

Suitable Applications:

Stormwater curb extensions are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Curb extension compatibility with narrow street widths
- Minimum widths for service trucks and emergency response vehicles
- Soil permeability
- Curb break location (route stormwater to GMPs prior to draining to catch basins)
- Landscaping curb extensions with deep rooted native plants and trees
- Use of permeable pavers, pervious concrete or porous asphalt for on-street parking
- Use of a concrete edge on permeable pavers, pervious concrete or porous asphalt to limit clogging and facilitate street cleaning
- Existing utility locations and any conflict with curbing, soil depths, or other design improvements

Residential Implementation

Stormwater curb extensions can be located in urban or residential settings. The following pictures demonstrate the use of stormwater curb extensions in a residential setting.

Existing: Curb and Gutter Infrastructure ➔

This photo shows a traditional curb and gutter used in a residential neighborhood with grass and landscaped swales.

(Photo: Erin Wagoner, URS)

(Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option: Multiple GMPs

In this rendering, stormwater curb extensions create space for a bioretention cell and permeable pavers that are used to define on-street parking lanes. These practices capture stormwater runoff while enhancing the streetscape of the neighborhood.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.4 Green Alleys

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales

Green Alley Concept (Concept Rendering: Katherine Holmok, URS)

Description:

Green alleys use linear landscape and hardscape GMPs to capture and reduce runoff from the alley and adjacent properties. Green alleys capture, infiltrate and treat stormwater runoff through various GMPs.

Suitable Applications:

Green alleys are suitable for a wide variety of land uses of mid and high densities including residential and commercial.

Special Considerations:

- Alley width compatability with various GMPs
- Minimum widths for service trucks and emergency response vehicles
- Soil permeability
- Crowned alleys require primary GMPs along right-of-way edges
- Inverse crowned alleys require primary GMPs along the alley centerline
- Curb breaks can be retrofitted (route stormwater to GMPs prior to draining to catch basins)
- Existing utility locations

Green Alley Illustrations

Green alleys utilize centerline strips as infiltration areas or incorporate GMPs along the full width of the alley as demonstrated in the following pictures.

Existing: Traditional Alley ➔

Traditional inverse crowned alley with runoff from multi-family and single-family residences.

(Photo: Chad McCormick, URS)

← Green Option #1: Permeable Pavers Combined with a Rain Garden

In this concept rendering, permeable pavers span the full width of the street with rain gardens and bioswales along the right-of-way. Rain gardens capture the parking lot runoff prior to draining to the alley. Tree boxes with curb cuts can be used in place of rain gardens.

(Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #2: Permeable Paver Strip with a Rain Garden ➔

Permeable paver strip located along the alley centerline with rain gardens and bioswales along the right-of-way.

(Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option #3 Pervious Concrete Strip with Multiple GMPs

In this design, a porous asphalt strip along the alley centerline with rain gardens and bioswales along the right-of

(Concept Rendering: Shea Powell, Dropseed Nursery)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.5 Green Parking

Potential Green Management Practices Included:

- ☑ Permeable Pavers
- ☑ Pervious Concrete
- ☑ Porous Asphalt
- ☑ Tree Boxes and Planter Boxes

Grass Grid Pavers (Photo: Erin Wagoner, URS)

Description:

Traditional parking lots generate stormwater runoff that typically enters the storm sewer system though inlets at various points around the parking lot. Green parking incorporates various GMPs to capture, filter and infiltrate stormwater.

Suitable Applications:

GMPs include permeable pavers, pervious concrete, porous asphalt, pervious catch basin rings, infiltration planters and tree/planter boxes that are suitable for both new construction and to retrofit projects involving parking lots.

Special Considerations:

- Minimize the footprint of the parking lot, shared parking or create overflow parking green spaces
- Soil permeability and stability
- GMP locations relative to impervious areas
- Permeable catch basin rings, infiltration planters, tree boxes or permeable parking spaces can be used for retrofit applications
- Permeable pavers can be used to designate traffic lines, parking spaces or cross walks

Concept Parking Lots

Green parking can utilize various GMPs to reduce or offset the amount of impervious area of a parking lot as demonstrated in the following pictures.


(Photo: Erin Wagoner, URS)

Green Option #1: Permeable Catch Basin Rings ➔

Parking lot retrofit added a ring of permeable concrete and an aggregate sub base to infiltrate stormwater prior to entering the storm sewer system.


(Photo: Erin Wagoner, URS)

← Green Option #2: Permeable Grass Grid Pavers

Permeable grass grid pavers provide parking for low traffic areas at this park entrance. The permeable parking lot allows the opportunity for stormwater to infiltrate into the soil rather than running off into the adjacent creek.


(Photo: Erin Wagoner, URS)

Green Option #3: Permeable Concrete/Asphalt ➔

Traditional pavement is paired down gradient with pervious concrete parking spaces to capture and filter stormwater runoff prior to entering the adjacent creek.


(Photo: David Dods, URS)

← Green Option #4: Parking Drains to Bioswale

Through the use of a curb cut, this parking lot drains to a bioswale to treat stormwater.

Concept Commercial Parking Lots

Green parking can utilize various GMPs to reduce or offset the amount of impervious area of a parking lot as demonstrated in the following pictures.

Green Option #5: Parking Drains to Bioswale ➔

As an alternative to raised landscape and tree beds lining the entrance to this business, a tree bioswale accepts runoff from the parking lot and sidewalk.

(Photo: Lara Kurtz, URS)

← Green Option #6: Parking Drains to Tree Lined Swale

Stormwater from the parking lot of this shopping center drains off into a grass swale lined with trees. In addition, the catch basin is raised to allow temporary storage of stormwater.

(Photo: Erin Wagoner, URS)

Green Option #7: Internal Bioswale ➔

This parking lot at the Office of Employment in Louisville was designed with an internal bioswale to treat stormwater runoff from the parking lot, rather than using traditional raised beds.

(Photo: Erin Wagoner, URS)

← Green Option #8: Parking Drains to Corner Bioretention Cell

The parking lot of the Office of Employment in Louisville drains to a corner bioretention cell. Curbs with curb cuts allow stormwater to enter the bioretention cell while also keeping cars out.

(Photo: Erin Wagoner, URS)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.6 Downspout Disconnection

Potential Green Management Practices Included:

- ☑ Cisterns
- ☑ Rain Barrels
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Planters


Downspout Disconnection (Photo: Louisville & Jefferson County MSD)

Description:

Downspouts convey rooftop runoff, prevent basement flooding and reduce sewer system overflows when they are disconnected from the sewer system. Connected downspouts are most common in older neighborhoods. As part of the Plumbing Modification Program (PMP), MSD encourages property owners to disconnect downspouts, conveying stormwater to lawns, or to a GMP. Contact MSD Customer Relations at (502) 587-0603 for more information on the downspout disconnection program and the PMP.

Suitable Applications:

Downspout disconnection should be considered for any structure with improper downspout connections to the sewer system. For new construction or redevelopment, it is prohibited to connect downspouts to the sewer system.

Special Considerations:

- Proximity of adjacent buildings
- Direction of downspout conveyance prior to disconnection
- Routing disconnected downspouts to other GMPs, including rain barrels or rain gardens

Downspout Disconnections Illustrations

Downspout disconnection reduces sewer system overflows and can be paired with various GMPs to infiltrate and treat stormwater as demonstrated in the following photos.

Green Option #1: Disconnected Downspouts Flow Through Cisterns to a Bioswale ➔

In these two photos, tall cisterns store and release rooftop runoff to irrigate adjacent bioswales and rain gardens.


(Photo: Ted Wathen)


(Photo: Erin Wagoner, URS)


(Photo: Lara Kurtz, URS)

← Green Option #2: Disconnected Downspout Flows to a Rain Barrel

The rain barrel at this office building has a low profile and color that blends with the building. The rain barrell captures rooftop runoff released onto the lawn.

Green Option #3: Disconnected Downspout Flows to a Rain Garden ➔

The interior roof drains at this office building were disconnected from the sewer system and plumbed to discharge to a rain garden.


(Photo: Louisville & Jefferson County MSD)

Downspout Disconnections Illustrations (Cont.)

Downspout disconnection reduces sewer system overflows and can be paired with various GMPs to infiltrate and treat stormwater as demonstrated in the following photos.

Green Option #4: Disconnected Downspout Flows to a Rain Garden ➔

Downspouts on this building are routed to discharge to a rain garden.

(Photo: Louisville & Jefferson County MSD)

(Photo: Erin Wagoner, URS)

🡐 Green Option #5: Disconnected Downspout Flows to a Flow-Through Planter

The interior roof drains at this storefront on 4th Street are disconnected from the combined sewer system and routed to a small planter box with flowering annual plants.

18.4.7 Green Roofs

Extensive Green Roof Bed and Patio (Photo: Chad McCormick, URS)

Potential Green Management Practices Included:

☑ Extensive Green Roof
☑ Intensive Green Roof

Description:

Green roofs are roofs of buildings that are planted over a waterproof membrane with vegetation including plants, shrubs or trees. Green roofs capture and absorb rainwater, resulting in decreased stormwater runoff. Green roofs provide more than a stormwater benefit, such as reducing rooftop temperatures, creating urban habitats and enhancing outdoor gathering spaces. Green roofs include two types of GMPs: extensive and intensive green roofs.

Suitable Applications:

Green roofs are typically used in urban areas. All buildings must have the structural capacity to hold a green roof. Extensive green roofs use less than six inches of planting media, whereas intensive green roofs use greater than six inches of planting media. Rooftop applications will vary based on structural capacity of the building.

Special Considerations:

- Structural capacity of building
- Maintenance requirements
- Leak detection systems or tray systems
- Replacement of the green roof layers
- Green roofs can be used as a rooftop garden or gathering space
- Planting plans (choose plants with minimal irrigation requirements)

Concept Green Roofs

Green roofs absorb rainwater and can be constructed as elaborate rooftop gardens, gathering spaces or simply a low-maintenance and energy efficient building option.

Green Option #1: Extensive Green Roof Vegetable Garden ➔

This apartment building green roof is a rooftop garden for residents to gather. The garden includes beds for shrubs and vegetables.

(Photo: Chad McCormick, URS)

🡐 Green Option #2: Extensive Green Roof with Sedums

This extensive green roof was planted with sedums in a landscaped pattern that can be viewed from the office spaces. Excess stormwater that is not absorbed by the planting media is collected by cisterns and then conveyed to a bioswale and rain garden.

(Photo: Ted Wathen)

(Photo: Maggie Huber)

Green Option #3: Combination Extensive and Intensive Green Roof ➔

This green roof combines shallow extensive beds with deeper intensive beds planted with trees.

(Photo: Lousiville & Jefferson County MSD)

(Photo: Louisville & Jefferson County MSD)

🡐 Green Option #4: Green Wall

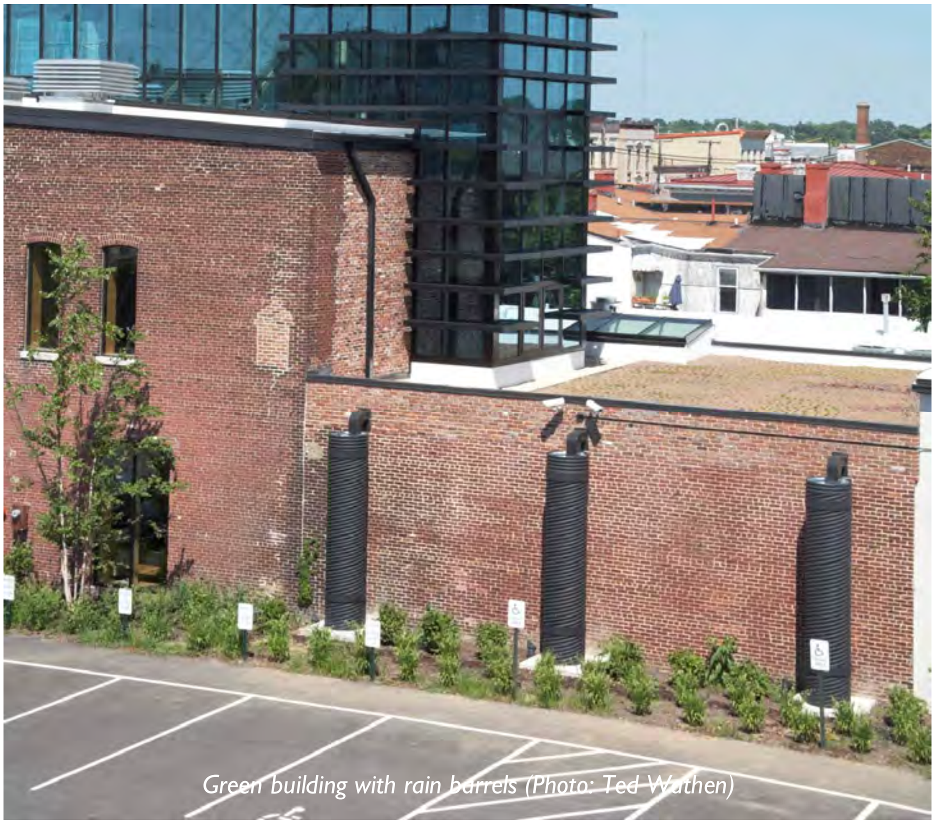
For added plant space and reuse of water collected from rooftops, green walls utilize similar concepts of a green roof, only they are planted vertically.

(Photo Erin Wagoner, URS)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.8 Rainwater Harvesting



Green building with rain barrels (Photo: Ted Wathen)

Potential Green Management Practices Included:

- ☑ Cisterns
- ☑ Rain Barrels

Description:

Rainwater harvesting is the practice of capturing and temporarily storing rainwater, typically from rooftops, in a cistern or rain barrel for beneficial use. The beneficial use often includes landscape watering, but may include water for flushing toilets (contact Louisville Metro Public Health & Wellness for regulations regarding reuse of rainwater), make-up water for HVAC units and boilers, and water for vehicle washing.

Suitable Applications:

Rainwater harvesting can be used in most land use practices including: high-density residential, commercial, institutional and industrial areas. Rainwater in a cistern or rain barrel can be used before the next rain event.

Special Considerations:

- Distance of the harvested rainwater from its intended use
- Water treatment requirements may limit use of harvested rainwater
- Storage of harvested rainwater below ground vs. above ground
- Contact Louisville Metro Public Health & Wellness for regulations regarding reuse of rainwater
- Use of harvested rainwater prior to the next rain event allows for continued harvesting

Commercial Rainwater Harvesting

The type of container used for rainwater harvesting, and its location below ground or above ground, can vary to match the needs of the site.

Existing: Downspout at Garden Center →

Typical downspout at the garden center of local box store.

(Photo: John Ricketts, URS)

(Photo: John Ricketts, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option: Cistern Utilized to Collect Stormwater

In this concept rendering, a cistern has been added and collects rainwater that can be used to irrigate plants in the

Existing: Car Wash with Traditional Design →

Typical car washing facility.

(Photo: John Ricketts, URS)

(Photo: John Ricketts, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

← Green Option: Cistern Utilized to Collect Stormwater

In this rendering, a cistern has been added to collect rainwater that can be used to supplement water for car washing.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.9 Urban Forestry

Potential Green Management Practices Included:

- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Constructed Wetland
- ☑ Wet Basins
- ☑ Dry Basins

Urban Forestry (Photo: Kory Johnson Photography)

Description:

Urban forestry is defined by the care and management of trees in urban settings. Urban forestry can vary from planting trees boxes in a sidewalk to preserving large acreages of trees in a city. The benefits of urban forestry include: reduction of the heat island effect, reduction of soil erosion, reduction of stream temperatures and reduced stormwater run-off. Trees direct precipitation towards the ground through their trunks and absorb stormwater through their roots. Trees can also provide bank stabilization in riparian buffers.

Suitable Applications:

Urban forestry practices can be used in residential neighborhoods, along urban streets, in street islands, in urban parks and multi-use facilities among others.

Special Considerations:

- Soil types and conditions (compaction, root volume, elevated pH, etc.)
- Combination of urban forestry with the disconnection of impervious areas
- Use of urban forestry as a visual buffer or part of a filter strip
- Types of tree species should be suitable for site conditions and aesthetics
- Location of the tree(s)
- Irrigation
- Location of other GMPs

Example Island Water Sinks

These pictures demonstrate some of the options for implementation of urban forestry into green site planning.

(Photo: David Dods, URS)

Green Option #1: Tree Boxes Used in Ultra-urban Area ➔

The picture to the right demonstrates the use of tree boxes along the street in an urban setting, adjacent to large impervious areas. These GMPs not only provide stormwater benefits, but also beautify the community.

(Photo: Lara Kurtz, URS)

🡐 Green Option #2: Trees Planted in a Bioswale

The picture to the left demonstrates the use of trees as part of a bioswale, serving both an aesthetic purpose and providing additional water quantity and quality benefits.

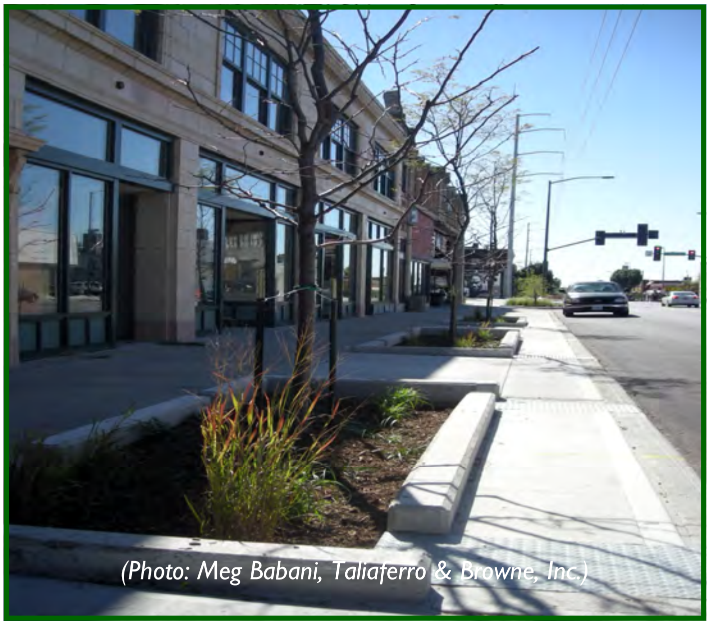
(Photo: Meg Babani, Taliaferro & Browne, Inc.)

Green Option #3: Tree Boxes in an Island ➔

The picture to the right demonstrates the use of urban forestry in a center island. This island not only provides stormwater benefits, but also provides a safety benefit by slowing traffic.

Concept Uses of Urban Forestry

These pictures demonstrate some of the options for implementation of urban forestry into newly developed and re-developed areas and the versatility of urban forestry.



(Photo: Meg Babani, Taliaferro & Browne, Inc.)

Green Option #1: Tree Boxes in an Urban Area ➔

The picture to the right demonstrates the use of urban forestry in a commercial development with a large amount of impervious area. The tree boxes provide both a water quality benefit and are aesthetically pleasing.

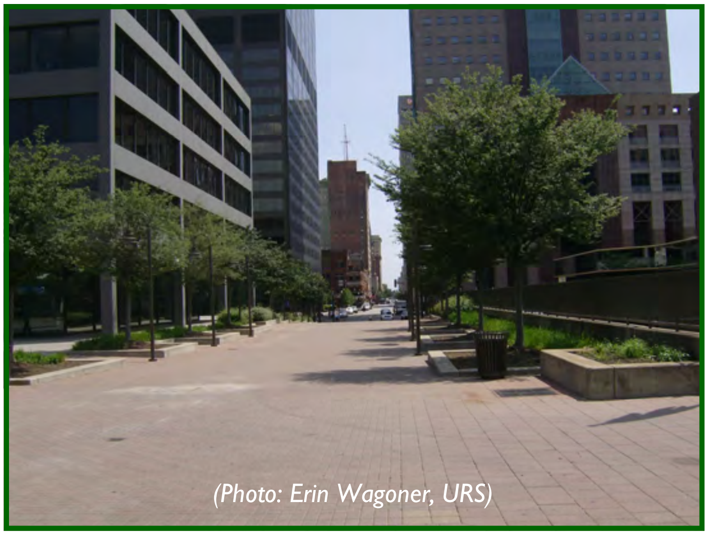
(Photo: David Dods, URS)

➔ Green Option #2: Tree Boxes with a Bioswale Curb Extension

The picture to the left demonstrates the use of urban forestry with tree boxes between a green space and street.

Green Option #3: Tree Boxes Used in a Metropolitan Multi-use Area ➔

The picture to the right demonstrates the use of urban forestry in an urban center with significant impervious area.



(Photo: Erin Wagoner, URS)

Concept Uses of Urban Forestry

These pictures demonstrate the wide variety of applications of urban forests designed in combination with other GMPs.


(Photo: David Dods, URS)

Green Option #1: Urban Forestry in a Constructed Wetland ➔

The picture to the right demonstrates the combination of a constructed wetland and urban forestry.


(Photo: David Dods, URS).

🡐 Green Option #2: Urban Forestry Used with a Wet Basin

The picture to the right demonstrates the use of a mowed buffer surrounding a wet basin, combined with urban forestry.

Green Option #3: Urban Forestry Used in a Dry Basin ➔

In this photo, young trees are planted in a green dry basin along the highway. These trees serve a stormwater benefit, provide aesthetic benefits, as well as noise reduction.


(Photo: David Dods, URS. Concept Rendering: Shea Powell, Dropseed Nursery)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.10 No Mow Buffer Zones

Bioretention cell at Willow Pond at Lexington Road and Grinstead Drive (Photo: Erin Wagoner, URS)

Potential Green Management Practices Included:

- ☑ Bioswales
- ☑ Rain Gardens
- ☑ Basins

Description:

No mow buffer zones are natural undisturbed areas that treat and control stormwater before entering a stream or wetland. These areas remove pollutants through filtration and infiltration. There are many benefits from the use of no mow buffer zones, including: groundwater recharge, valuable corridor protection for streams and wetlands, and the reduction of pollutant loads to local waterways and wetlands.

Suitable Applications:

No mow buffer zones can be used in residential, commercial and industrial developments. They can also be used in combination with GMPs on nearby properties to manage stormwater quantity and quality.

Special Considerations:

- Natural depressions utilized for runoff storage
- Buffers must be fully vegetated
- Local ordinances and minimum buffer requirements (check local MS4 and floodplain management ordinances)
- Public outreach and education of citizens regarding the purpose of no mow buffer zones
- Reduced mowing costs
- No mow signage

No Mow Buffers Concepts

No Mow Buffers can be used with various land uses. The pictures below demonstrate No Mow Buffers in residential and park settings.

(Photo: Sabak, Wilson and Lingo, Inc.)

Green Option # 1: Residential No Mow Buffer ➔

The picture to the right demonstrates the use of a no mow buffer in a residential area. Education and outreach is a key component for obtaining community acceptance of no mow buffers.

(Photo: Sabak, Wilson and Lingo, Inc.)

🡐 Green Option #2: Walking Trail with a No Mow Buffer

No mow buffers can be used in multi-use areas and parks.

Green Option # 3: No Mow Buffer in a Park ➔

No mow buffers preserve habitat for wildlife and provide stormwater benefits.

(Photo: Kristen Dunaway, URS)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.4.11 Stream Buffers

Potential Green Management Practices Included:

N/A

(Photo: Lousiville & Jefferson County MSD)

Description:

Stream buffers are vegetated filter strips or undisturbed natural areas that treat and control stormwater before entering the stream. These areas remove pollutants through filtration and infiltration. There are many benefits from the use of stream buffers, including: groundwater recharge, valuable corridor protection for streams and wetlands, and the reduction of pollutant loads to local waterways and wetlands.

Suitable Applications:

Stream buffers can be used in residential, commercial and industrial developments. They can also be used in combination with GMPs on nearby properties to manage stormwater quantity and quality. When planned, designed and maintained correctly stream buffers can protect streams from polluted stormwater discharges, manage stormwater quantity, especially during rain events, and play an important role in protecting habitats.

Special Considerations:

- Width and planned vegetation (buffers must be fully vegetated)
- Legal mechanism to preserve the buffer into perpetuity
- Protection of the native vegetation
- Local ordinance (Land Development Code) requirements
- Natural depressions utilized for runoff storage

Stream Buffers Illustrations

Stream Buffers are an important part of floodplain management. The following pictures demonstrate different stream buffers and their application in various types of land uses.

Green Option #1: Stream Buffer ➔

The stream buffer to the right demonstrates the use of urban forestry and a stream buffer.

(Photo: Erin Wagoner, URS)

(Photo: Erin Wagoner, URS)

🡐 Green Option #2: Stream Buffer Used as a Filtration Practice for a Parking Lot

This parking lot drains to a stream buffer before entering the local stream. The use of the buffer will slow the stormwater runoff, filter pollutants and reduce the temperature of the stormwater before entering the stream. Pervious concrete, asphalt, or pavers can be used in combination with the stream buffer.

Green Option #3: Stream Buffer Used in a Residential Development ➔

This picture demonstrates a stream buffer that would be common as part of a residential development. The use of the buffer will help to prevent streambank erosion in this neighborhood.

(Photo: Kristen Dunaway, URS)

(Photo: Louisville & Jefferson County MSD)

🡐 Green Option #4: No Mow Stream Buffer

This stream buffer demonstrates a riparian buffer, under high water conditions, that is not mowed.

Stream Buffer Illustrations

Stream buffers can be used to protect structures and in combination with GMPs.

Green Option #1: Stream Buffer Used to Protect Residential Land Use ➔

This picture demonstrates the benefit of a stream buffer after a rain event. Water overflows stream banks and does not flood the lower level of a structure on the adjacent property.

(Photo: Louisville MSD)

(Photo: Louisville MSD)

← Green Option #2: Stream Buffer in an Urban Forest

This picture demonstrates the use of stream buffers and urban forestry through the preservation of regional GMPs.

Green Option #3: Use of Pervious Pavers Near a Stream Buffer ➔

The picture to the right demonstrates the use of pervious pavers near a stream buffer in a parking lot.

(Photo: Erin Wagoner, URS)

(Photo: Louisville MSD)

← Green Option #4: Multi-use Stream Buffer in a Local Park

During dry weather the buffer areas in this park are used for recreation, including areas for picnic tables.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Infrastructure Design Strategies

18.4.12 Green Detention Basins


Cedar Pond Park Lake (Photo: Rusty Schmidt, URS)

Potential Green Management Practices Included:

☑ Green Wet Basins
☑ Green Dry Basins

Description:

Retrofitting a wet detention basin involves the addition of native, deep-rooted plantings along the perimeter of the basin, just below the normal pool level and along the banks in the extended detention portion of the basin. A new wet basin should be designed to include these plantings. Retrofitting a dry detention basin or installing a new dry detention basin involves the addition of native, deep-rooted plantings along the entire bottom of the basin, a sediment forebay to collect the heavier sediment, a multi-stage outlet to temporarily detain runoff from smaller, more frequent rain events, and the removal of any low flow channels to promote sheet flow across the basin floor. All of these options provide water quality benefits not afforded by the traditional wet and dry basins.

Suitable Applications:

Newly designed basins or any wet or dry basin that was not designed with native, deep-rooted plantings to provide water quality treatment through the vegetation up taking and filtering pollutants and that does not include a multi-stage outlet to temporarily detain the smaller, more frequent rain events.

Special Considerations:

- Proper slope to accommodate a vegetated bench, prevent ponding water, etc.
- Reconfiguration of outlet structures to properly detain smaller storms

Retrofit Illustrations

Traditional wet and dry basins are modified to add native, deep-rooted plantings and multi-port outlets that allow temporary detention of runoff from smaller, more frequent rain events.

Existing: Traditional Wet Basin →

This picture illustrates a traditional wet basin in a business park.

(Photo: David Dods, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Existing: Dry Basin with a Low Flow Channel →

A traditional dry basin is shown here, with a concrete-lined, low flow channel near an interstate.

(Photo: David Dods, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

(Photo: David Dods, URS)

← Green Option: Retrofit with a Vegetated Beach

This concept rendering shows a vegetated bench around the perimeter of this green wet basin provides water quality benefits.

(Photo: David Dods, URS)

← Green Option: Retrofit with Native Vegetation

In this concept rendering, native vegetation and the promotion of sheet flow along the bottom of the green dry basin provides water quality benefits.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18. 4.13 Parks and Multi-Use Areas

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Wet Basins
- ☑ Dry Basins
- ☑ Constructed Wetland

Arthur K. Draut Park, St. Matthews (Photo: Kristen Dunaway, URS)

Description:

Parks and multi-use areas are an opportunity for communities to provide water quality and quantity benefits. These green spaces can be used to collect and treat water during storm events. During dry weather, these areas can be used for public facilities, including parks, sports, hiking, walking and biking paths.

Suitable Applications:

If the conditions are appropriate all of the GMPs in this manual can be implemented into parks and multi-use areas.

Special Considerations:

- Goals for the area
- Existing infrastructure and surrounding development
- Local ordinance requirements (check MS4 ordinances and Land Development Code)
- Fencing around some GMPs for safety

Multi-use Illustrations

These pictures demonstrate some of the options for GMPs in multi-use areas.

Green Option #1: Wetland Area with Walking Paths ➔

A wetland in an urban area that includes walking paths.

(Photo: Kristen Dunaway, URS)

(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

➔ Green Option #2: Baseball Field Used in a Dry Basin

This picture demonstrates a sports field located in a detention basin. Multi-use areas can be included in large detention basin areas for larger storms.

Green Option #3: Play Ground and Picnic Area in a Dry Basin ➔

Multi-use areas are an efficient land use in urban or built out areas where land for detention is limited.

(Photo: Erin Wagoner, URS)

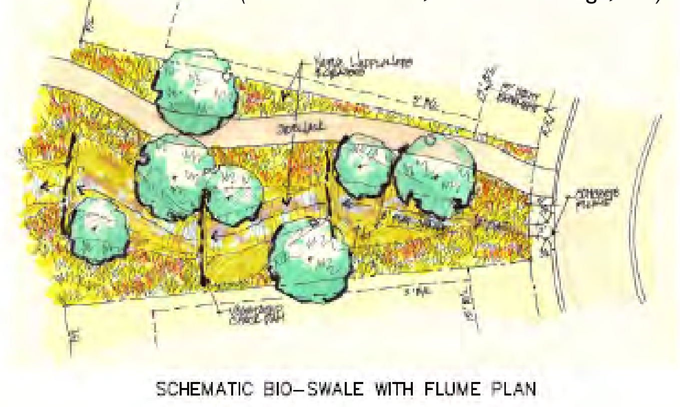
Multi-use examples:
These pictures demonstrates the variety of uses for multi-use areas ranging from business offices to detention areas.

Green Option #1: Rain Garden Used in an Open Space Near an Office Complex ➔

This project demonstrates the use of an open space area with a rain garden. This area not only serves stormwater management needs but is also an area for employees to enjoy. Native plants and multi-cultivars are options for plantings.

(Photo: Lara Kurtz, URS)

(Schematic: Sabak, Wilson and Lingo, Inc.)



← Green Option #2: Traditional Gray Infrastructure Used in Combination with Green Infrastructure

This schematic demonstrates the use of gray infrastructure with a bioswale.

Green Option #3: Swale in a Residential Green Space ➔

This picture demonstrates an open space in a residential area that also serves as drainage during storm events.

(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Local Park and Multi-use Areas

These pictures demonstrate some of the options for multi-use areas with stormwater benefits.

(Photo: Kristen Dunaway, URS)

Green Option #1: Park Space and Urban Forestry➔

This picture demonstrates a combination of green infrastructure design strategies, including urban forestry and multi-use concepts. The picture also shows the use of elevation for permanent structures.

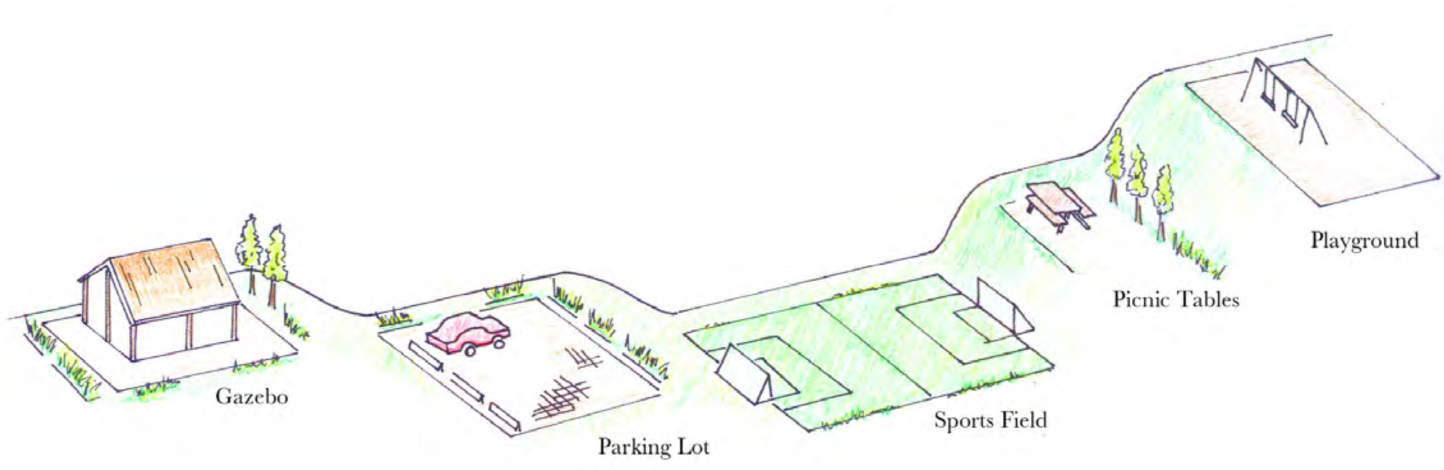
(Photo: Kristen Dunaway, URS)

← Green Option #2, Walkways, Urban Forestry, Stream Buffers, and Use of Retention Areas

This picture demonstrates the use of stream buffers and the use of retention areas in an urban park.

Local Park and Multi-use Areas

These pictures demonstrate some of the options for multi-use areas with stormwater benefits.



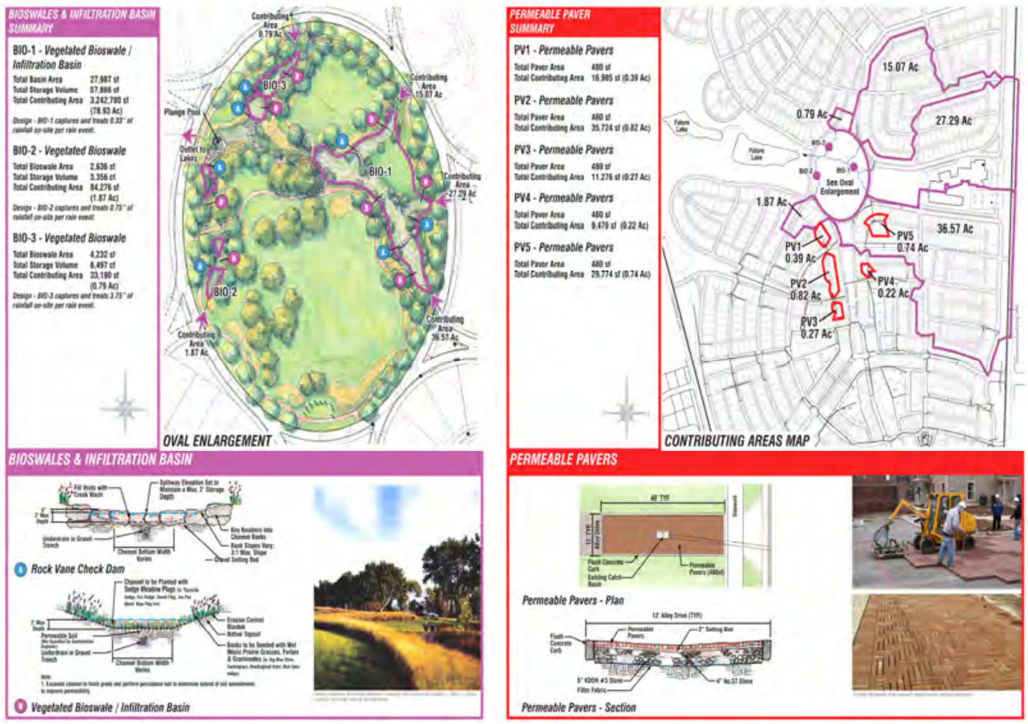
(Sketch: Shea Powell, Dropseed Nursery)

The sketch demonstrates the concept of a multi-use area that can serve recreational purposes as well as stormwater benefits. The sports field is located where it is more likely to have standing water for longer periods of time, when compared to the higher elevations. As the elevation increases, so do the structures, since flooding of these areas is less likely to occur.

18.4.14 Residential Neighborhoods

Potential Green Management Practices Included:

- ☑ Pervious Pavement
- ☑ Tree Boxes
- ☑ Planter Boxes
- ☑ Rain Gardens
- ☑ Bioswales
- ☑ Rainwater Harvesting
- ☑ Pervious Pavers
- ☑ Catch Basin Inserts
- ☑ Detention Basins
- ☑ Downspout Disconnections



Residential Neighborhood Concept Plan (Sabak, Wilson and Lingo)

Description:

GMPs can be used in new and existing residential neighborhoods. A variety of green infrastructure approaches can be used in a residential setting. There are many benefits resulting from the implementation of GMPs that include but are not limited to: increased greenspace, reduced paving if clustering is used, encouraged recreational use, preservation of historical features, forests, streams and agricultural areas, stormwater runoff reduction, improved water quality, and increased property values.

Suitable Applications:

Applications of GMPs in residential neighborhoods is dependent on site specifics and community acceptance of aesthetics. For example, a cistern may not be as accepted from an aesthetics perspective as a well maintained detention pond.

Special Considerations:

- Local planning and land development codes
- Future resident acceptance of GMPs
- Narrow street widths and their compatibility with GMPs
- Minimum widths requirements for service trucks and emergency response vehicles
- Narrow sidewalks on one side of the street only
- Driveway length and width, or shared driveways
- Use of permeable pavement in parking areas, sidewalks and driveways
- Use of bioswales or other GMPs in right of ways
- Retrofitted curb breaks used to route stormwater to GMPs
- Green roofs for multi-family residential sites
- Use of planter boxes for stormwater treatment

GMPs in Residential Neighborhoods

The following pictures demonstrate implementation of GMPs in residential neighborhoods.

Green Option #1: Plan for a Low Impact Development ➔

This plan demonstrates practices for reducing impervious cover and conserving natural site features, including tree cover.

(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

Green Option #3: Bioswales Used for Drainage in Apartment Complex ➔

This picture demonstrates the use of a bioswale in a residential area.

(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

(Concept Plan: Sabak, Wilson and Lingo, Inc.)

🡐 Green Option #2: Pervious Pavers and Curb Cuts

Pervious pavers and curb cuts can be used in combination with rain gardens and bioswales, as demonstrated in this picture. This rain garden captures the street runoff and replaces the catch basin.

(Photo: David Dods, URS)

🡐 Green Option #4: Pervious Pavers Used Between Street and Sidewalk

The photo rendering to the left demonstrates the use of pervious pavers. The pervious pavers are depicted where cars park along the road, as opposed to high traffic areas.

Rain Garden and Bioswales Illustrations

These pictures provide examples of GMPs in residential neighborhoods.

(Photo: David Dods, URS)

Green Option #1: Rain Garden in an Existing Development ➔

This picture shows a rain garden in an existing development. A modification has been made to the traditional curb and gutter to direct stormwater to the rain garden.

(Photo: Erin Wagoner, URS; Concept Rendering: Shea Powell, Dropseed Nursery)

🡐 Green Option #2: Rain Garden Used along a Parkway

This GMP design replaced a traditional curb and gutter so that stormwater run-off drains to the rain garden.

Green Option #3: Rain Garden for Drainage Between Two Homes ➔

The use of a rain garden between two homes is used to manage stormwater for two properties. This rain garden has aesthetic benefits while providing stormwater benefits.

(Photo Courtesy of Louisville & Jefferson County MSD)

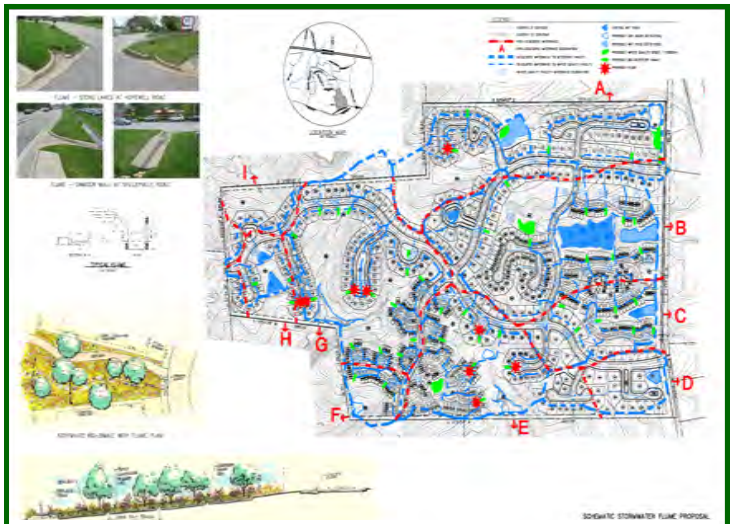
Planning Illustrations

The following demonstrate the implementation of GMPs during the planning phase.

Green Option #1: Concept Plan for Conservation Subdivision ➔

GMP practices are proposed in the concept plan to the right. This concept plan promotes stormwater infiltration rather than conveyance and concentration to reduce erosion and enhance stormwater quality. Infiltration and grass swales are used as GMPs in place of piping, culverts and paved ditches to reduce runoff, promote infiltration and improve water quality. The plan for this conservation subdivision also preserves tree canopies.

(Concept Plan: Sabak, Wilson & Lingo, Inc.)



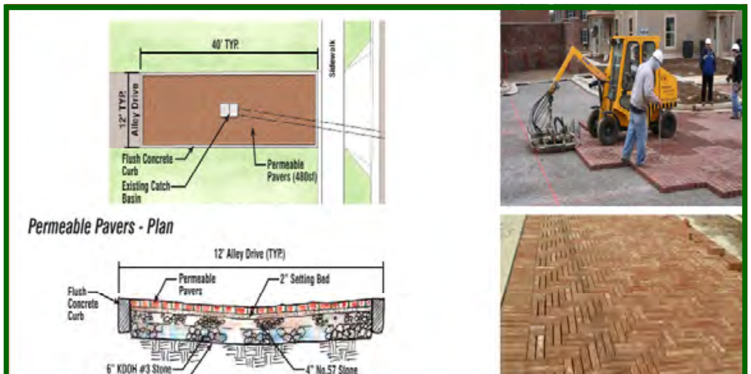
(Concept Plan: Sabak, Wilson & Lingo, Inc.)

🡐 Green Option #2: Design Demonstrates the Use of Traditional Gray Infrastructure with GMPs

The plan to the left demonstrates the use of a bioswale containing an energy dissipating flume to direct the runoff from the street to the bioswale.

Green Option #3: Use of Permeable Pavers in Residential Development ➔

The picture to the right demonstrates the use of pervious pavers in a residential area.



(Concept Plan: Sabak, Wilson & Lingo, Inc.)

Planning Illustrations

The following demonstrate the implementation of GMPs during the planning phase.

Green Option #1: Aerial Photo of Narrow Streets ➔

This residential neighborhood used narrow streets to reduce impervious area and to enhance preservation of open spaces.

(Photo: Sabak, Wilson and Lingo, Inc.; Concept Rendering: Shea Powell, Dropseed Nursery)

(Concept Plan: Sabak, Wilson and Lingo, Inc.)

🡐 Green Option #2: Open Space Preservation

This development demonstrates the implementation of open space preservation in a residential development.

Green Option #3: Preservation of Natural Areas ➔

In this residential neighborhood, sinkholes were preserved as natural areas.

(Concept Plan: Sabak, Wilson and Lingo, Inc.)

GMP Illustrations

The following demonstrates the various GMPs that can be used in residential areas.

Green Option #1: Detention Basin in a Residential Area ➔

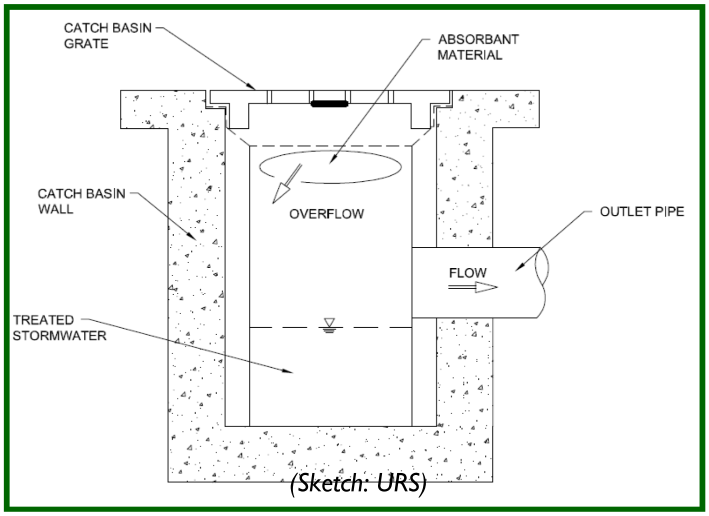
This picture demonstrates the use of a detention basin in a residential neighborhood.

← Green Option #2: Downspout Disconnection on a Residential Home

Downspouts can be disconnected in a residential neighborhood to capture rooftop run off and store it in a rain barrel, or to discharge and infiltrate into a rain garden.

Green Option #3: Catch Basin Inserts Can Be Used in Residential Neighborhoods ➔

Catch basin inserts can be used for construction and post-construction purposes.



Fact Sheet Key

Louisville and Jefferson County MSD logo and address

Louisville and Jefferson County Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.1 Bioswales

Chapter and section number and the GMP type.

Examples of areas that the GMP is typically installed or examples of the most applicable site for installation.

Typical Implementation Areas:

- Multi-use areas (commercial courtyards, entranceways)
- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/ median
- Downspout conveyance
- Drainage areas up to 5 acres

Areas of interest or special considerations required for installation of the given GMP.

Key Considerations:

- Use native vegetation
- Overflow structure

Typical relative capital cost and maintenance efforts for each GMP are categorized as Low, Low-Medium, Medium, Medium-High, and High.

Cost: Low
Maintenance: Low

Landscaped bioswale shown adjacent to sidewalk (Photo: David Dods, URS)

Photo/illustration of a typical implementation or schematic of the GMP.

Stormwater Management Benefits

Typical pollutant removal benefits of the GMP.

Typical hydrologic capabilities of the GMP.

Typical ability of the GMP to capture the volume of runoff from the drainage area.

Stormwater Management Benefits	
Pollutant Reduction	
Sediment	Significant Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Partial Benefit
Oil and Grease	Partial Benefit
Dissolved Pollutants	Partial Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Partial Benefit
Infiltration	Partial Benefit
Stormwater Conveyance	Partial Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Partial Benefit

Key: Significant Benefit; Partial Benefit; Low or Unknown Benefit

Signifies the amount of benefit the GMP will provide.

General description of the GMP with bulleted items that highlight the GMPs ability to improve water quality.

Bioswales are stormwater conveyance features that mimic the ecological function of a landscape, often as replacements to open ditches or underground pipes. Bioswales are generally shallow, wide, and gently sloped, and contain deep rooted native vegetation that helps slow and filter stormwater. In some cases they also promote infiltration or contain underdrains. Bioswales improve water quality through:

- ☑ Reduction of runoff velocities passing through dense vegetation
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater (dependent upon design)
- ☑ Biological uptake through native plants

Potential design limitations and benefits with installation of the GMP.

Advantages/Benefits

- Conveys runoff while improving water quality
- Reduces volume of stormwater runoff
- Infiltration and groundwater recharge
- Fits in narrow spaces
- Increases biodiversity by providing urban habitats for wildlife
- Reduces channel/stream bank erosion
- Lowers curb and pipe costs

Disadvantages/Limitations

- Increased maintenance over traditional curb and gutter drainage systems
- Potential for erosion if not installed and maintained properly
- Increased maintenance during and following large storm events
- Property ownership and long-term maintenance agreements
- Not recommended for steep slopes (>4%)

Effective:

Effective date

Page number

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
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Green Management Practice (GMP) Fact Sheet

18.5.1 Bioswales

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- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/ median
- Downspout conveyance
- Drainage areas up to 5 acres

<u>Key Considerations:</u>
- Use native vegetation
- Overflow structure

<u>Cost:</u> Low
<u>Maintenance:</u> Low

Landscaped bioswale shown adjacent to sidewalk (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant Benefit
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Disadvantages/Limitations

- Increased maintenance over traditional curb and gutter drainage systems
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- Property ownership and long-term maintenance agreements
- Not recommended for steep slopes (>4%)

Application and Site Feasibility

Bioswales are linear features that are used to convey stormwater runoff at a slower rate to promote filtration and infiltration. They may also be designed in non-linear or meandering shapes to match site characteristics, or to create a naturalized appearance. Bioswales are appropriate for use in a wide variety of land use applications such as commercial, industrial or medium to high density residential areas.

Physical Site Considerations

Key physical considerations are:

- Space available—Sufficient space is required to convey peak flow rates without overtopping the swale
- Slopes—Slopes affect flow rates, swale capacities, infiltration rates, and erosion
- Soil types—Soil types affect infiltration and erosion; sandy permeable soils promote infiltration but are also susceptible to erosion

Design Criteria

The design of a bioswale includes several elements to manage stormwater infiltration, as well as stormwater conveyance, to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.1-A. Note that bioswale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Design criteria to consider includes:

- Flow capacity, velocity and freeboard
- Erosion prevention
- Slopes
- Inlet and pretreatment
- Soil composition
- Plant selection
- Outlet design
- Mosquito Control
- Maintenance

Flow Capacity, Velocity and Freeboard

Since swales are conveyance features, they are designed to slow and detain small storm events while also safely passing large storms with adequate freeboard. Flow velocity calculations for evaluating erosion protection needs are typically done assuming new or short vegetation. Flow conveyance and freeboard calculations for large storms typically assume taller, denser vegetation when the plants are fully grown.

Stepping stones allow accessibility across this bioswale (Photo: Rusty Schmidt, URS)

Bioswales along the roadway should have adequate flow conveyance and maintain adequate freeboard to avoid flooding or overtopping the pavement. When bioswales are in close proximity to the pavement structure, they should have enough flow capacity to provide positive subgrade drainage.

Erosion Prevention

Bioswales should be lined with biodegradable erosion control matting for erosion prevention and sediment control during the plant establishment period. Turf reinforcement mats, or other enhanced erosion protection may be necessary in locations of concentrated flow or to protect against high stormwater velocities produced by large storm events. Mat selection should be based upon anticipated flow velocities, vegetation planting requirements, and longevity needs. When bioswales are used in conjunction with underdrains or storm sewer systems along roadways, make sure that drainage inlets are not blocked or obstructed by bioswale features.

Slopes

Site topography should be considered in bioswale design, including slope and cross-sectional area to maintain non-erosive velocities. Typically, slopes should be 1 to 2%. Where there are poor soils or slopes less than 1%, an underdrain system should be used. In areas with slopes greater than 4%, check dams or weirs should be placed perpendicular to the flow to increase detention and extend time for infiltration. Placement of check dams or weirs should include scour protection to limit erosion. See Figures 18.5.1-F, G, H, & K for check dam placement and bioswale design layouts.

Inlet and Pretreatment

Pretreatment should be used for most applications to ease maintenance, especially in land use areas with high sediment loads. The use of a forebay, weir or check dam at the inlet facilitates maintenance and removal of accumulated sediment.

Soil Composition

Consider soil types when selecting erosion control materials. Soil type affects erosion potential and infiltration rates. Heavier clay soils are less prone to erosion but have lower infiltration rates. Sandy, permeable soils promote infiltration, but are more prone to erosion. Infiltration rates in tighter soils will improve over time as plants grow and their root systems penetrate into the soil.

Check dams can be used temporarily to pond water within swales to slow flows, prevent erosion and promote infiltration. Consider whether you want them to be impermeable and pool water behind them for prolonged periods, or allow water to slowly drain through them after storm events pass. Typical construction materials are earth, stone, river rock, and rot resistant timbers.

Evaluate in situ soil conditions and consider the following options when designing the soil composition for a bioswale:

1. In Situ Soils Option 1: If the primary purpose is to convey drainage while filtering, consider a bioswale design with in situ soils. Topsoil should be stripped and stockpiled for reuse or after final grading, 2 to 3 inches of compost should be tilled to support plant growth. This is the least expensive option, but allows minimal infiltration. See Figure 18.5.1-A.
2. Engineered Soils Option 2: If the primary purpose is to promote infiltration and improve water quality, amend in situ soils with an engineered soil mix and add check dams. Erosion control design options must be considered when using engineered soils, however they provide increased pollutant filtering capacity and pore space. See Figure 18.5.1-B.
3. Engineered Soils with Underdrain Option 3: If the primary purpose is to promote infiltration and improve water quality while limiting standing water, amend in situ soils with an engineered soil mix and add check dams and an underdrain system. This option is more expensive and requires careful consideration of erosion control design options, but has increased filtering capacity and void space. See Figures 18.5.1 C & D.

Bioswale with naturalized, established native plantings (Photo: David Dods, URS)

Bioswale with rustic log check dam and new plantings (Photo: David Dods, URS)

For soil composition Option 2 and 3, the soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum for Option 1, but higher infiltration rates are recommended for the Engineered Soils Options.

For all options, the soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5%, by weight. The following soil mix is recommended, but other soil mixtures may be used based on site characteristics and proposed plantings. To enhance infiltration rates and prevent soil consolidation over time, a soil mix with a high sand content is recommended. The typical soil mix to enhance infiltration rates and prevent soil consolidation over time consists of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

For plants that need a higher organic content and less well-drained soils to support growth and development, a soil mix with a higher content of compost may be appropriate. However, testing of infiltration rates and soil aeration may be needed over time to maintain the functionality of the bioswale. Where appropriate for site conditions and plantings, consider this soil mix consisting of the following materials, by volume:

- 60% organic compost
- 30% construction sand
- 10% topsoil

When grading and soil mix placement are performed, care should be taken that soil is not compacted, resulting in diminished infiltration capacity. For soil composition Option 3, underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed KY #57 stone. Filter fabric should be avoided due to its propensity for clogging. To minimize the migration of soil particles into the stone layer and underdrain, layer double washed KY #8 stone over the double washedKY #57 stone layer (Option 3a). Where filter fabric is necessitated, choose non-woven filter fabric (Option 3b). Cross-sections of soil composition options and underdrain schematics are provided. See Figures 18.5.1 -A through 18.5.1-E.

A primary function of bioswales, like traditional swales, is the conveyance of stormwater. For this reason, the use of a herbaceous layer of ground cover is recommended over mulching to prevent erosion of mulch and soil layers. As the herbaceous ground cover is established, it will stabilize the soil layers beneath during significant flow events. However, if mulch is used, fresh shredded bark mulch is preferred to maximize nitrogen retention. The slope of the bioswale should be designed to minimize erosion. Mulch should be applied as an even 2 to 3 inch layer avoiding mounding around trees and shrubbery.

Plant Selection

Bioswales are typically planted with deep rooted native grasses, sedges, and forbes. They are also planted with shrubs and trees avoiding inflow entrance areas or other areas where they may block flow. In selecting plants, consider whether the swales are designed to dry out between storm events, or retain water for prolonged periods behind check dams. Also consider the different planting zones in the swales because the bioswale bottom may be moist while the sides will dry out quickly. Select various plants accordingly.

Whether to plant with seed or plugs is often an economic concern. Seeding is less expensive initially, but requires a longer establishment period. Plugs are more expensive than seed, but grow in quicker.

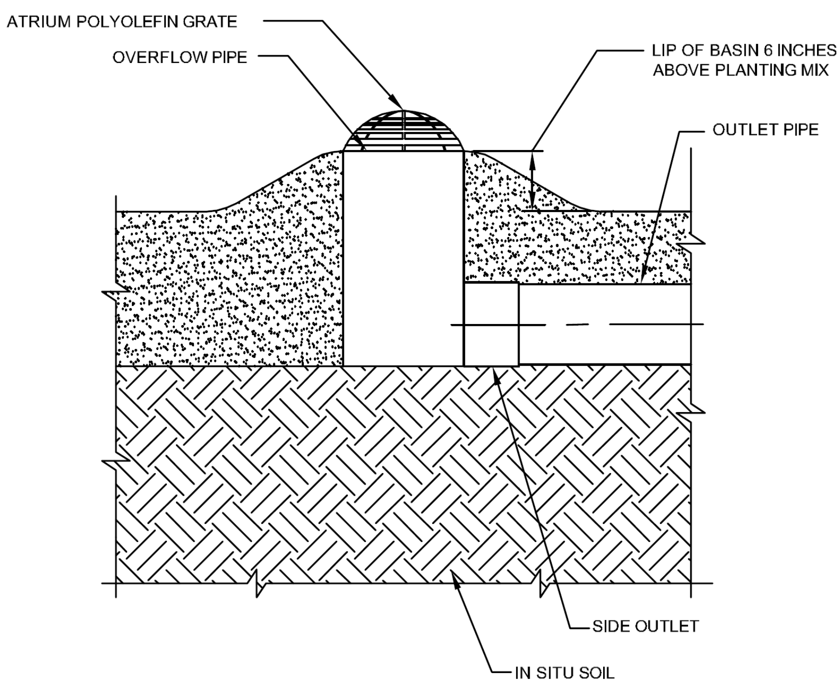


Figure 18.5.1-E. Overflow drain detail

A list of native species is provided in Chapter 13 of the MSD Design Manual. Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Cultivar species are provided in Chapter 13 of the MSD Design Manual.

Outlet Design

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. See Figure 18.5.1-E.

Mosquito Control

By their design, bioswales are not in danger of becoming a breeding ground for mosquitoes. See Table 18.5.1-A for bioswale residence time and drawdown time. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining bioswale, the chances of providing mosquito habitat are virtually eliminated. If the bioswale holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Bioswales are typically linear practices, but can be located in series with other GMPs such as rain gardens or bioretention to supplement infiltration and volume control.

Educational Awareness

The difference between bioswales and traditional landscaped areas may not be visible to the maintenance staff or the general public. It is important that those maintaining it as well as the public including customers, visitors or staff can understand that its features move beyond aesthetic landscaping to manage and treat stormwater. At a minimum, signage should include a message for maintenance staff that the bioswale is a "no mow" zone for purposes of carrying and treating stormwater runoff. For information on educational credits, call MSD Customer relations at (502) 587-0603.

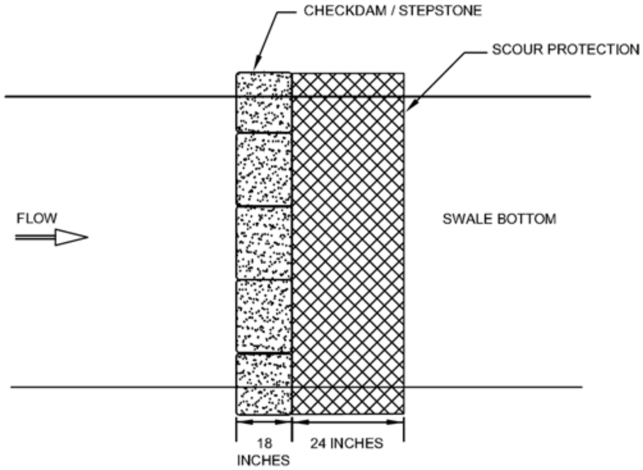


Figure 18.5.1-G. Stone check dam—typical plan view

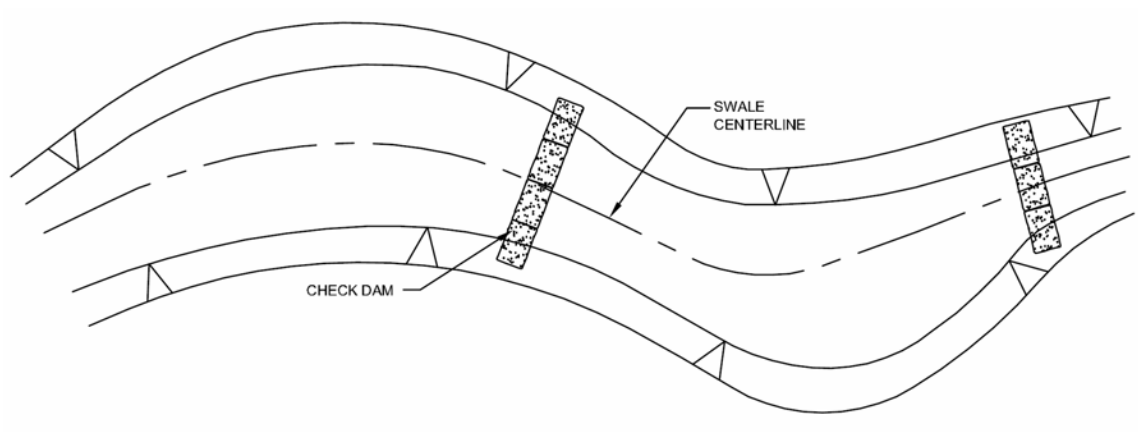


Figure 8.5.1-F. Alternate bioswale layout concept—typical plan view

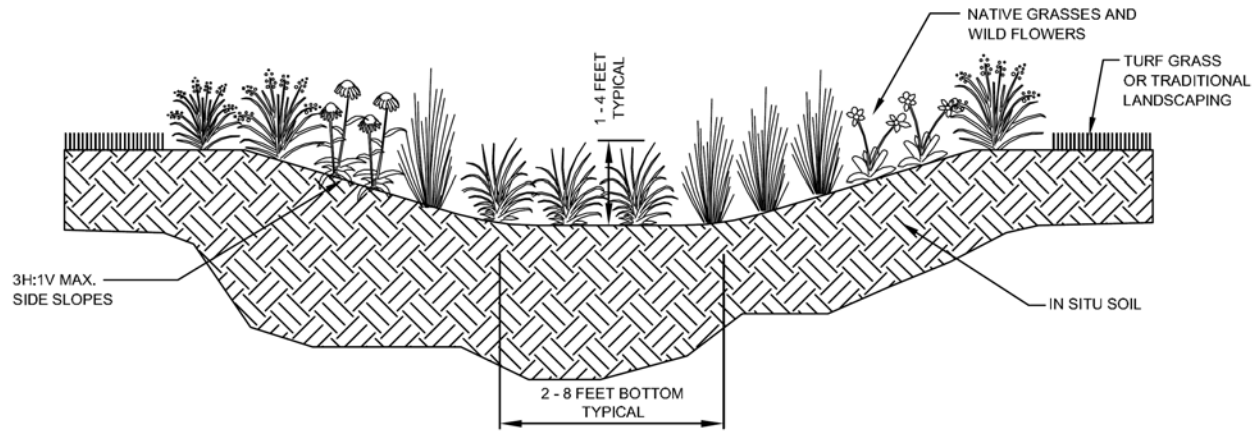


Figure 18.5.1-A. Soil Composition Option 1—In Situ Soils: Bioswale typical section

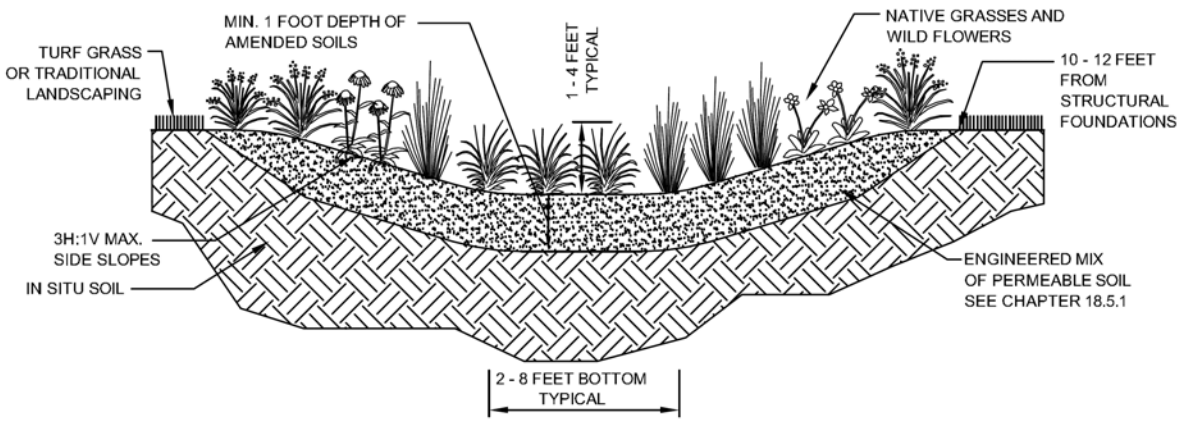


Figure 18.5.1-B. Soil Composition Option 2—Engineered Soils: Bioswale typical section

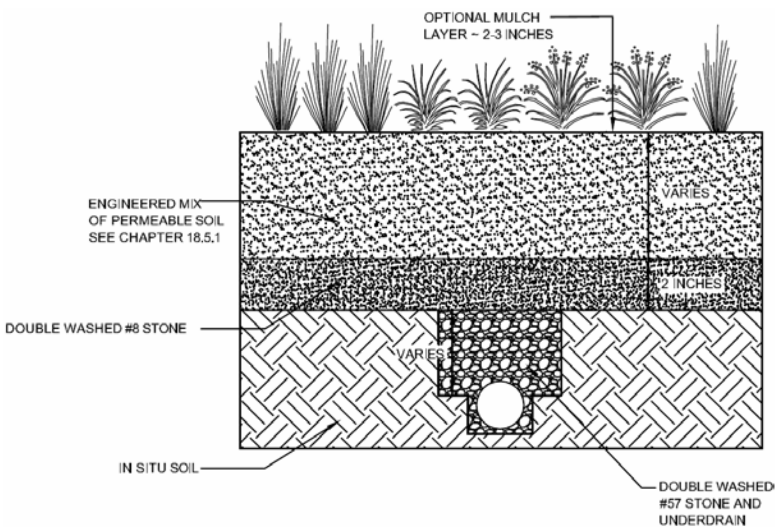


Figure 18.5.1-C. Soil Composition Option 3a—Engineered Soils with Underdrain: Schematic

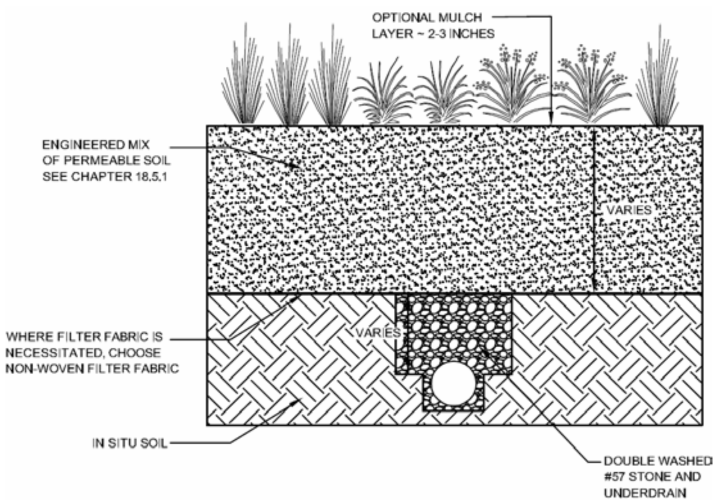


Figure 18.5.1-D. Soil Composition Option 3b—Engineered Soils with Underdrain: Schematic
Note: Filter fabric should be avoided due to its propensity for clogging.

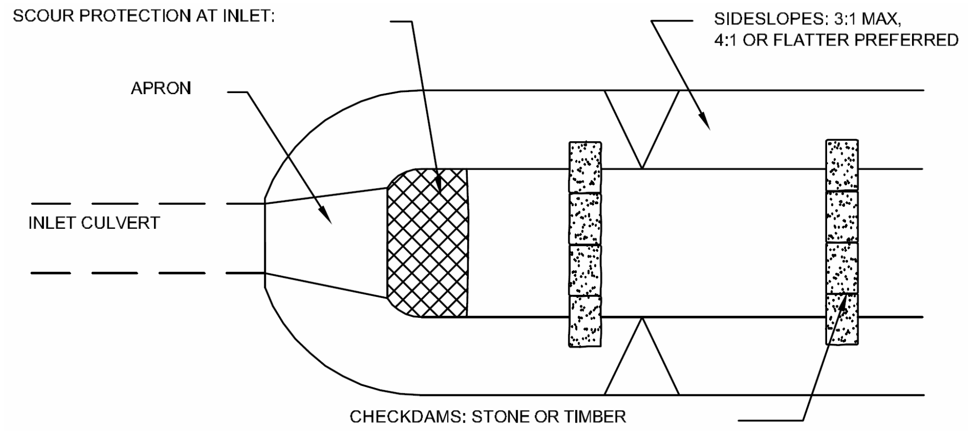


Figure 18.5.1-H. Typical bioswale features—typical plan view

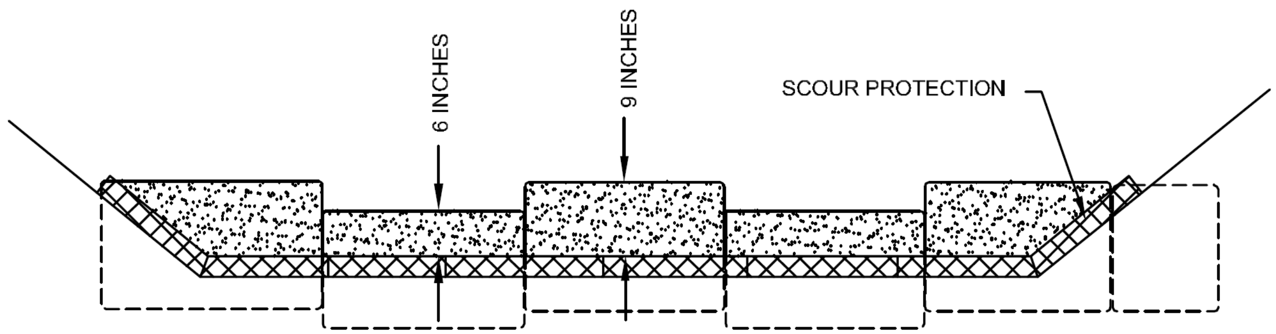


Figure 18.5.1-J. Stone check dam—typical section

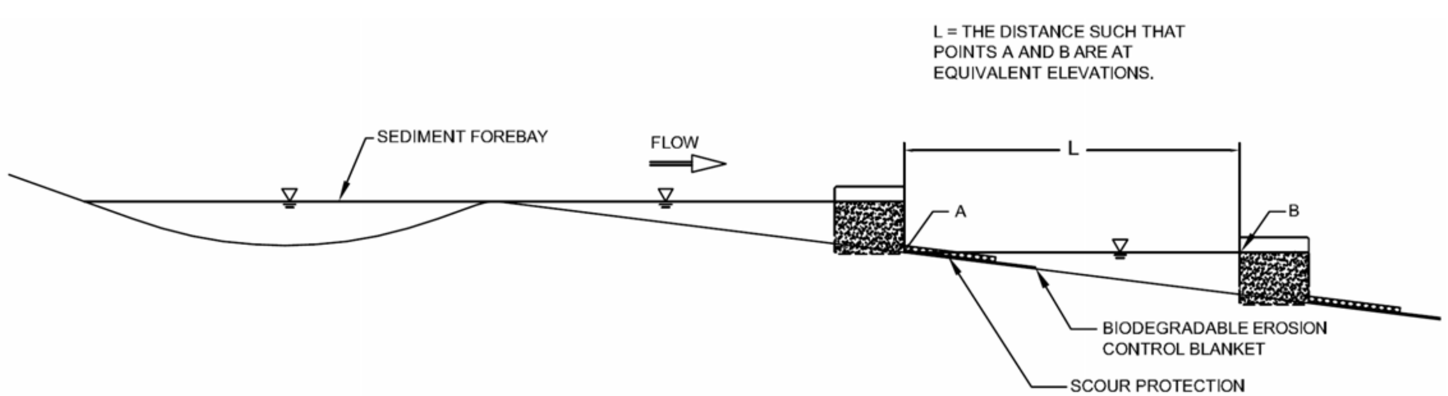


Figure 18.5.1-K. Check dam spacing—typical profile view

Bioswales Application and Site Feasibility Criteria

Table 18.5.1-A.

Design Parameter	Criteria
Longitudinal Slope	Typically less than 4% 1 - 2% preferred If greater than 4%, use check dams to achieve slopes as needed
Bottom Width	2 - 8 feet typical
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Maximum Permissible Velocity	• 1 fps for water quality storm peak flow • 4.5 fps for the 100-year, 24-hour storm peak flow
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm
Soils	Engineered soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate for the In Situ Soils Option, however higher infiltration rates are recommended for the Engineered Soils Options. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5% by weight. The soil mix will consist of the following materials, by volume: • 60% construction sand • 30% organic compost • 10% topsoil
Residence Time for WQv Storm Event	• Optimal greater than 9 minutes (to achieve >80% TSS removal) Minimum = 5 minutes (to achieve~60% TSS removal) • Maximum ponding time typically about 24 hours • Installation of check dams to provide adequate residence time
Pretreatment	Size pretreatment forebay to hold 10% to 15% of the WQv
Outlet Protection	Scour protection required at discharge point
Drawdown Time	Check dams and underdrains should dewater within 24 hours
Storage Capacity	Bioswale total volume should be equivalent to the required WQv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the bioswale (ft^2) The design volume provided by the bioswale is V (ft^3) = (A)(d)(P) + (A)(h), where • A = area of the bioswale (ft^2) • d = depth of the media (ft) • P = media porosity (% void) • h = average height of water above the media during the WQv rain event in feet

* Note that bioswale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Step by Step Design Procedures

Step 1: Define goals/primary function of the bioswale

Define the goals/primary function of the bioswale. Consider whether the bioswale is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide conveyance or fix a drainage problem
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. To design an appropriate bioswale, determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the bioswale. In conjunction with in situ topographic and soil conditions, this criteria will determine the elements of the bioswale (check dams, engineered soils, underdrain, etc).

Step 2: Determine the residence time, peak flow rate, and total runoff volume

Swales should achieve the residence time shown in Table 18.5.1-A. Swales must be designed to safely convey flow rates produced by larger storm events with adequate freeboard and minimum erosion.

Where space allows and check dams are used, bioswales should be sized to capture and detain the WQv in the volume behind check dams, as provided in Chapter 18.3 Green Infrastructure Plan Development Standards and Selection Process. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.1-A can be used in this form: WQv (ft^3) = $(RE_{WQV})(Rv)(A/12)$.

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following storm events:

- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a bioswale area. Utilize Table 18.5.1-A. Create a rough layout of swale dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

Pretreat with forebay, weir or check dam, and scour protection. Size the forebay per Table 18.5.1-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Step 5: Determine bioswale dimensions

Size bottom width, depth, length and slope necessary to achieve the residence time and/or store the WQv per Table 18.5.1-A.

Step 6: Determine check dam needs

Lay out preliminary check dam locations based on the grade of the swale. Consider adding/adjusting check dam locations where crossing access is needed. Calculate the number of check dams required to detain the WQv. Check that the velocity for the Water Quality storm is within 1 fps to reduce erosion potential.

Step 7: Check velocities for water quality storm

Based on the average bioswale cross-section and slope, check flow velocities and water surface elevations for the WQv Rain Event. Check that the velocity for the WQv Rain Event is within 1 fps to promote sediment drop out and filtration as well as reduce erosion potential.

Step 8: Check velocities and freeboard for larger storms

Based on the average bioswale cross-section and slope, check flow velocities and water surface elevations for the 2-, 10- and 100-year, 24-hour storm events for the bioswale to pass safely. This includes meeting freeboard requirements per Table 18.5.1-A and determining the need for erosion prevention measures. Modify design as appropriate. Assess energy dissipation options at outlets points.

Step 9: Select erosion control measures

Compare peak flow velocities calculated for the 2-, 10- and 100-year, 24-hour storm events to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and determine the need for biodegradable erosion control materials. For most bioswales, a biodegradable erosion control mat will be needed to limit soil erosion while the vegetation is becoming established. Choose biodegradable erosion control mat based on the manufacturer's specifications that meet the peak flow velocities.

Step 10: Prepare vegetation and landscaping plan

Choose deep rooted native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones within the bioswale. In general, the sides of the bioswale will be well drained and the plants on the sides will need to tolerate dry conditions as well as occasional wet conditions. The bottom of the bioswale will have more moist conditions, so plants located in the bottom of the bioswale will need to tolerate longer periods of saturation. If check dams are not used, the bottom of the bioswale may be well drained. If check dams are used, water will be held behind the check dams for a longer period of time. Choose plants appropriate for the conditions that will be created in the bioswale.

Native and cultivar species are provided in Chapter 13 of the MSD Design Manual. Although native, deep rooted species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Invasive species should <u>not</u> be used. A list and description of Louisville and Kentucky invasive species are provided in Chapter 13, Appendix II of the MSD Design Manual.

Louisville and Jefferson County Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.2 Rain Gardens

Typical Implementation Areas:
- Commercial & residential landscaping
- Multi-use areas (courtyards, entranceways)
- Parks and greenways
- Parking lot islands, edges
- Drainage easements
- Roadway right-of-way, island/median

Key Considerations:
- Use of native vegetation
- Overflow structure
- Infiltration

Cost:	Low
Maintenance:	Low

Landscaped rain garden with native and cultivar plants (Photo: Lara Kurtz, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■ Significant
Phosphorus	Partial
Nitrogen	Partial
Metals	Partial
Pathogens	Partial
Floatables	Partial
Oil and Grease	Partial
Dissolved Pollutants	Partial
Hydrologic Characteristics	
Surface Flow Reduction	Partial
Infiltration	Partial
Stormwater Conveyance	Low or Unknown
Stream Channel Protection	Partial
Peak Flow Control	Partial
Runoff Volume Reduction	
Runoff Capture	■ Significant

Key: ■ Significant Benefit; Partial Benefit; Low or Unknown Benefit

Rain gardens, also referred to as bioretention cells, biofiltration cells or bioinfiltration cells, are shallow stormwater basins (typically 4 to 12 inches deep) that mimic the ecological functions of a natural landscape. Rain gardens contain deep rooted native vegetation or cultivar species to filter stormwater, promote infiltration and provide wildlife habitat. Rain gardens improve water quality through:

☑ Treatment of stormwater percolating through soil and filter media
☑ Groundwater recharge and detention of stormwater
☑ Natural evapotranspiration
☑ Biological uptake

Advantages/Benefits

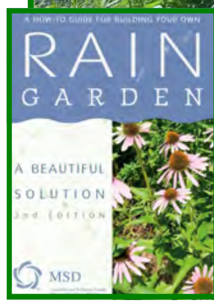
- Good retrofit capability
- Reduces volume of stormwater runoff
- Provides infiltration and groundwater recharge, filtering pollutants and reducing runoff volume
- Suitable for runoff from highly impervious areas
- Increases biodiversity by providing urban habitats for wildlife

Disadvantages/Limitations

- Location constraints (utilities, shallow groundwater, bedrock, sinkholes, downgradient from buildings/ basements, overflow pathway, etc.)
- Maintenance commitment (basic gardening/landscape maintenance)
- Available space for capture of target volume
- Not recommended for slopes >15%.

Application and Site Feasibility

Rain gardens are shallow basins landscaped with deep rooted, native or non-invasive cultivar plants to capture, filter and infiltrate stormwater runoff. They can be flexible in design to accommodate landscape requirements. Rain gardens are appropriate in a wide variety of land use applications such as commercial, industrial, or residential areas and they are often located adjacent to parking lots or roof downspouts. This fact sheet includes guidance for rain gardens in non-residential applications, such as commercial or industrial properties. MSD's *A How-To Guide for Building Your Own Rain Garden* was developed specifically for homeowners. A copy can be downloaded from the MSD website at www.msdlouky.org.



This photo is an example of a residential rain garden using MSD's How-To Guide as a resource for homeowners (Photo: Louisville & Jefferson County MSD)

Physical Requirements

Key physical considerations are:

- Soil type and infiltration—Rain gardens should drain within 24 hours. Infiltration rates for native soils with clay content may improve over time with installation of deep rooted plants as they have the potential to penetrate and loosen the soils. Soils shall have an infiltration rate of 0.5 inches per hour or greater.
- Deep rooted plants—Native plants are preferred and non-invasive cultivars/hardy plants can be used to landscape the rain garden. Native, hardy plants with deeper root systems and tolerance for drought to wet conditions are suitable for the varying wet and dry conditions of rain gardens.

Design Criteria

The design of a rain garden includes several elements to manage stormwater ponding and infiltration as well as to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.2-A.

Design criteria to consider includes:

- Location
- Inlet and pretreatment
- Sizing and ponding area
- Soil composition
- Plant selection
- Outlet design
- Mosquito control
- Maintenance

Location

Since rain gardens are retention structures, they are designed to effectively capture stormwater runoff. When finding the most appropriate location for the rain garden, it is best to find a site with a small drainage area. For larger drainage areas, it is recommended that more than one rain garden be established.

Rain gardens should be built where the groundwater table is significantly lower than the lowest point of the rain garden to promote affective infiltration. Areas with heavy sediment flow are not suitable locations for rain gardens because the structures or soil may become clogged. In addition, rain gardens should be placed at least 10 feet from building foundations and underground utilities. See Figure 18.5.2-D for a rain garden typical cross-section.

Inlet and Pretreatment:

Pretreatment is a key feature that can ease maintenance, especially in land use areas with high sediment loads. The use of a forebay, or other energy dissipating device, such as a strip of vegetative or gravel filter to spread the flow at the inlet, facilitates maintenance and removal of accumulated sediment while preventing erosion.

Sizing and Ponding Area

The surface storage parameter should be designed to retain/ capture the volume produce by the rainfall events specified in Table 18.5.2-A. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. Ponding depth should be limited to 6 inches or less. An overflow drain also should be installed to move excess water during a large storm event or due to clogging.

Sizing of a rain garden is based on the volume provided by the porosity of any amended soils and in the ponding above any amended or in situ soils. This volume should at least be equal to the Water Quality Volume (WQv).

See Table 18.5.2-A for the minimum surface area of the rain garden.

Soil Composition

The composition of media used within a rain garden is vital because it will either promote or hinder the ability for runoff to infiltrate through the structure. Consider soil types when selecting erosion control materials. Soil affects erosion potential and infiltration rates. Heavier clay soils are less prone to erosion but have lower infiltration rates. Sandy, permeable soils promote infiltration, but are more prone to erosion. Soils used should not have excessive levels of phosphorus due to treatment because this can affect water quality. Infiltration rates in tighter soils will improve over time as plants grow and their root systems penetrate into the soil.

It is important to evaluate in situ soil conditions and determine the need for an underdrain and engineered soils:

1. Engineered Soils Option 1: If the primary purpose is to promote infiltration and improve water quality, amend in situ soils with an engineered soil mix. This option works best with well draining soils.
2. Engineered Soils with Underdrain Option 2: If the primary purpose is to promote infiltration and improve water quality while limiting standing water, amend in situ soils with an engineered soil mix and add an underdrain system. This option is more expensive, but has increased filtering capacity, increased void space, and will prevent permanent standing water where clay prevents total infiltration.

In situ soils should have an infiltration rate of 0.5 inches per hour or greater and higher infiltration rates are recommended for the Engineered Soils Options 1 & 2. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5%, by weight. The following soil mix is recommended, but other soil mixtures may be used based on site characteristics and proposed plantings. To enhance infiltration rates and prevent soil consolidation over time, a soil mix with a high sand content is recommended. The typical soil mix to enhance infiltration rates and prevent soil consolidation over time consists of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

For plants that need a higher organic content and less well-drained soils to support growth and development, a soil mix with a higher content of compost may be appropriate. However, testing of infiltration rates and soil aeration may

Rain garden at Louisville & Jefferson County MSD main office with naturalized native plantings. (Photo: Carolyn Cromer, Dropseed Nursery)

Native plants suitable for rain gardens (Photo: Louisville & Jefferson County MSD)

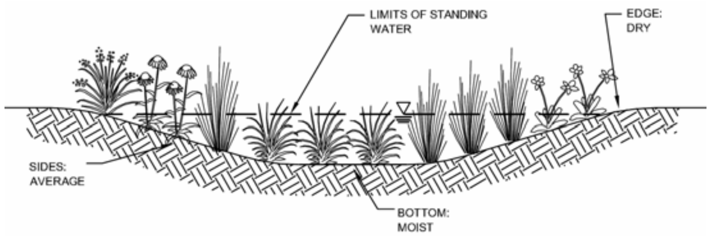


Figure 18.5.2-A. Rain garden (no underdrain) planting considerations for wet/dry tolerant plants

be needed over time to maintain the functionality of the bioswale. Where appropriate for site conditions and plantings, consider this soil mix consisting of the following materials, by volume:

- 60% organic compost
- 30% construction sand
- 10% topsoil

At inflow and outflow areas of the rain garden, the use of a herbaceous layer of ground cover is recommended over mulching to prevent erosion of mulch and soil layers. Ground covers also act as a weed control by providing a thick cover that inhibits the growth of unwanted plants. However, if mulch is used fresh shredded bark mulch is preferred to maximize nitrogen retention. The slope of the rain garden should be designed to minimize erosion. Mulch should be applied as an even 2 to 3 inch layer avoiding mounding around trees, shrubbery and plants.

For soil composition Option 2 (Engineered Soils with Underdrain), underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed KY #57 stone. Filter fabric should be avoided due to its propensity for clogging. To minimize the migration of soil particles into the stone layer and underdrain, layer double washed KY #8 stone over the double washed KY #57 stone layer (Option 2a). Where filter fabric is necessitated, choose non-woven filter fabric (Option 2b). Cross-sections of soil composition options and underdrain schematics are shown in Figures 18.5.2-B through 18.5.2-C.

Rain garden with native and cultivar plants (Photo: Lara Kurtz, URS)

Plant Selection

Rain gardens are typically planted with deep rooted native grasses, sedges, and forbes. In selecting plants, consider the favorable conditions where plants can thrive. The conditions for plants used should be able to survive droughts as well as inundated scenarios.

Whether to plant with seed, plugs or container plants is often an economic and maintenance decision. Seeding is less expensive initially, but requires a longer establishment period, and makes maintenance and weeding more intense. Plugs and container plants are more expensive than seed, but plants will grow and establish quicker and less weeding will be required.

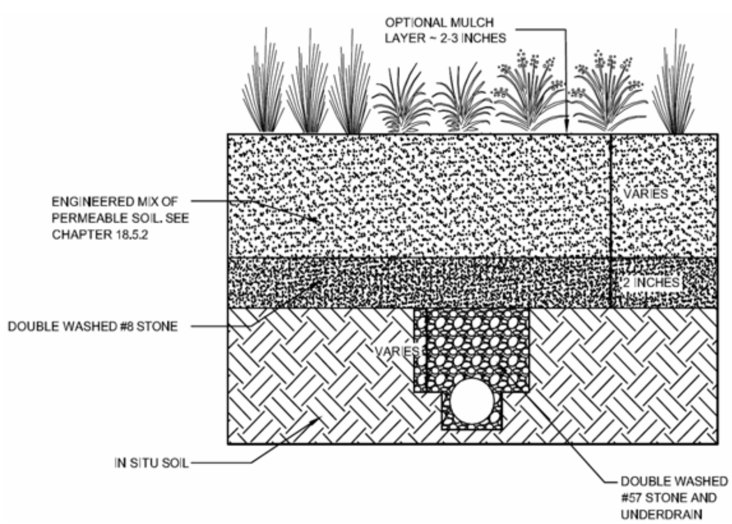


Figure 18.5.2-B. Soil Composition Option 2a—Engineered Soils with Optional Underdrain: Schematic

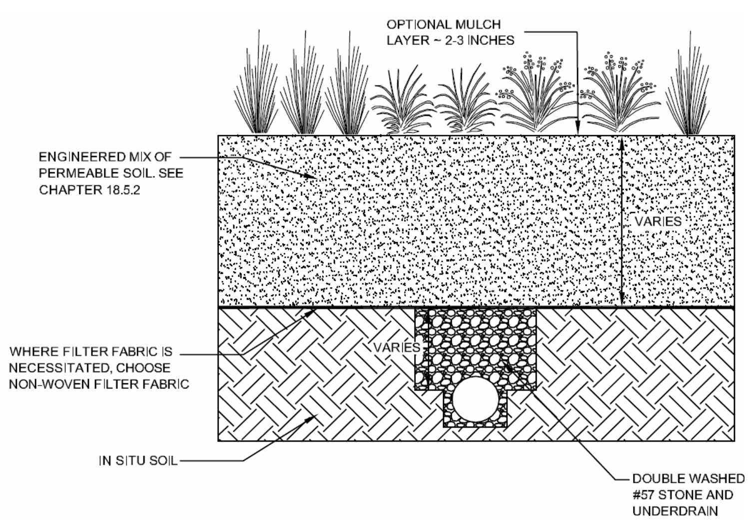


Figure 18.5.2-C. Soil Composition Option 2b—Engineered Soils with Optional Underdrain: Schematic
Note: Filter fabric should be avoided due to its propensity for clogging.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Native species and non-invasive cultivar/hardy species are provided in Chapter 13 of the MSD Design Manual.

Outlet Design

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. If an underdrain is used, this may also help expedite the infiltration process when there is an excess amount of water retained within the structure after ground saturation has occurred.

Mosquito Control

By design, rain gardens should not be in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By designing a properly functioning and draining rain garden, the chances of providing mosquito habitat are virtually eliminated. If the rain garden holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for rain garden maintenance activities and schedules.

Treatment Trains—Combination and Location in Series With Other GMPs

Rain gardens can be located in series with other GMPs such as forebays and bioswales to supplement erosion prevention sediment control and infiltration. Energy dissapators or other erosion prevention sediment control features can be used inside the rain gardens to prevent excessive erosion during heavy rainfall.

No mowing sign for Metro Parks promotes maintenance awareness at a rain garden (Photo: Erin Wagoner, URS)

Interpretive signage explains how a rain garden and other GMPs work in this regional watershed demonstration project (Photo: Erin Wagoner, URS)

Educational Awareness

The difference between rain gardens and traditional landscaped areas may not be visible to the general public. It is important that those maintaining it, as well as the public, including customers, visitors or staff, understand that its features move beyond aesthetic landscaping to manage and treat stormwater. Educational signage varies from an interpretive sign that explains how the rain garden functions to a simple "no mow" sign. Signage and edging should be used to delineate the rain garden from adjacent landscaped or lawn areas. Signage may include awareness information that the rain garden is a "no mow" zone and used for purposes of carrying and treating stormwater runoff. Stone or raised edging will help to delineate the rain garden from surrounding landscape, however care should be taken to ensure edging does not inhibit the flow of drainage into the rain garden. For information on educational credits, call MSD Customer relations at (502) 587-0603.

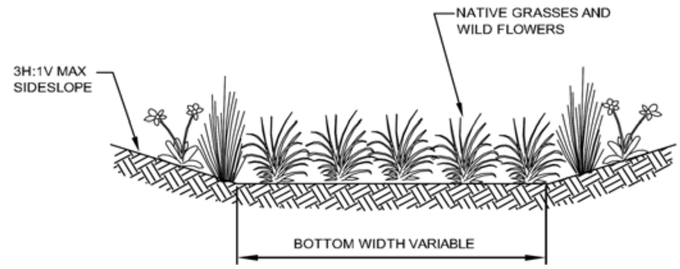


Figure 18.5.2-D. Rain garden typical cross-section

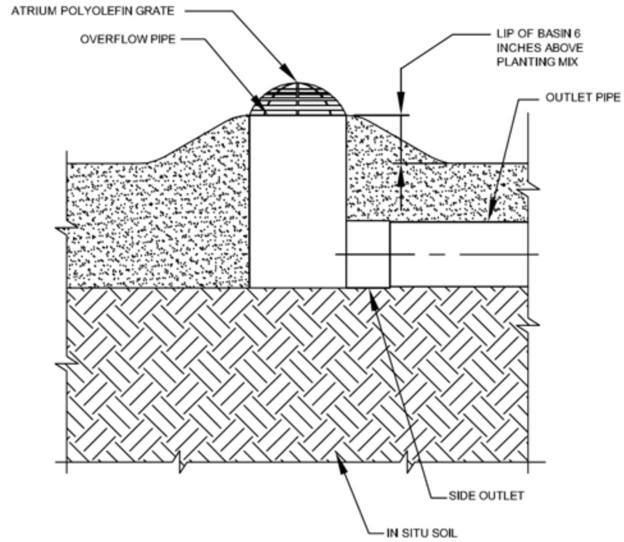


Figure 18.5.2-E. Overflow drain detail

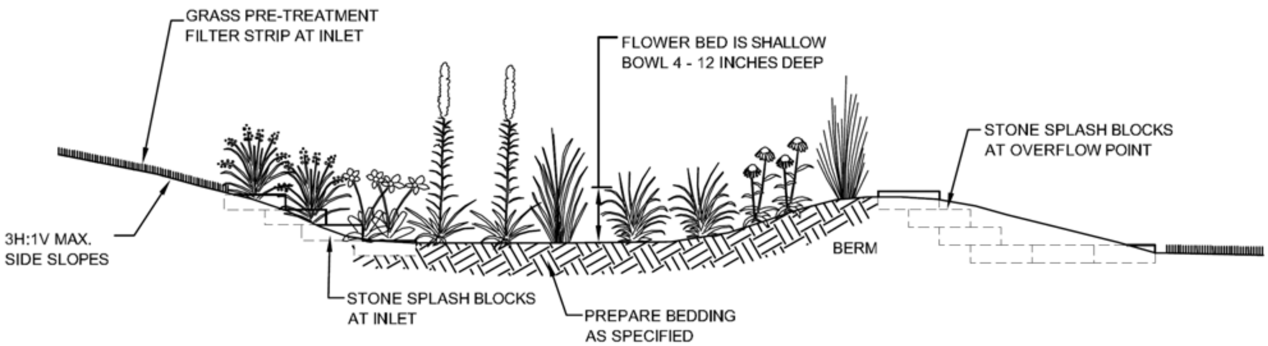


Figure 18.5.2-F. Rain garden typical cross-section with overflow splash blocks

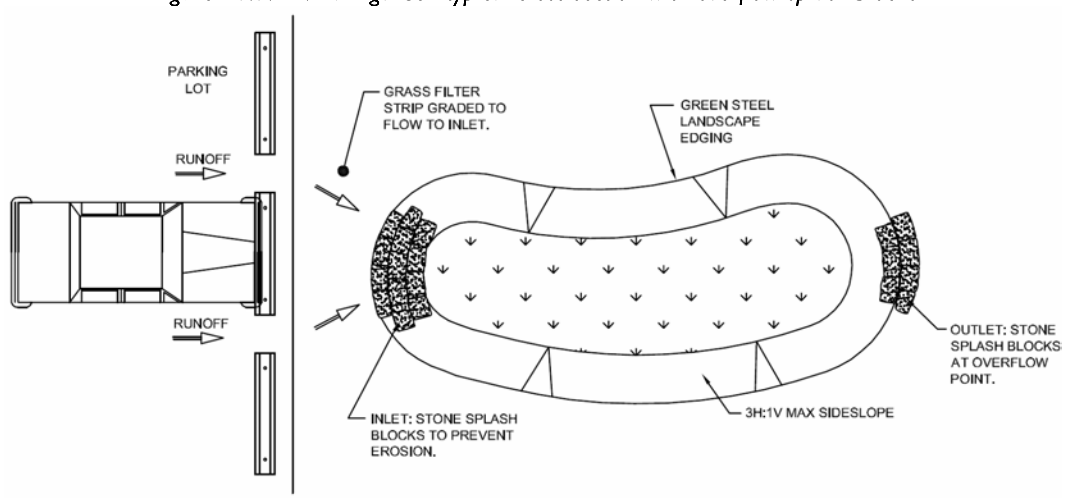


Figure 18.5.2-G. Rain garden typical plan view with splash blocks

Rain Garden Application and Site Feasibility Criteria

Table 18.5.2-A.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: $A = (WQv)/[(d)(P)+h]$, where • A = surface area of the ponding area of the rain garden (ft^2) • WQv = required water quality volume (ft^3) • d = depth of any amended soils (ft) • P = porosity of any amended soils (% void) • h = average height of water above the amended/in situ soils during WQv rain event (ft)
Longitudinal Slope	No greater than 15%.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm with 6" of freeboard
Soils	Engineered soil mix should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate for the In Situ Soils Option, however higher infiltration rates are recommended for the Engineered Soils Options. The soil composition may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix should not exceed 5% by weight. For many projects, the mix will consist of the following materials, by volume: • 60% construction sand • 30% organic compost • 10% topsoil
Pretreatment (optional)	Size pretreatment forebay to hold 10% to 15% of the WQv.
Inlet/Outlet protection	Scour protection required at inlet and discharge point.
Drawdown Time	Dewatering of the rain garden should occur within 24 hours.
Storage Capacity	Rain garden total volume should be equivalent to the Required Water Quality Volume. Required WQv (ft^3) = $(RE_{WQv})(Rv)(A)$, where • RE_{WQv} = required water quality volume rain event (refer to chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the rain garden (ft^2)

Rain Garden Step by Step Design Procedures

Step 1: Define goals/primary function of the rain garden

Define the goals/primary function of the rain garden. Consider whether the rain garden is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide a fix to an excess drainage problem
- Enhance landscape aesthetic qualities

Consider whether the rain garden requires any special site-specific design conditions/criteria. Inventory any site restrictions and/or surface water or watershed requirements that may apply or effect the design.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the rain garden. In conjunction with in situ topographic and soil conditions, this information will determine the elements and design of the rain garden (engineered soils, underdrain, outlet/overflow, etc).

Step 2: Determine the total runoff volume and rain garden footprint

Rain gardens should be sized to capture and retain the water quality volume (WQv). To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.2-A can be used in this form:

WQv (ft^3) = (RE_{WQV})(Rv)(A/12).

To determine he minimum surface area of the rain garden use the following formula:

A = (WQv)/[d(P)+h] (see table 18.5.2-A).

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Water Quality
- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a rain garden area. Consider Table 18.5.2-A. Create a rough layout of the rain garden dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

It may be desired to use pretreatment to reduce flow velocities or facilitate sediment removal and maintenance of the rain garden. Pretreatment with a forebay, weir or check dams are optional for rain gardens. Size the forebay per Table 18.5.2-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations. Splash blocks or level spreaders should be considered to dissipate the concentration of stormwater runoff at the inlet and to prevent scour.

Step 5: Determine rain garden parameters

Size any engineered soils depth to achieve the WQv per Table 18.5.2-A.

Step 6: Prepare native vegetation and landscaping plan

Choose deep rooted native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones for a high functioning rain garden. In general, the sides of the rain garden will be well drained and the plants on the sides will need to tolerate both dry and wet conditions. The bottoms of the rain garden will have more moist conditions, so plants here may need to tolerate longer periods of saturation. Choose plants that are appropriate for the conditions that will be created in the rain garden.

Rain garden with newly installed native plants (Photo: Erin Wagoner, URS)

MSD
Metropolitan Sewer District

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.3 Constructed Wetlands

Constructed wetland (Photo: David Dods, URS)

Typical Implementation Areas:
- Parks and greenways
- Commercial, residential and institutional developments

Key Considerations:
- Used to both retain and treat stormwater
- Use native vegetation
- Enhances local ecosystem with new, connected habitat
- Proper design needed to avoid mosquito concerns

Cost: Medium
Maintenance: Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant
Phosphorus	Partial
Nitrogen	Partial
Metals	Partial
Pathogens	Partial
Floatables	Partial
Oil and Grease	Partial
Dissolved Pollutants	Partial
Hydrologic Characteristics	
Surface Flow Reduction	Partial
Infiltration	Low or Unknown
Stormwater Conveyance	Low or Unknown
Stream Channel Protection	Partial
Peak Flow Control	Partial
Runoff Volume Reduction	
Runoff Capture	Partial

Key: Significant Benefit; Partial Benefit; Low or Unknown Benefit

Constructed wetlands incorporate marsh and pool areas to temporarily store stormwater runoff, treat pollutants and create habitat. Constructed wetlands are generally shallow, except for the pool areas, and contain dense native aquatic vegetation, typically covering 50% of the surface area that helps treat the stormwater. Wetland systems can store additional runoff, provide extended detention, or incorporate the benefits of a pond in a pond/wetland system. Constructed wetlands improve water quality through:

- ☑ Biological uptake through native plants and biodegradation by microorganisms
- ☑ Sediment settling
- ☑ Adsorption and other chemical/physical processes

Advantages/Benefits

- One of the most effective GMPs for pollutant removal because it does not infiltrate
- Increases biodiversity by providing habitat for wildlife
- Reduces channel/stream bank erosion by reducing number of downstream bankfull events
- Opportunity for multiple uses, including passive recreation

Disadvantages/Limitations

- Typically requires larger tracts of land
- Needs regular flow of water, so stormwater runoff may need to be supplemented during dry conditions
- Needs to be properly designed and managed to reduce potential to breed mosquitoes
- Water quality of discharge can change with seasonal growth of plantings

Application and Site Feasibility

Constructed wetlands are a basin feature, similar to stormwater ponds in scale, that are used to treat and temporarily store stormwater runoff. Generally, to help sustain wetlands during dry periods, design should incorporate a drainage area of 25 acres, 10 acres for pocket wetlands. The permeability of the soils around the constructed wetlands should be less than 0.14 inches per hour to prevent drainage. In addition, wetlands should have an aerial extent of 2-5% of the watershed they drain and a minimum elevation difference between the inlet and outlet of about 2-5 feet. Constructed wetlands are appropriate for use in a wide variety of land use applications such as commercial, industrial, or residential areas.

There are three basic types of constructed wetlands, which are depicted in Figure 18.5.3-A: shallow wetlands, pond/ wetland systems, and extended detention wetlands. Shallow wetlands consist of a combination of shallow water areas, 6 to 18 inches deep in combination with deeper pools. Extended detention shallow wetlands are similar, except they incorporate additional storage above the normal pool elevation. Pond/wetland systems utilize detention ponds and shallow wetlands in series.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to treat and temporarily store the stormwater runoff
- Drainage area—Have an adequately large drainage area to provide base flow during drier weather
- Soil conditions—Soils need to have a low permeability to allow ponding of the water; constructed wetlands typically do not infiltrate stormwater runoff

Design Criteria

The design of constructed wetlands includes several elements to facilitate water quality improvement and routing and detention of stormwater runoff. For a summary of design parameters, see Table 18.5.3-A on page 7.

Design criteria to consider includes:

- Configuration and layout
- Soils
- Conveyance
- Forebay (pretreatment)
- Treatment
- Outlet
- Landscaping/plant selection
- Safety
- Maintenance

Pocket wetland (Photo: David Dods, URS)

Configuration and Layout

Common constructed wetlands components include the following:

- Inlet(s)
- Sediment forebay
- Shallow water zones
- Outlet and overflow structures
- Deeper pool zones, including a micropool near the outlet to allow for final settling and prevent and re-suspension of settled matter prior to discharge

These components are shown in Figures 18.5.3-B and 18.5.3-C on page 4. The configuration and layout of these components will be dictated by the site topography, flow paths and access.

Soils

Constructed wetlands are intended to stay wet, so the soils need to be relatively impermeable and limit infiltration; however, they should be above the local high water table. If the underlying soils have a permeability of 0.14 inches per hour or less, then they will not typically require the use of an impermeable or low permeability liner. Soils with

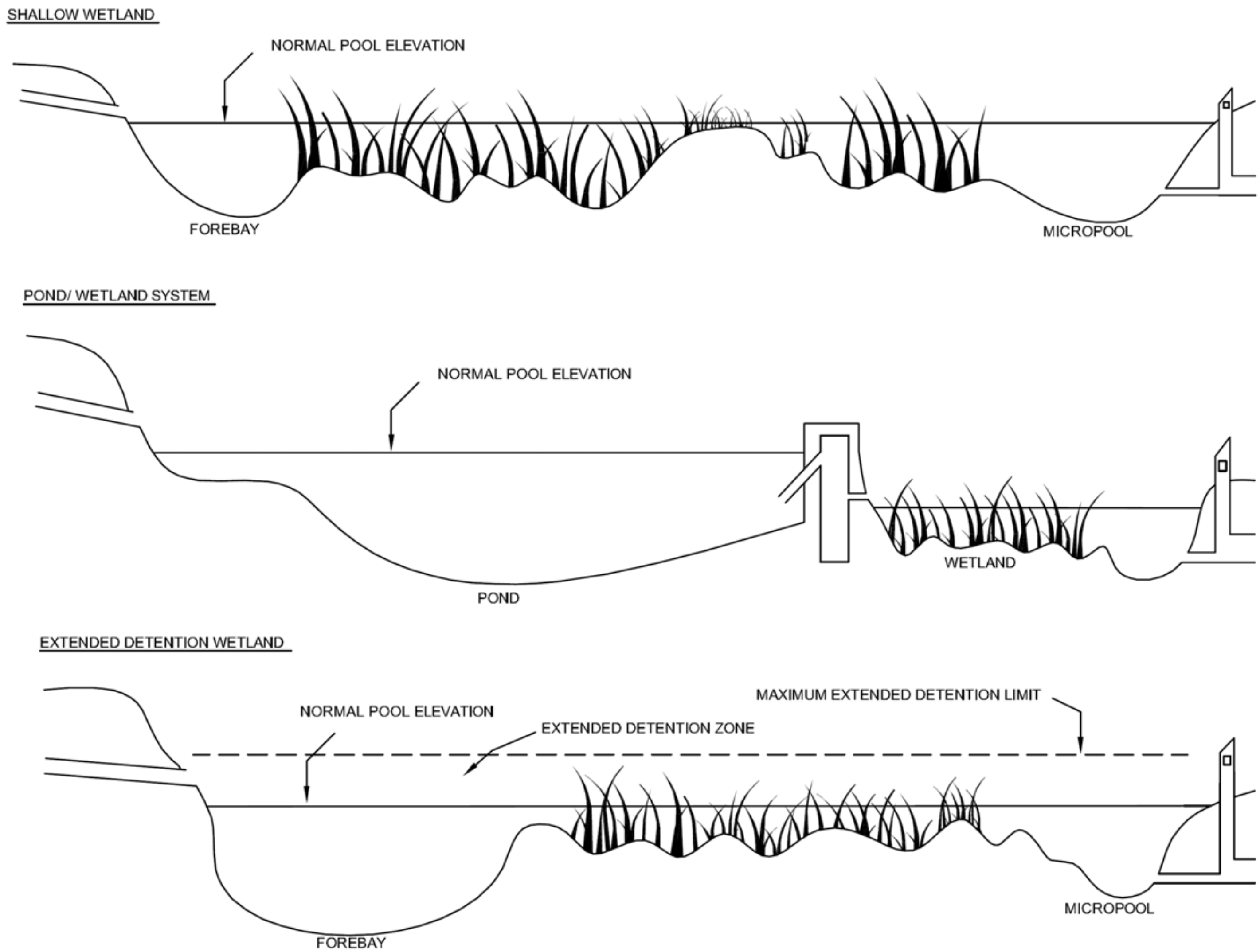


Figure 18.5.3-A. Three Typical Types of Constructed Wetlands

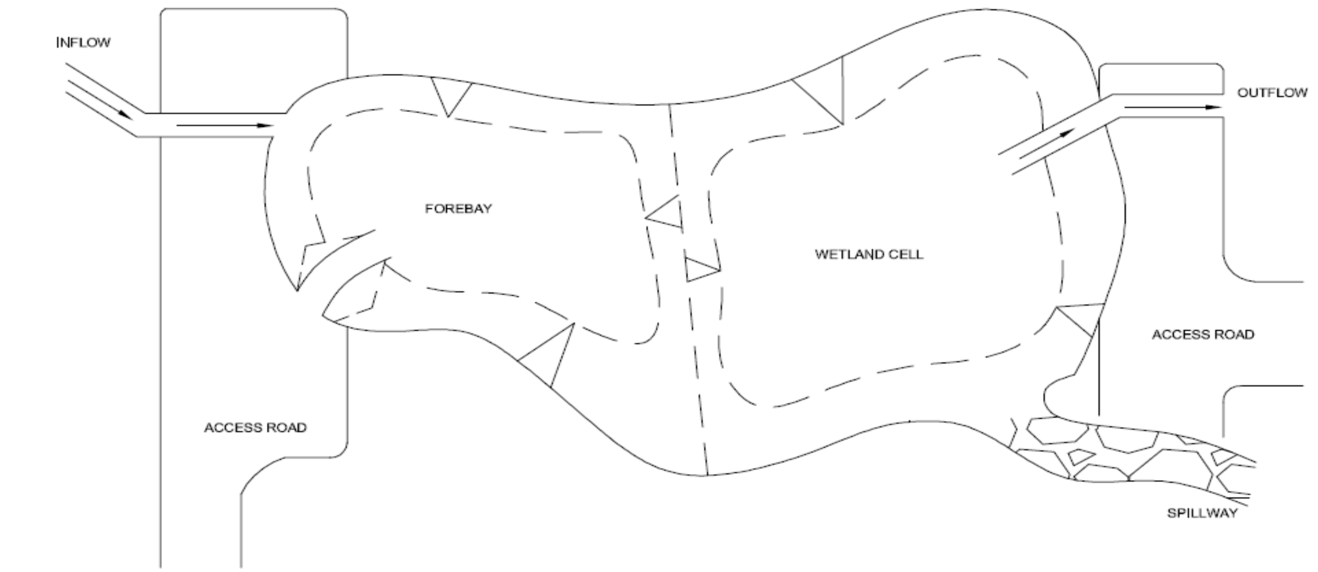


Figure 18.5.3-B. Typical Shallow Wetland (Plan View)

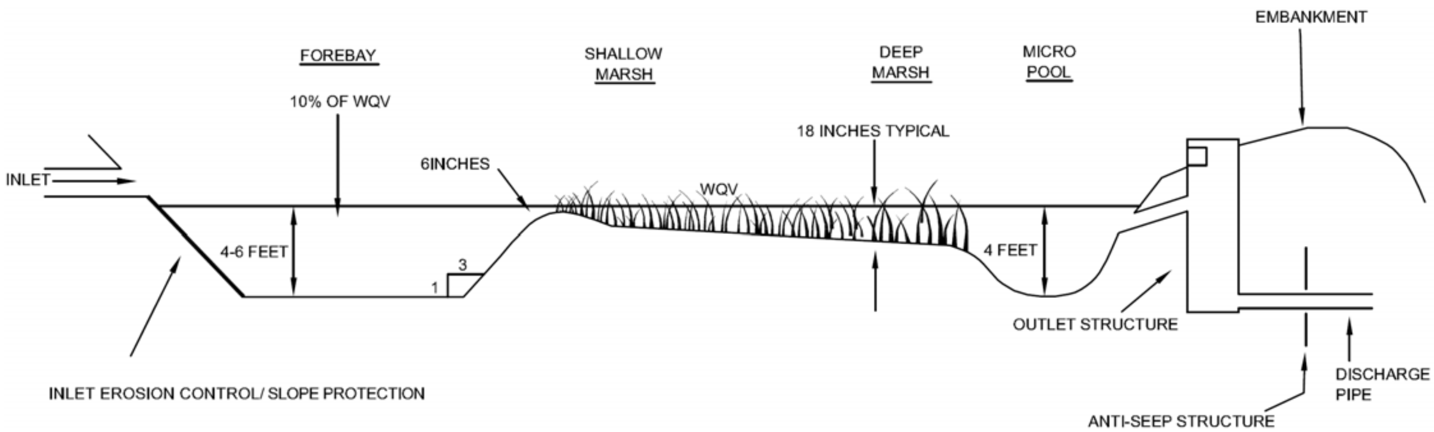


Figure 18.5.3-C. Typical Constructed Shallow Wetland (Profile View)

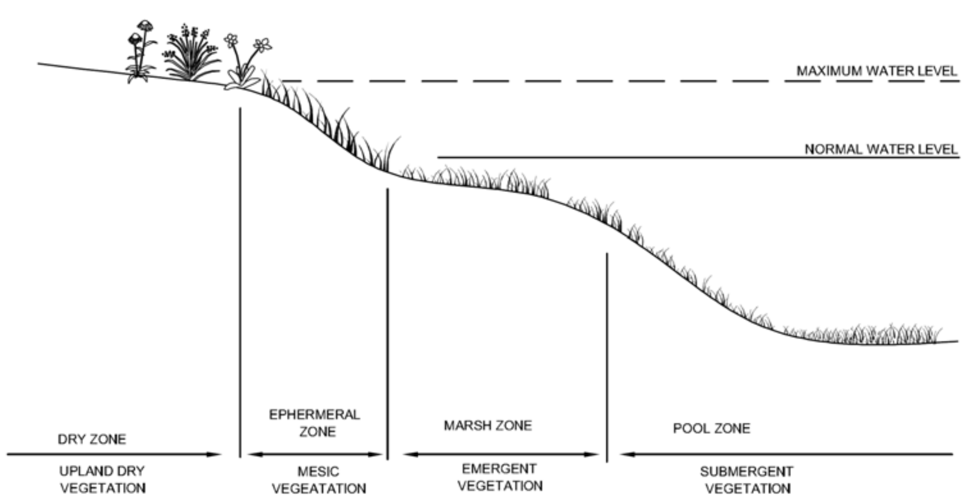


Figure 18.5.3-D. Typical Plant Selection Zones

permeability rates greater than 0.14 inches per hour will require the use of an impermeable or low permeability liner.

Conveyance

Though the constructed wetlands primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because the pooled water in the wetlands allows opportunity for solid particles in the stormwater to settle, the flow path should be diffuse and as long as possible. To provide a long flow path, the wetlands need to have a length to width ratio of at least 2:1, with 3:1 preferred, or internal dikes that provide a winding path for the stormwater runoff.

Constructed wetlands need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the wetlands will help to reduce velocities during larger flows, reducing the potential for erosion. An emergency spillway is also needed to safely convey high flow out of the wetlands. The area downstream of the emergency spillway needs to be protected to prevent scour.

Pretreatment—Forebay

Excessive sediment accumulation in a wetland can reduce hydraulic capacity, block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the wetlands. The forebay should be sized to provide approximately 10% of the WQv and prevent the resuspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 4-6 feet, which will also prevent the growth of unwanted vegetation and allow for the survival of mosquito eating fish. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the wetlands system and reduce velocities to prevent erosion. The forebay should also be designed to allow for ready access to perform maintenance, including removal of accumulated sediment.

Treatment

The primary pollutant removal mechanism in wetlands is sedimentation, since many pollutants are affiliated with sediment particles in stormwater. Consequently, proper design, construction and maintenance of the sediment forebays are critical to the wetlands' performance.

The shallow water zones in the wetlands promote numerous treatment processes. Slowing flows over these zones promotes additional particle settling and biological activity degrades some of the organic pollutants while exposure to sun and air promotes other degradation processes.

A micropool near the outlet helps keep vegetation from encroaching on and clogging the outlet and helps prevent re-suspension of sediment into the discharge. Fish in the micropool can also help manage mosquito larvae production within the wetlands.

Constructed wetland with native plantings (Photo: David Dods, URS)

Shallow wetlands should be sized to have a permanent pool volume equal to the required WQv. The distribution of the volume amongst the forebay, shallow water zone, deep water zone, and micropool should be as follows:

- 10-15% for forebay
- 10-15% for micropool
- 30-35% for shallow water zones
- 35-40% for deeper water zones

Extended detention shallow wetlands and pond/wetland systems should be designed to store above the normal pool level the stormwater runoff from storms greater than the WQv storm event. In addition, the wetland or pond should drain to the normal pool level within 36 hours following the rain event.

Constructed wetland with soft rush (Photo: David Dods, URS)

Because keeping the wetlands wet is critical for their viability, a water balance should be performed. Estimate the seasonal inflows, such as rainfall, stormwater runoff and groundwater contribution, and outflows. Evaporation, transpiration and any infiltration should be included in the estimate. Size the wetlands to be able to sustain the wetland vegetation should there be minimal rainfall and runoff in a thirty day time period. If seasonal drying is anticipated, compensate in the plant selection process, but the effectiveness of the wetlands may be reduced.

Outlet

The design and configuration of the outlet structure will depend on whether storage is provided over and above the WQv. Typical outlet structures include reverse-sloped pipes, weirs or risers connected to a discharge pipe that discharges to the downstream receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars around the discharge pipe to prevent seepage.

A high flow bypass either separate from, or in conjunction with, the outlet structure should be included to safely convey high flows from storm events greater than the WQv rain event. A minimum of one foot of freeboard should be provided during the 100-year rain event. The discharge from the outlet structure should be equipped with armoring, plunge pool, energy dissipater or similar best management practices to prevent scour.

Landscaping/Plant Selection

A landscaping plan is recommended for planting constructed wetlands. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Identify deep pools, deep and shallow water zones, ephemeral zones that will be subject to wet and dry periods, and dry zones (see Figure 18.5.3-D). Select plants appropriate for each zone.

Choices available for planting the wetlands include seed, rhizomes, bare root stock, potted plants and transplanting vegetation from an established site. Planting rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species an cultivar species are provided in Chapter 13 of the MSD Design Manual.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 4:1 or flatter and relatively flat safety benches should be provided in the water just above the permanent pool level of the deep pool zones. In addition, a vegetated buffer around the wetlands can be provided to minimize undesired access or direct desired access and enhance wildlife habitat.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed wetlands are typically basin-scale practices that can be located in series with other GMPs such as wet ponds to supplement runoff volume control.

Educational Awareness

It is important that those maintaining constructed wetlands, as well as the public, including customers, visitors or staff understand that wetlands and their associated buffers are stormwater management features that also provide aesthetic beauty and ecosystem benefit. At a minimum, signage should include awareness information that the constructed wetlands and their associated buffer are a "no mow" zone for purposes of carrying and treating stormwater runoff.

Wetland at Buechel Basin (Photo: Erin Wagoner, URS)

Constructed Wetlands Application and Site Feasibility Criteria

Table 18.5.3-A.

Design Parameter	Criteria
Drainage Area	At least 25 acres of upstream drainage area, 10 acres for pocket wetlands, to maintain adequately wet conditions during dry weather
Sizing	Footprint of constructed wetland should be 2-5% of the area draining to it
Side Slopes	No greater than 4:1 (H:V), flatter is recommended
Soil Permeability	Soil permeability should be ≤ 0.14 inches/hour
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred
Design Flows and Conveyance Capacity	Pass the 2-, 10- and 100-year storms with one foot of freeboard
Pretreatment	Size pretreatment forebay to hold 10% to 15% of the WQv with a depth of 4-6 feet
Outlet Protection	Scour protection required at discharge point
Soils	Low permeability soils, typically in the hydrologic groups "C" and "D". Hydric soil designations should be used.
Sizing	Wetland total volume should be equivalent to the Required WOv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the wetland (ft^2)

Constructed Wetlands Step by Step Design Procedures

Step 1: Define goals/primary function of the constructed wetlands

To define the goals/primary function and location of the constructed wetlands by considering whether the wetlands is intended to:

- Treat the WQv
- Provide temporary storage of larger stormwater flows

If the wetlands is to be primarily a water quality feature, define the primary pollutant(s) of concern and design the wetlands to address the pollutant(s). For example, if suspended sediment is the primary concern, extra attention should be given to the sediment forebay design. If nitrogen is a priority, then detention times become important.

Also, define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements. In addition site access should be a major consideration.

Step 2: Calculate the peak flow rate and total runoff volume

At a minimum, the constructed wetland should be sized to store the required WQv. To find the WQv in cubic feet, the Storage Capacity equation from the Table 18.5.3-A can be used in this form: WQv (ft^3) = (RE_{WQV})(Rv)(A/12). If possible, extended detention should be provided to capture and temporarily store the 2-year storm event runoff. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- WQv rain event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a constructed wetland. Consider Table 18.5.1-A. Create a rough layout of constructed wetland dimensions including existing trees, utility lines, and other site obstructions, as well as soil types.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per Table 18.5.3-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Step 5: Determine constructed wetland configuration

The wetland cell portion of the constructed wetland should be designed with a micropool at the outlet and shallow and deep water zones to provide the WQv, less the portion of the WQv provided in the forebay. The allocation of the remaining WQv should be about 10-20% for the micropool, 35-40% for the shallow water zone and 40-45% for the deep water zone.

Extended detention should be provided above the water quality level. Benches should be provided just above the WQv level and within the water just above the deep pools for safety and to provide planting surfaces. The wetland configuration should be irregularly shaped aerially and have uneven surfaces within the wetland to provide for long flow paths and microhabitats. Provide the length to width ratio and side slopes per Table 18.5.3-A. Maintenance access needs to be provided, especially for the forebay and micropool.

Step 6: Determine inlet and outlet design

Based on the constructed wetland configuration, check water surface elevations for all design storm events (shown in Step 2) so the constructed wetland can pass these flows safely. This includes meeting freeboard requirements of one foot and determining the need for erosion prevention measures at inlets, outlets, overflow points and slopes. Modify design as appropriate. Assess energy dissipation options at inlets, overflow and outlet points.

Step 7: Select erosion control measures

Compare peak flow velocities and water levels calculated for the design flow storm events (see Table 18.5.3-A) to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and assess the need for erosion control materials. A biodegradable erosion control mat may be needed on slopes and embankments to limit soil erosion while the vegetation is becoming established. Choose erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements. Hard armoring may be required for scour protection at inlets, outlets and overflow points within the wetlands.

Step 8: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated water depth zones within the constructed wetland. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

18.5.4 Green Wet Basins

Typical Implementation Areas:
- Parks, greenways and common areas
- Retrofit of exiting wet retention basin
- Commercial, residential and institutional developments
- Retrofit of existing retention basins

Key Considerations:
- Provides water quality treatment for traditional wet basin
- Need low permeability soils
- Use native vegetation throughout perimeter

Cost: Medium
Maintenance: Low

Wet basin with native vegetation along the perimeter (Photo: Rusty Schmidt, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Partial Benefit
Floatables	Partial Benefit
Oil and Grease	Partial Benefit
Dissolved Pollutants	Partial Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Partial Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Low or Unknown Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Partial Benefit

Key: Significant Benefit; Partial Benefit; Low or Unknown Benefit

Green wet basins are similar to standard wet basins, except they contain an aquatic bench along the perimeter of the pond just below the normal pool level and possibly other plantings above the normal pool elevation (safety bench) in the extended detention portion of the basin that provide water quality benefits. The vegetation helps provide water quality benefits. Green wet basins improve water quality by:

☑ Biological uptake and filtering of native plants
☑ Sediment settling, including attached pollutants
☑ Temporary retention of stormwater

Advantages/Benefits

- Relatively high removal rate for many pollutants
- Increases biodiversity by providing habitats for wildlife and aquatic life
- Reduces channel/stream bank erosion by reducing number of bankfull events
- Opportunity for multiple use, including active and passive recreation

Disadvantages/Limitations

- May need to comply with KDOW dam regulations
- Large space requirement
- Possible safety concerns with a pool of water, fence may be required
- Not to be used in high groundwater areas

Application and Site Feasibility

Green wet basins are similar to a standard wet basin, except for the addition of vegetation. In addition, features may need to be included in the basin to minimize short circuiting between the inlet and outlet. Green wet basins can be constructed new or can be the result of retrofitted standard wet basins. Green wet basins are appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to treat and temporarily store the stormwater runoff
- Drainage area—Have adequately large drainage area to provide base flow during drier weather
- Plantings—Robust aquatic planting around the perimeter of the green wet basin to provide water quality treatment

Design Criteria

Generally, green wet basins need to have a drainage area of 25 acres to help sustain them during dry periods and keep the aquatic bench wet The size of green wet basins should be determined using the design requirements for detention basins as described in Chapter 10.3.8 of MSD's Design Manual. The following additional criteria should also be included in the design of green wet basins. For a summary of design parameters, see Table 18.5.1-A on page 5.
Design criteria to consider for green wet basins include:

- Conveyance
- Soils
- Landscaping/plant selection
- Safety
- Maintenance

Conveyance

Although green wet basins' primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because the pooled water in the basins allow opportunity for solid particles in the stormwater to settle, the flow path needs to be diffused and as long as possible. To provide a long flow path, basins need to have a length to width ratio of at least 2:1, with 3:1 preferred. Internal dikes can be added, especially in retrofit situations, to provide a winding path for the stormwater runoff and the necessary length to width ratio.

Green wet basins need to be capable of passing the 100-year storm without damaging the vegetation or the surrounding embankments. The basin should be a minimum of 3 feet deep. A wide flow path through green wet basins will help to spread out and slow down larger flows, reducing the potential for erosion. An emergency spillway to safely convey the flow out of the green wet basin is also needed. The area downstream of the emergency spillway should be protected to prevent any scour. See Figure 18.5.4-A for a typical plan and section of a green wet basin.

Soils

Green wet basins are intended to hold water; therefore the underlying soils need to be relatively impermeable. Soils should have a permeability ≤ 0.14 inches/hour.

Landscaping/Plant Selection

A bench around the perimeter of green wet basins provides the opportunity for aquatic plantings. This bench may be 10-15 feet wide with a slope of 4:1 or flatter and a depth of no more than 18 inches. The bench should cover approximately 25% of the total pond surface area.

In addition, plantings may be made in the basin slope just above the normal pool level that will be inundated during rain events due to the storage characteristics of the basins. These plantings need to be located such that they do not impact access for maintenance activities.

A landscaping plan is recommended for planting green wet basins. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. In addition, the plan should identify wet zones, ephemeral zones that will be subject to wet and dry periods and dry zones in order to select plants appropriate for each zone. Plants should be

Buechel basin has a naturalized buffer (Photo: Erin Wagoner, URS) placed so that their roots do not impact any piping or other structures.

Choices available for planting the green wet basins include seed, rhizomes, bare root stock and potted plants. Planting rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but grow in and provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 4:1 or flatter and relatively flat safety benches should be provided just above the permanent pool level. In addition, a buffer around the green wet basins can direct public access and enhance wildlife habitat.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Train - Combination and Location in Series With Other GMPs

Green wet basins, if used in series with other GMPs, are typically near the end of the treatment train. Upstream GMPs may include vegetated swales, rain gardens and bioretention basins. One exception to being placed at the end of a treatment train is when it is used in a pond/ constructed wetland system.

Educational Awareness

It is important that those maintaining green wet basins, as well as the public, including customers, visitors or staff understand that the basins and their associated plantings and buffers are a stormwater management feature that also provides aesthetic beauty and ecosystem benefits. Signage should be provided at green wet basins to include awareness information that green wet basin perimeters and their associated buffers are a "no mow" zone, that no swimming is allowed and that the basin is for managing stormwater runoff.

Wet basin with buffer (Photo: David Dods, URS)

Wet basin with small buffer (Photo: David Dods, URS)

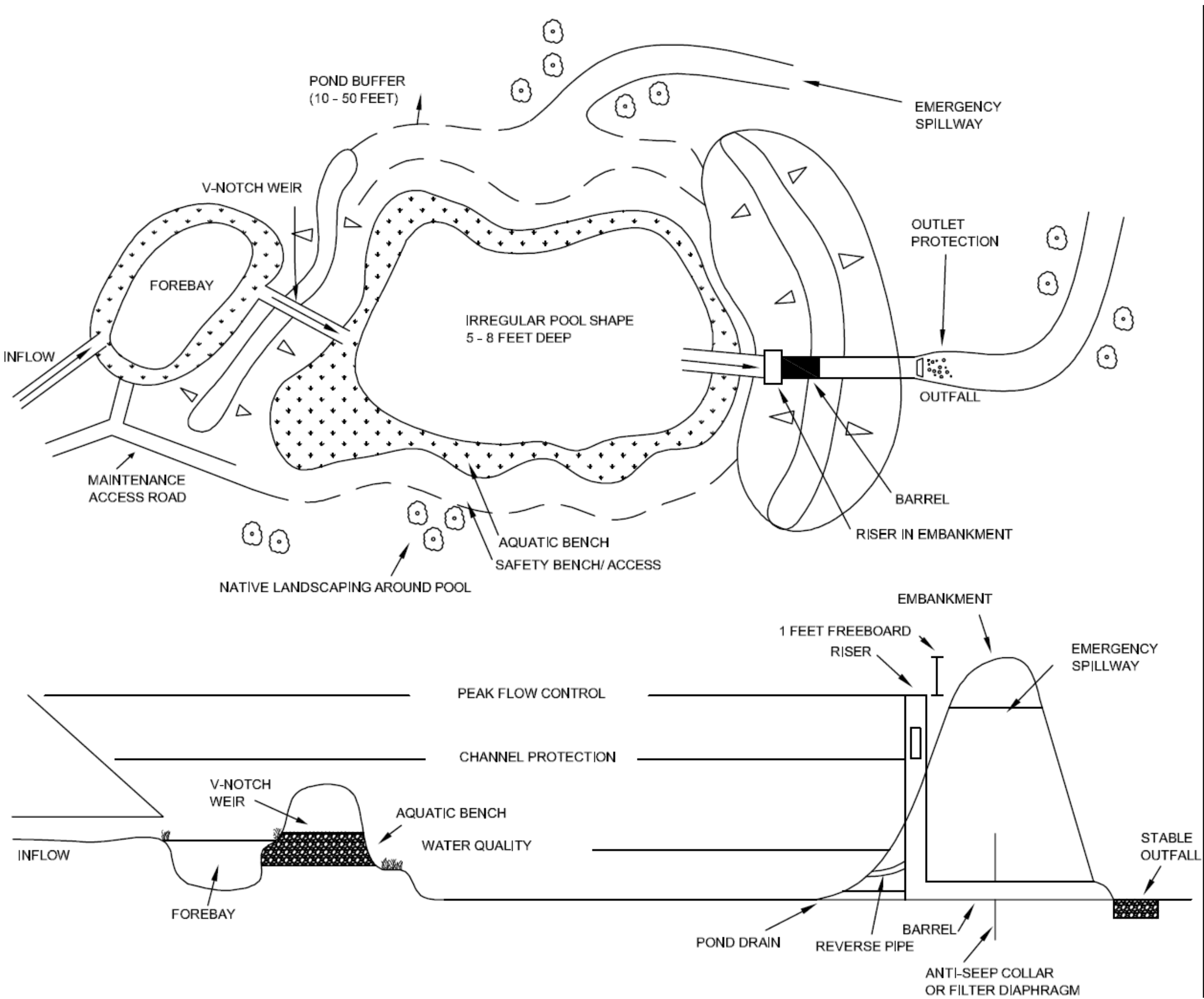


Figure 18.5.4-A. Plan and section of typical green wet basin

Green Wet Basins Application and Site Feasibility Criteria

Table 18.5.4-A.

Design Parameter	Criteria
Drainage Area	At least 25 acres of upstream drainage area to maintain water levels during dry weather
Side Slopes	No greater than 3:1 (H:V), flatter is recommended. Aquatic bench should be no greater than 4:1 and safety bench should be relatively flat.
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred
Soil Permeability	Soil permeability should be ≤ 0.14 inches/hour.
Pretreatment—Forebay	Size pretreatment forebay per MSD Design Manual requirements.
Design Flows and Conveyance Capacity	Pass the 2-, 10- and 100-year storms with at least one foot of freeboard. Detention basins shall be fully discharged within 36 hours after the storm event per MSD Design Manual.
Storage Capacity	MSD Design Manual requirements.

Green Wet Basins Step by Step Design Procedures

Step 1: Define goals/primary function of the green wet basin

Begin by defining the goals/primary function of the green wet basin, especially the extended detention of stormwater runoff. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations. The design should be based on detention basin requirements stipulated in the MSD Design Manual.

Step 2: Determine the peak flow rate and total runoff volume

The green wet basin should be sized to capture and temporarily store the runoff volume required by the MSD Design Manual. If MSD's Design Manual requirements are met, the required WQv is presumed to be met as well. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows per MSD's Design Manual. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a green wet basin, including topography, impermeable soils and a groundwater table below the bottom of the pond. Consider Table 18.5.4-A. Create a rough layout of green wet basin dimensions including existing trees, utility lines, topography and other obstructions.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per MSD's Design Manual.

Step 5: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2-year to 100-year storm events to maximum permissible velocities for the soil types present at the site (or for engineered soils used in the design) and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the basin is filling and vegetation is established. Choose erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Step 6: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated water depth zones within the green wet basin. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.5 Green Dry Basins

Typical Implementation Areas:

- Parks, greenways and common areas
- Detention basin retrofits
- Commercial, multi-family residential and institutional developments

Key Considerations:

- Provides water quality treatment for traditional dry basin
- Used to both detain and treat stormwater
- Use deep rooted, native vegetation along bottom of basin

Cost: Low-Medium
Maintenance: Low-Medium

Green dry basin rendering
(Photo: David Dods, URS, Concept rendering: Shea Powell, Dropseed)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◩
Nitrogen	◩
Metals	◩
Pathogens	□
Floatables	◩
Oil and Grease	◩
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	◩
Infiltration	□
Stormwater Conveyance	□
Stream Channel Protection	◩
Peak Flow Control	◩
Runoff Volume Reduction	
Runoff Capture	◩

Key: ■ Significant Benefit
◩ Partial Benefit
□ Low or Unknown Benefit

Green dry basins are similar to standard dry basins. The exceptions are that a green dry basin contains a forebay for capturing the heavier sediment and floatables, non-turf grass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm events and no low flow channel so sheet flow can be promoted instead. By design green dry basinssw allow for extended detention, about 48 hours. Green dry basins improve water quality through:

- ☑ Biological uptake and filtering through deep rooted, native plants
- ☑ Sediment settling, including attached pollutants
- ☑ Temporary detention of stormwater
- ☑ A slower rate of release that reduces downstream bank erosion

Advantages/Benefits

- Effective at removing sediment
- Increases biodiversity by providing urban habitats for wildlife
- Reduces channel/stream bank erosion by reducing number of bankfull events downstream
- Well accepted by community

Disadvantages/Limitations

- Relatively large space requirement
- Tends not to drain well, leading to maintenance challenges
- Can pose a safety hazard due to water pooling during rain events
- Not to be used in high groundwater areas

Application and Site Feasibility

Green dry basins are similar to standard dry basins, except for the addition of native vegetation, a forebay and a multi-stage outlet. Features may need to be included in basins to minimize short circuiting between the inlet and outlet. Generally, dry ponds need to have a drainage area of at least 10 acres to keep the vegetation watered during the dry periods and to not have too small of a low flow orifice that would likely become plugged with debris. Green dry basins can be constructed new or can be the result of retrofitting standard dry basins. Green dry basins are appropriate for use in a wide variety of land use applications such as commercial, industrial or multi-family residential areas.

Physical Requirements

Key physical considerations are:

- Space available—Sufficient space is required to temporarily store the stormwater runoff
- Drainage area—Have adequately large drainage area to provide some flow during drier weather and maintain larger low flow orifices.
- Plantings—Robust plantings along the bottom of green dry basins provide water quality treatment; plantings need to be able to survive the dry to submerged conditions that they will experience

Design Criteria

The size of green dry basins should be determined using the design requirements for detention basins as described in Chapter 10.3.8 of MSD's Design Manual. The following additional criteria should also be included in the design of green dry basins. For a summary of design parameters, see Table 18.5.5-A on page 7.

Design criteria to consider for green dry basins include:

- Pretreatment—Forebay
- Conveyance
- Outlet
- Landscaping/plant selection
- Safety
- Maintenance

Pretreatment—Forebay

Excessive sediment accumulation in green dry basins can block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the basin. The forebay should be sized to meet the requirements of Chapter 10.3.8 of MSD's Design Manual and prevent the resuspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 4-6 feet, which will also prevent the growth of unwanted vegetation and allow for the survival of mosquito eating fish. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the green dry basin and reduce velocities to prevent erosion. The forebay should also be designed to allow for ready access to perform maintenance, including removal of accumulated sediment and floatables.

Conveyance

Though green dry basins' primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because pooled water in the basins allows opportunities for the solid particles in the stormwater to settle, the flow path needs to be diffuse and as long as possible. To provide a long flow path, basins need to have a length to width ratio of at least 2:1, with 3:1 preferred.

Green dry basins need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the green dry basins will help to spread out and slow down larger flows, reducing the potential for erosion. An emergency spillway is also needed to safely convey the flow out of the green dry basins. The area downstream of the emergency spillway needs to be protected to prevent scour.

Outlet

The design and configuration of the outlet structure should allow for extended detention of the stormwater runoff from the required WQv, 2-year, 10-year and 25-year rain events. The outlet structure will likely consist of a riser connected to a discharge pipe that discharges to the downstream receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars around the discharge pipe to prevent seepage.

A high flow bypass either separate from or in conjunction with the outlet structure should be included to safely convey high flows from large storm events. A minimum of one foot of freeboard should be provided during the 100-year rain event. The discharge from the outlet structure should be equipped with armoring, plunge pool, energy dissipater or similar best management practices to prevent scour.

Landscaping/Plant Selection

A landscaping plan is recommended for planting green dry basins. The plan should include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Identify ephemeral zones that will be subject to wet and dry periods and dry zones and select plants appropriate for each zone.
Choices available for planting the green dry basins include seed, rhizomes, bare root stock and potted plants. Planting

rhizomes is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Safety

Like any GMP that holds water, safety is a significant consideration. The side slopes should be 3:1 or flatter and relatively flat safety benches should be provided in the water just above the permanent pool level of the forebay. The maximum depth of the basin should be 10 feet to provide an additional factor of safety.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Green dry basins, if used in series with other GMPs, are typically installed near the outlet structure or the end of the series. Upstream GMPs may include rain gardens and bioretention basins.

Educational Awareness

To maintain the integrity of green dry basins, those maintaining them need to understand that the basins and their associated plantings are a stormwater management feature that also provides aesthetic beauty and ecosystem benefit. Signage should be provided at green dry basins to include awareness information that they are a "no mow" zone and for managing stormwater runoff.

Green dry basin rendering
(Photo: Erin Wagoner, URS, Concept rendering: Shea Powell, Dropseed)

Green Dry Basins Application and Site Feasibility Criteria

Table 18.5.5-A.

Design Parameter	Criteria
Drainage Area	At least 10 acres of upstream drainage area to provide watering of vegetation during dry weather
Side Slopes	No greater than 3:1 (H:V), flatter is recommended. Safety bench around forebay just below the permanent water level should be relatively flat.
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred
Pretreatment—Forebay	Size pretreatment forebay per MSD Design Manual requirements
Design Flows and Conveyance Capacity	Pass the 2-, 10- and 100-year storms with at least one foot of freeboard. Detention basins shall be fully discharged within 36 hours after the storm event per MSD Design Manual.
Sizing Storage Capacity	MSD Design Manual detention basin requirements

Green Dry Basins Step by Step Design Procedures

Step 1: Define goals/primary function of the green dry basin

Begin by defining the goals/primary function of the green dry basin, especially the extended detention of stormwater runoff. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations. The design should be based on MSD's detention basin requirements stipulated in the MSD Design Manual.

Step 2: Determine the peak flow rate and total runoff volume

The green dry basin should be sized to capture and temporarily store the runoff volume required by the MSD Design Manual. If the Design Manual requirements are met, the required WQv is presumed to be met as well. If extended detention is provided, the water level should drain back down to the normal pool elevation in approximately 36 hours. Larger storms (10- and 100-year) should be checked to size outlet and emergency overflow structures and pipes to convey these flows per MSD's Design Manual. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of a green dry basin. Consider Table 18.5.5-A. Create a rough layout of green dry basin dimensions including existing trees, utility lines, topography and other obstructions.

Step 4: Determine the pretreatment (forebay) volume

Size the forebay per the Chapter 10.3.8 of MSD's Design Manual.

Step 5: Determine outlet design

Based on the green dry basin configuration, check water surface elevations for all storm events (shown in Step 2) so the basin can pass these flows safely and drain empty within 36 hours. This includes meeting the 1 foot freeboard requirement for the 100-year storm event and determining the need for erosion prevention and energy dissipation measures at the outlet. Modify design as appropriate.

Step 6: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2-year to 100-year storm events to maximum permissible velocities for the soil types present at the site and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the basin is filling and vegetation is becoming established. Choose an erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Step 7: Prepare native vegetation and landscaping plan

Choose native plants based on aesthetic preferences, plant heights, sun/shade tolerances and the anticipated water depth zones within the green dry basin. The plan should include the following information:

- Different planting zones and the water depths, the water level fluctuations and wetting characteristics of each zone
- Species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

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18.5.6 Extensive Green Roof

Extensive green roof planted with vegetables (foreground) and sedum (background)
(Photo: Chad McCormick, URS)

Typical Implementation Areas:

- Rooftops including urban commercial and residential use
- Urban public space

Key Considerations:

- Structural capacity of building
- Slope of roof
- Use of drought tolerant native vegetation or cultivars

Cost: High
Maintenance: Low

Stormwater Management Benefits

Pollutant Reduction	
Sediment	□
Phosphorus	□
Nitrogen	□
Metals	□
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	□
Stormwater Conveyance	□
Stream Channel Protection	◩
Peak Flow Control	■
Runoff Volume Reduction	
Runoff Capture	■

Key: ■ Significant Benefit
◩ Partial Benefit
□ Low or Unknown Benefit

An extensive green roof is a roofing system made up of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive green roofs are classified as green roofs with a soil depth of six inches or less. This shallow soil layer is designed to support dense, low growing, drought tolerant vegetation. Green roofs may also be called vegetated roofs or eco-roofs. Green roofs improve water quality through:

- ☑ Significant reduction of roof runoff volume
- ☑ Reduction of runoff pollutant loads compared to traditional roof applications
- ☑ Reduction of impervious area
- ☑ Biological uptake through drought tolerant plants

Advantages/Benefits

- Reduces energy costs
- Provides additional roof insulation
- Reduces urban heat island effect
- Improves air quality
- Extends life of roof
- Adds landscaping value to outdoor rooftop gathering spaces
- Provides wildlife habitat
- Allows for retrofit opportunities

Disadvantages/Limitations

- Roof strength/structure may limit retrofit application
- Extreme sun and wind conditions can challenge plant survival
- Potential for roof leaks
- Irrigation often necessary to establish plants
- Planting on a sloped roof requires erosion control structures

Application and Site Feasibility

An extensive green roof can be placed on high density residential, commercial, or industrial buildings that have the structural stability to support the increased loads of the green roof system. Passive outdoor amenity/recreational spaces may benefit or compliment a green roof with paths and patio areas adjacent to planting beds. Rooftops may be flat or sloped as steep as 25%, given consideration for structural stability and erosion control of the system. An extensive green roof may be constructed on a new roof, or a remodeled roof that has the waterproofing and structural stability to hold the system in saturated, wet weather conditions. Especially in ultra urban areas, green roofs can be used as passive recreational spaces including roof garden patios or functioning vegetable and herb gardens.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof must be structurally capable of supporting saturated soil media, vegetation and other structural loads. Substrate depths for extensive green roofs may vary from 2 to 6 inches. Shallower planting depths can reduce costs and structural loads.
- Roof waterproofing and drainage—The drainage layer is a key component to convey excess moisture through saturated soils and off the roof deck. The roof must be waterproofed to prevent leaking and damage of the structure below. Leak detection systems may be installed to identify and locate leaks.
- Plant selection—Plant selection is limited due to extreme rooftop weather conditions including wind, sun, drought and cold winter temperatures. Plants selected should be able to withstand these extreme conditions.
- Slope of rooftop—Extensive green roofs are suitable for both flat or sloped rooftops, but are much easier to design and install for flat rooftops (with a pitch of up to 1.5 %). Rooftops with steep slopes require additional structural components to hold the soil and drainage layers in place and prevent erosion. Rooftops with slopes greater than 25% are not suitable for extensive green roofs.

Design Criteria

Green roofs should be designed to manage the WQv of runoff. Extensive green roofs have several elements to manage stormwater including eliminating impervious area, stormwater retention and plant absorption and reduction of stormwater runoff volumes. There are proprietary applications on the market that design green roof systems, in addition to utilizing the guidance provided here. See Figure 18.5.6-A for a typical exstensive green roof cross-section. For a summary of design parameters, see Table 18.5.6-A on page 6.

Design criteria to consider includes:

- Location of the green roof bed
- Structural integrity
- Waterproofing
- Drainage
- Soil and plants
- Maintenance

Newly planted sedum on extensive green roof (Photo: Erin Wagoner, URS)

Established sedum plants on extensive green roof (Photo: Chad McCormick, URS)

Location of Green Roof Bed

Consider the purpose of the green roof. If the roof is intended for access by building occupants or patrons, beds must be separated by walking paths and patio areas. Beds should be clearly delineated and separated to minimize damage to plants and compression of soils due to walking or standing.

Wind and uplift pressures tend to be higher around the roof perimeter, and therefore should have a vegetation-free buffer between the green roof bed and the edge of the roof. Any rooftop openings should also have a vegetation-free buffer.

Structural Integrity of Roof

The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an extensive green roof. Both the dead load, including the total weight of green roof materials; saturated soil and snow loads, and other live loads must be considered.

Waterproofing

Since water is being retained on the rooftop, it is essential to have adequate waterproofing to minimize leaks that can damage the building interior. Waterproofing may be accomplished through the use of a waterproofing membrane or other waterproofing roofing systems. See Figure 18.5.6-A. Coordinate with the roofing system manufacturer for application and comply with their specifications for installation.

A protective layer or root barrier should be used to prevent roots from damaging the waterproof membrane. Electronic leak detection systems may also be considered to notify and locate leaks when they occur.

Drainage

The drainage layer often consists of a manufactured material or a shallow gravel layer to store stormwater for plant uptake and routing of stormwater. Rooftops should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.

Downspouts should not be directly connected to the sewer system, and should be routed to another green management practice, such as a cistern, rain garden, bioswale or pervious pavement.

Roof garden patio includes a green house and extensive green roof planted with vegetables and herbs (Photo: Chad McCormick, URS)

Installation of plants on an extensive green roof (Photo: Louisville & Jefferson County MSD)

Soil and Plants

Soils for extensive green roofs should be between 2 and 6 inches thick. The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical extensive green roof soil mix may consist of the following materials, by volume:

- 50% pumice perlite
- 25% organic compost
- 25% topsoil

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. Although perennial, self-sustaining, native plant varieties are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities or function. Native and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Green roofs, if used with other GMPs, are typically the first in the series or treatment train, collecting stormwater at the source. Excess runoff from saturated soils or from the roof perimeter can be routed from downspouts to a treatment train of cisterns, pervious pavement, rain gardens or planters.

Educational Awareness

To maintain a green roof and the structure beneath it, those maintaining it need to understand that the roof is a stormwater management feature that needs to be maintained.

Extensive green roof showing drainage slots and non-vegetated buffer along roof perimeter (Photo: Erin Wagoner, URS)

Extensive green roof with non-vegetated access path and buffers around vents (Photo: Erin Wagoner, URS)

Excess drainage from extensive green roof flows from drainage layer slots over non-vegetated buffer to roof downspouts, which discharge into a rain garden (Photo: Erin Wagoner, URS)

Stormwater treatment train flows from green roof to cisterns to a bioswale (Photo: Ted Wathen The Green Building)

Extensive Green Roof Application and Site Feasibility Criteria

Table 18.5.6-A.

Design Parameter	Criteria
Waterproofing Roof	Roof must contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Soil Mix	The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical green roof soil mix may consist of the following materials, by volume: • 50% pumice perlite • 25% organic compost • 25% topsoil
Storage Capacity	Green roof total volume should be equivalent to the Required WQv. Required WQv (ft^3) = $(^1/_{12})(RE_{WQV})(Rv)(A)$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I), where ◆ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the green roof (ft^2)
Structural Integrity of Roof	The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an extensive green roof.

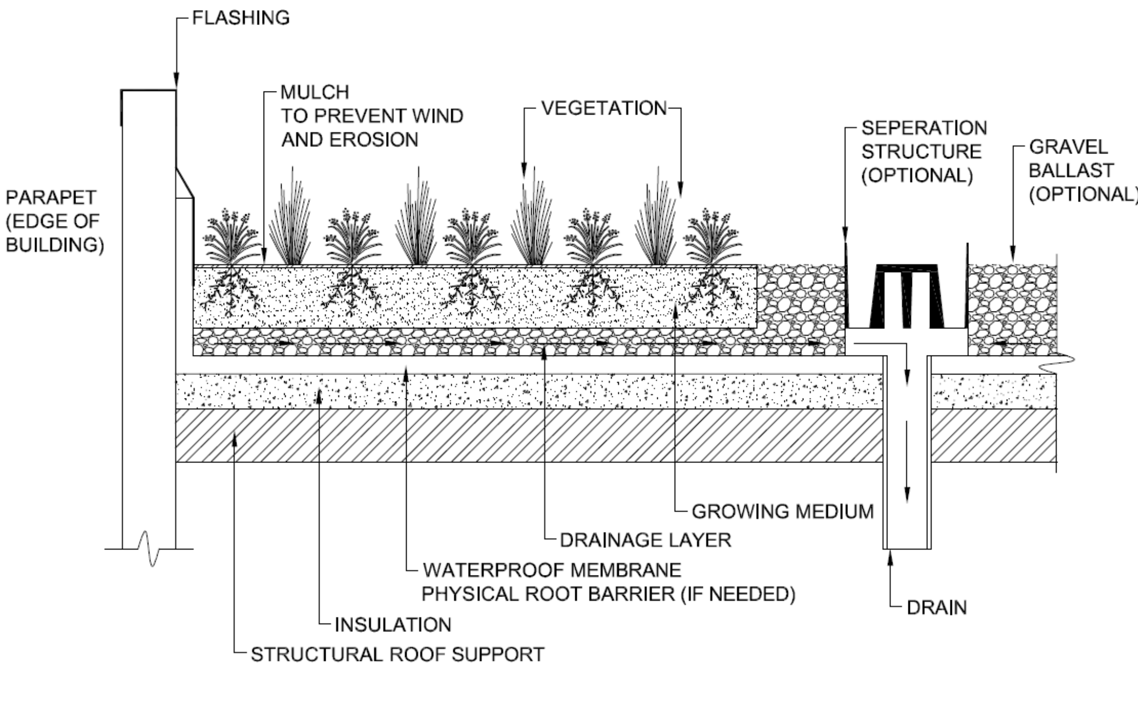

Figure 18.5.6-A. Typical extensive green roof (soil depth of 6 inches or less)

Extensive Green Roof Step by Step Design Procedures

Step 1: Define goals/primary function of the green roof

Define the goals/primary function of the green roof. Consider whether the roof is intended to:

- Provide passive recreational space
- Support loads in addition to the green roof system
- Treat excess stormwater by routing through a series of GMPs

Consider any special site-specific design conditions/criteria. Where traditional rooftops may be proposed, consider using a green roof as an alternative if the structure will support additional loads. Locate roof downspouts and check potential locations/available space incorporating a series of GMPs down gradient of the green roof. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions, requirements, goals and primary function(s) of the green roof. Manufactured systems may be used and could include modular, tray or rolled systems.

Step 2: Determine if structure is appropriate

Based on the defined goals for the green roof, determine if the structure is appropriate and can support additional loads. Use Table 18.5.6-A.

Step 3: Determine the total runoff volume and drainage

The green roof system should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.6-A can be used in this form:

WQv (ft^3) = (RE_{WQV})(Rv)(A/12).

Green roofs must be designed to safely convey excess runoff produced by larger storm events through a drainage layer. Sloped rooftops should consider erosion protection and stabilization.

Step 4: Determine green roof dimensions

Calculate the required volume of the green roof based on the void space of the planting media and storage of the drainage layer so that it can store the WQv per Table 18.5.6-A. Locate non-vegetated buffers along the roof perimeter and around the base of any openings in the roof.

Step 5: Prepare vegetation plan

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Invasive species must not be used.

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18.5.7 Intensive Green Roof

Intensive (deep) and extensive (shallow) green roof beds
(Photo: Louisville & Jefferson County MSD)

Typical Implementation Areas:
- Rooftops including urban commercial and residential use
- Urban public space

Key Considerations:
- Structural capacity of building
- Use of drought tolerant native vegetation or cultivars
- Slope of roof

Cost:	High
Maintenance:	Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Low or Unknown Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Low or Unknown Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Low or Unknown Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Significant Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Low or Unknown Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Significant Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

Key: ■ Significant Benefit; ◩ Partial Benefit; □ Low or Unknown Benefit

An intensive green roof is a roofing system made up of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Intensive green roofs have soil depths greater than six inches to support the root growth of larger plants, shrubs and trees. The soil layer is designed to support trees or elaborate rooftop gardens. Green roofs may also be called vegetated roofs or eco-roofs. Green roofs improve water quality through:

- ☑ Significant reduction of roof runoff volume
- ☑ Reduction of runoff pollutant loads compared to traditional roof applications
- ☑ Reduction of impervious area to closely mimic pre-developed hydrology
- ☑ Biological uptake through drought tolerant plants

Advantages/Benefits

- Reduces energy costs
- Provides additional roof insulation
- Reduces urban heat island effect
- Improves air quality
- Extends life of roof
- Adds landscaping value to outdoor rooftop gathering spaces
- Provides wildlife habitat
- Allows for retrofit opportunities

Disadvantages/Limitations

- Roof strength/structure may limit retrofit application
- Extreme sun and wind conditions can challenge plant survival
- Potential for roof leaks
- Irrigation often necessary to establish and maintain plants
- Not recommended for sloped rooftops

Application and Site Feasibility

An intensive green roof can be placed on high density residential, commercial or industrial buildings that have the structural stability to support the increased loads of the green roof system. Passive outdoor amenity/recreational spaces may benefit or compliment a green roof with paths and patio areas adjacent to planting beds. Rooftops for intensive green roofs must be flat or slightly sloped. Although an intensive green roof may be constructed on an existing structure, they are more often designed for new construction due to the increased loads. Intensive green roof beds can be combined with shallower, extensive beds to supplement the roof with larger shrubs or trees at less cost than designing the entire roof as an intensive green roof.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof must be structurally capable of supporting saturated soil media, vegetation and other structural loads. Substrate depths for intensive green roofs are greater than 6 inches and less than 24 inches, to accommodate tree and shrub root systems.
- Roof waterproofing and drainage—The drainage layer is a key component to convey excess moisture through saturated soils and off the roof deck. The roof must be waterproofed to prevent leaking and damage of the structure below. The waterproofing layer should be protected to prevent roots from damaging it. Leak detection systems may be installed to identify and locate leaks.
- Plant selection—Plant selection is limited due to extreme rooftop weather conditions including wind, sun, drought and cold winter temperatures. Plants selected should be able to withstand these extreme conditions. Intensive green roofs require increased maintenance or irrigation during extreme conditions
- Slope of rooftop—Intensive green roofs are suitable for both flat or slightly sloped rooftops, up to 10%.

Design Criteria

Green roofs should be designed to manage the WQv of runoff. Intensive green roofs have several elements to manage stormwater including eliminating impervious area, stormwater retention and plant absorption to facilitate water and air quality improvement and reduction of stormwater runoff volumes into the sewer system. There are manufacturers and proprietary applications on the market that design green roof systems, in addition to utilizing the guidance provided here. See Figure 18.5.7-A for a typical cross-section of an intensive green roof planting. For a summary of design parameters, see Table 18.5.7-A.

Intensive green roof beds, planted with evergreen shrubs (Photo: Chad McCormick, MSD)

Design criteria to consider includes:

- Location of the green roof bed
- Structural integrity
- Waterproofing
- Drainage
- Soil and plants
- Maintenance

Location of Green Roof Bed

Consider the purpose of the green roof. Most intensive green roofs are intended for use by building occupants, patrons or the general public. Green roof beds must be separate from walking paths and patio areas. Beds should be clearly delineated and separated to minimize damage to plants and compression of soils due to walking or standing.

Wind and uplift pressures tend to be higher around the roof perimeter, and therefore should have a vegetation-free buffer between the green roof bed and the edge of the roof. Any rooftop openings should also have a vegetation-free buffer.

Structural Integrity of Roof

The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an intensive green roof. The dead load, including the total weight of green roof materials; saturated soil and snow loads; and other live loads must be considered. The placement of large trees or shrubs should be located over columns or main beams to support the heavy weight of the soil and plant.

Waterproofing

Since water is being retained on the rooftop, it is essential to have adequate waterproofing to minimize leaks that can damage the building interior. Waterproofing may be accomplished through the use of a waterproofing membrane or other waterproofing roofing system. Coordinate with the roofing system manufacturer for application and comply with their specifications for installation.

A protective layer or root barrier should be used to prevent roots from damaging the waterproof membrane. The root balls of large trees and shrubs should also be anchored to avoid piercing the waterproof membrane. Electronic leak detection systems may also be considered to notify and locate leaks when they occur.

Drainage

The drainage layer often consists of a manufactured material or a shallow gravel layer to store stormwater for plant uptake and routing of stormwater. Rooftops should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.

Downspouts should not be directly connected to the sewer system, and should be routed to another green management practice, such as a cistern, rain garden, bioswale or pervious pavement.

Soil and Plants

Soils for intensive green roofs should be greater than 6 inches thick. The soil mix may be determined by the designer or product manufacturer and can vary based on selected plant species. A typical extensive green roof soil mix may consist of the following materials, by volume:

- 50% pumice perlite
- 25% organic compost
- 25% topsoil

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Intensive green roof plants require more maintenance such as irrigation and pruning compared to extensive green roof plants. To reduce maintenance, plants should be selected with the goal of reducing the need for irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Although perennial, self-sustaining, native plant varieties are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities or function. Native and cultivar species are provided in Chapter 13 of the MSD Design Manual. Especially in ultra urban areas, extensive green roofs can be used as passive recreational spaces including elaborate roof garden patios or functioning vegetable and herb gardens.

Extensive green roof beds (foreground) are paired with intensive green roof beds (background), planted with evergreen shrubs (Photo: Chad McCormick, MSD)

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Train—Combination and Location in Series With Other GMPs

Green roofs, if used with other GMPs, are typically the first in the series or treatment train, collecting stormwater at the source. Excess runoff from saturated soils or from the roof perimeter can be routed from downspouts to a treatment train of cisterns, pervious pavement, rain gardens or planters.

Educational Awareness

To maintain a green roof and the structure beneath it, maintenance of this stormwater management feature is critical. It is especially important to check for leaks in the waterproofing, weed periodically to pull out any plant growth over one foot tall (typically from tree seeds), limit irrigation and keep gutters and downspouts clear of leaves and debris.

Application and Site Feasibility Criteria

Table 18.5.7-A.

Design Parameter	Criteria
Waterproofing Roof	Roof must contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Soil Mix	The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical green roof soil mix may consist of the following materials, by volume: • 50% pumice perlite • 25% organic compost • 25% topsoil
Storage Capacity	Green roof total volume should be equivalent to the Required WQv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the green roof (ft^2)
Structural Integrity of Roof	The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating an intensive green roof.

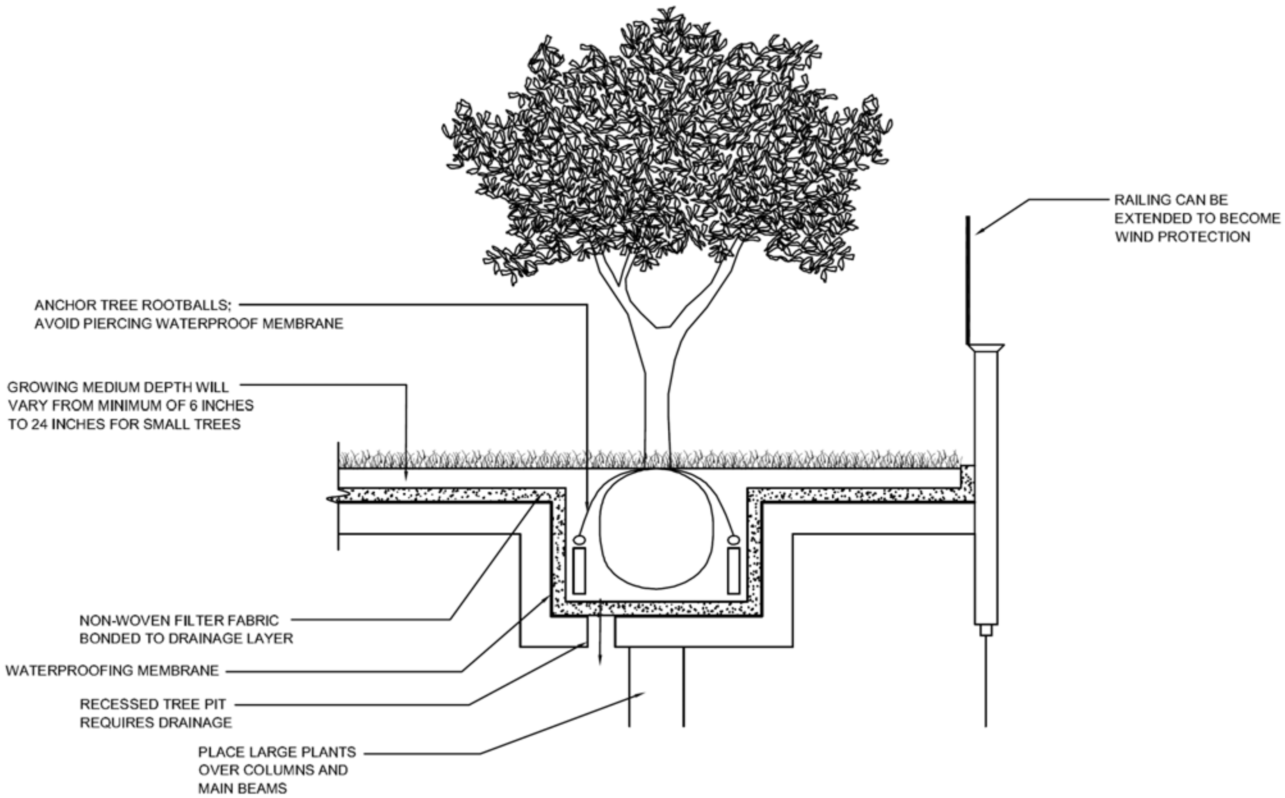

Figure 18.5.7-A. Cross-sectional View

Step by Step Design Procedures

Step 1: Define goals/primary function of the green roof

Define the goals/primary function of the green roof. Consider whether the roof is intended to:

- Provide passive recreational space
- Support loads in addition to the green roof system
- Treat excess stormwater by routing through a series of GMPs

Consider any special site-specific design conditions/criteria. Where traditional rooftops may be proposed, and where the structure will support additional loads consider using a green roof as an alternative. Locate roof downspouts and check potential locations/available space incorporating a series of GMPs down gradient of the green roof. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply. The design should be based on the restrictions/requirements, goals and primary function(s) of the green roof.

Step 2: Determine if structure is appropriate

Based on the defined goals for the green roof, determine if the structure is appropriate and can support additional loads. When designing intensive green roofs, the placement of large trees or shrubs should be located over columns or main beams to support the heavy weight of the soil and plant. Use Table 18.5.7-A.

Step 3: Determine the total runoff volume and drainage

The green roof system should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.7-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12)$.

Green roofs must be designed to safely convey excess runoff produced by larger storm events through a drainage layer. Sloped rooftops should consider erosion protection and stabilization.

Step 4: Determine green roof dimensions

Calculate the required volume of the green roof based on the void space of the planting media and storage of the drainage layer so that it can store the WQv per Table 18.5.7-A. Locate non-vegetated buffers along the roof perimeter and around the base of any openings in the roof.

Step 5: Prepare vegetation plan

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Plants should require little to no irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Invasive species must not be used.

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18.5.8 Blue Roof

Typical Implementation Areas:
- Commercial, industrial, multi-family residential and institutional developments
- Highly urbanized areas

Key Considerations:
- Waterproof and structurally sufficient roof
- Used to detain stormwater
- Slope of roof

Cost: Medium
Maintenance: Low

Blue roof adjacent to green roof (Photo: New York City Blue Roof and Green Roof Comparison Study)

Stormwater Management Benefits

Pollutant Reduction

Sediment	Low or Unknown
Phosphorus	Low or Unknown
Nitrogen	Low or Unknown
Metals	Low or Unknown
Pathogens	Low or Unknown
Floatables	Low or Unknown
Oil and Grease	Low or Unknown
Dissolved Pollutants	Low or Unknown

Hydrologic Characteristics

Surface Flow Reduction	Low or Unknown
Infiltration	Low or Unknown
Stormwater Conveyance	Low or Unknown
Stream Channel Protection	Partial
Peak Flow Control	Partial

Runoff Volume Reduction

Runoff Capture	Significant

Key: ■ Significant Benefit; ◩ Partial Benefit; □ Low or Unknown Benefit

A blue roof, also referred to as rooftop detention, is the practice of storing 1 to 4 inches of rainfall on the roof and slowly releasing it into the storm sewer system over a period of time, typically 24 hours. Some blue roofs also incorporate passive recreation, such as sun-bathing and water play areas, as an added bonus. To accomplish the rooftop detention, outlet devices consisting of weirs or orifice plates are placed around the roof drains, allowing some rainfall to discharge down the roof drain while the rest is temporarily stored. Should rainfall exceed the design detention depth and volume, the collected rainfall would flow over the weir or orifice plate and into the roof drain. A blue roof improves water quality through:

☑ Temporary detention of stormwater and reduction of peak flows

Advantages/Benefits

- Reduces channel/stream bank erosion by reducing number of downstream bankfull events
- Opportunity for multiple uses, including passive recreation
- Ability to store water around the perimeter of roofs if designed correctly
- Cost-effective way to capture rainfall volume

Disadvantages/Limitations

- Possible roof reinforcing requirements
- Potential for roof leaks
- Can only be applied to a relatively flat roof

Application and Site Feasibility

A blue roof is similar to a standard flat roof, except for the addition of a waterproofing system and the necessary structural stability to support the detained rainwater. The roof needs to be relatively flat to store the required rainwater without exceeding the ponding levels and load limits of the roof. A blue roof can be constructed on a new roof, or a remodeled roof that has the waterproofing and structural stability to store the desired rainfall depth. A blue roof is appropriate for use in a wide variety of land use applications such as commercial, industrial or multi-family residential highly urbanized areas.

Physical Requirements

Key physical considerations are:

- Roof stability—The roof has to be structurally capable of supporting the stored rainwater
- Roof waterproofing—Roof has to be waterproof to prevent leakage and damage of the structure below
- Slope of roof—Roof slope should be relatively flat

Design Criteria

A blue roof should be able to collect and temporarily detain the required WQv rainfall event over a 24 hour period following the rain event. Detainage of the rainfall can be accomplished through the use of weirs and orifice plates on the roof drains or valving. For a summary of design parameters, see Table 18.5.8-A on the next page.

Design criteria to consider for a blue roof includes:

- Water Storage Depth
- Structural Integrity
- Waterproofing
- Outlets
- Maintenance

Water Storage Depth

The water storage depth is typically between 1-4 inches, based on the storage volume needed, the slope of the roof and the structural integrity of the roof.

Structural Integrity

The structural integrity of the roof should be evaluated by a licensed structural engineer. The engineer should determine the loading limits of the roofing system to determine the depth and volume of rainwater that the roof can detain.

Waterproofing

For a roof to detain rainfall, it has to be waterproof. This may be accomplished through the use of a waterproofing membrane or a fluid applied waterproofing roofing system. Coordinate with the roofing system manufacturer for application and comply with their installation specifications .

Outlets

Weirs or orifice plates are needed around the roof drains/ outlets to restrict runoff from the roof and temporarily detain the rainfall. Valving can also be used to serve the same purpose. The roofing system needs to include overflows and an adequate number of roof drains/outlets to pass the larger rain events, even if 35% of the drains/ outlets are clogged with leaves and debris. Typically a minimum of two roof drains/outlets are required for a smaller roof (10,000 square feet and less) and four or more are required for a larger roof.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A blue roof, if used in series with other GMPs to provide stormwater management, is typically at the beginning of the treatment train because it collects water at the source.

Educational Awareness

To maintain the integrity of a blue roof and the structure under it, those maintaining should be aware that the roof is a stormwater management feature that needs to be maintained.

Blue Roof Application and Site Feasibility Criteria

Table 18.5.8-A.

Design Parameter	Criteria
Water Storage Depth	Determine the structural integrity of the roof. Typical water storage depth is 1-4 inches.
Waterproofing Roof	Roof has to contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations.
Detention	Stormwater should be slowly released over the 24 hours following the storm event.
Storage Capacity	Blue roof total volume of detained water should be equivalent to the Required WQv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A) where • RE_{WQV} = Required WQv Rain Event (refer to Chapter 18.3) • Rv = 0.05 + 0.009 (I) ♦ I = impervious cover in percent • A = the drainage area to the blue roof (ft^2).

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.9 Permeable Pavers

Typical Implementation Areas:

- Alleys, neighborhood streets, driveways
- Low volume roads
- Low speed roads
- Parking lots and overflow parking
- Crosswalks, sidewalks, multi-use paths

Key Considerations:

- Soil type and stability
- Grade
- Traffic volume
- Type of desired drainage
- Storage retention/infiltration

Cost: High
Maintenance: High

Installation of permeable interlocking concrete pavers (Photo: Louisville & Jefferson County MSD)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefits
Phosphorus	Low or Unknown Benefits
Nitrogen	Low or Unknown Benefits
Metals	Partial Benefits
Pathogens	Low or Unknown Benefits
Floatables	Low or Unknown Benefits
Oil and Grease	Low or Unknown Benefits
Dissolved Pollutants	Low or Unknown Benefits
Hydrologic Characteristics	
Surface Flow Reduction	Significant Benefit
Infiltration	Significant Benefit
Stormwater Conveyance	Low or Unknown Benefits
Stream Channel Protection	Partial Benefits
Peak Flow Control	Low or Unknown Benefits
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

Key: Significant Benefit; Partial Benefits; Low or Unknown Benefits

Permeable pavers are pavement surfaces that promote infiltration of stormwater. Pavers can be used in numerous locations, are aesthetically pleasing and are Americans with Disabilities Act (ADA) compliant. Permeable pavers consist of individual concrete or stone shapes that are placed adjacent to one another over a specially designed sub-base.

Advantages/Benefits

- Reduces volume of stormwater runoff
- Reduces impermeable areas
- Reduces need for drain pipe
- Longer life than traditional pavement
- Easier to maintain than vegetative systems (i.e. bioswales)
- Reusable product
- Reduces need for detention space
- Attractive/aesthetic pavement option

Disadvantages/Limitations

- High cost of pavers versus traditional concrete or asphalt pavement
- Geotechnical exploration required
- Maintenance requirements
- Specialized knowledge required for proper installation

Application and Site Feasibility

Permeable pavers are an alternative to traditional asphalt and concrete paving methods, and allow stormwater to infiltrate into the soil below. A Professional Engineer (Engineer) with geotechnical experience shall evaluate the soil in the site being considered for permeable pavers. The Engineer shall determine the capacity, permeability and the soil type of the selected site. Testing of the site shall be done in accordance with the recommendations of the Interlocking Concrete Pavement Institute (ICPI). More information on ICPI can be found at www.icpi.org. Permeable paver design procedures assume a subsoil California Bearing Ratio (CBR) strength of at least 4% to 5% to qualify for use under vehicular traffic. Table 18.5.9-A below summarizes typical CBR ranges based on soil classification.

Physical Site Considerations

Minimum site requirements:

- The natural water table should be a minimum of three feet below the subsoil surface
- Surrounding topography should have a maximum slope of 20%
- There should be a minimum separation of fifteen feet from buildings
- The site should have a low volume of traffic and not support construction vehicles
- Proper soil inspection

Table 18.5.9-A. Suitability of Soils and Typical CBR Ranges (Unified Soil Classification System)

USCS Soil Classification	Typical Ranges for Coefficient of Permeability, k, in/hour	Relative Permeability when Compacted and Saturated	Shearing Strength when Compacted	Compressibility	Typical CBR Range (%)
GW– well graded gravels	1.3 to 137	Permeable	Excellent	Negligible	30-80
GP– poorly graded gravels	6.8 to 137	Very Permeable	Good	Negligible	20-60
GM– silty gravels	1.3×10^{-4} to 13.5	Semi-Permeable to impermeable	Good	Negligible	20-60
GC– clayey gravel	1.3×10^{-4} to 1.3×10^{-2}	Impermeable	Good to Fair	Very Low	20-40
SW– well graded sands	0.7 to 68	Permeable	Excellent	Negligible	10-40
SP– poorly graded sands	0.07 to 0.7	Permeable to semi-permeable	Good	Very Low	10-40
SM– silty sands	1.3×10^{-4} to 0.7	Semi-permeable to impermeable	Good	Low	10-40
SC– clayey sands	1.3×10^{-5} to 0.7	Impermeable	Good to Fair	Low	5-20
ML– inorganic silts/low plasticity	1.3×10^{-5} to 0.07	Impermeable	Fair	Medium	2-15
CL– inorganic clays/ low plasticity	1.3×10^{-5} to 1.3×10^{-3}	Impermeable	Fair	Medium	2-5
OL– organic silts/ low plasticity	1.3×10^{-5} to 1.3×10^{-2}	Impermeable	Poor	Medium	2-5
MH– inorganic silts/high plasticity	1.3×10^{-6} to 1.3×10^{-5}	Very Impermeable	Fair to Poor	High	2-10
CH– inorganic clays/high plasticity	1.3×10^{-7} to 1.3×10^{-5}	Very Impermeable	Poor	High	2-5

Design Criteria

The base layer under the permeable pavers is key to their performance. The design of this layer is based on vehicle equivalent single axle loads (ESALS), soil subgrade (geotechnical review), frost heave, design vehicle, pedestrian usage and the paver manufacturer's instructions. While the actual paver is designed to last much longer, most pavement/base designs are based upon a 20 year pavement life. The design and installation of permeable pavers shall be performed by qualified professionals. See Figures 18.5.9-A through 18.5.9-C for permeable pavers typical sections. For a summary of design parameters, see Table 18.5.9-B on page 8.

- Storage Capacity
- Slopes (Subsoil and Pavement)
- Soil Stabilization
- Edge Restraint
- Base Design
- Choker Course
- Permeable Paver Selection
- Frost Heave Consideration
- Outlet Design
- Maintenance

Storage Capacity

The base layers of the permeable paver system are designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The base layers provide a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The engineer will design the base layers, or the appropriate outlet system, to provide a depth that will accommodate required water WQv (refer to Chapter 18.3).

The WQv provided by the designed permeable paver system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv. See Table 18.5.9-B for WQv formulas.

Slopes (Subsoil and Pavement)

If a large slope is applied to either the pavement surface or subsoil the depth of the base and/or the effective subsoil must be increased to account for the loss of capacity. If the base depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the surface and subsoil have a 0% slope and the surface have a 0.5% slope if it is at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with permeable pavers as a

Grass pavers used in a church parking lot (Photo: Site Supply, Inc)

These permeable pavers in a parking lot at Cherokee Park are concrete grid permeable pavers, consisting of a grid filled with topsoil and planted with grass. Concrete grid permeable pavers should be used for light traffic use, such as this overflow parking lot. (Photos: Erin Wagoner, URS) result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns, geo-grid shall be placed on the subsoil surface before any of the aggregate layers are placed. If the aggregate layer is greater than twelve inches it is recommended to place a second layer of geo-grid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geo-grid. The selection of geo-grid will be based on the size of aggregate used in the pavement system. The geo-grid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads the deformation/failure of the soil and pavement are greatly decreased resulting in less failure to the pavement system over time. Any geo-grid used in conjunction with the permeable pavers shall include the following Geo-Grid specifications, at a minimum:

- Manufactured from a punched polypropylene sheet
- Triangular geo-grid shall be used
- 100% resistant to weathering and chemical degradation

Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Mechanical installation of permeable interlocking concrete pavers (Photo: Erin Wagoner, URS)

Edge Restraint

An edge restraint is a concrete barrier around the perimeter of the permeable pavers not placed adjacent to another paved surface. It is typically made of concrete and can be made to look like a curb. This feature can be placed flush with the top of the pavers so that it can be driven over or if overflow is desired. The concrete edge restraint should extend to the lesser of: the bottom of the base layer or 18 inches below the surface of the permeable pavers. The edge restraint is used to keep the pavers from shifting after a load is placed on them.

Installation of permeable interlocking concrete pavers (Photo: Louisville & Jefferson County MSD)

Base Design

The base of the permeable paver system will act as the storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The base should be made up of 2 layers of washed aggregate. The first layer is placed directly on the geo-grid and consists of double washed No. 3 stone. This first layer should be a minimum thickness of 12 inches (18.5 inches where frost heave is a concern). Due to the thickness of the first layer a second layer of geo-grid is recommended to be placed between the two layers of stone in the base layer. The second layer of stone consists of double washed No. 57 stone and should be placed directly upon the geo-grid covering the No. 3 stone. This second layer of base should be a minimum of 4 inches thick. The entire base layer (including both the No. 3 and No. 57 layers should be a minimum of 16 inches thick (21.5 inches thick where frost heave is a concern). This minimum thickness will be structurally sufficient for the design ESAL of permeable pavers. The base thickness may be increased based on storage capacity. The base layer should completely drain after a design storm event if properly maintained.

Choker Course

The choker course is placed on top of the base layer and should be comprised of washed No. 8 aggregate. The minimum thickness of the choker course is 1.5 inches. This course serves as a leveling surface for the pavers. The aggregate in the base is too large to produce an even surface suitable for the pavers to achieve a smooth surface.

Permeable Paver Selection

Permeable Paver selection for the surface layer is dependent primarily on aesthetics and functionality. Types of permeable pavers include:

Brick

- Made of natural materials
- Suitable for road and paths
- Available in a variety of colors

Concrete

- Made of natural materials
- Suitable for roads and paths

Concrete Grid/Grass Grid

- Made of natural materials
- Suitable for overflow parking
- More difficult to maintain during winter months

Articulated Concrete Block

- Made of natural materials
- Suitable for roads, paths and parking lots

Frost Heave Considerations

As with any type of pavement surface, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the base layer should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average of a 3 feet frost depth).

Outlet Design

If the site prevents the surface and subsoil of the permeable pavers from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the use of an underdrain system or overflow must be implemented.

A snow plow removing snow from pavers (Photo: Advanced Pavement Technologies)

Installation of articulated concrete block mats (Photo: Site Supply, Inc)

Underdrain System

If the recommended CBR value for the subsoil does not yield the desired porosity for the water to percolate, or if it is desired to capture and reuse the runoff, then an underdrain system should be used. Underdrain systems are a series of pipes that run longitudinal with the pavers. The pipes used in an underdrain system are perforated pipes that tie into a non-perforated outlet. The size of the pipe is determined by the calculated stormwater capacity drained onto the permeable pavers.

Overflow Design

An alternative to the underdrain system, if the soil has been determined unable to adequately infiltrate stormwater, is an overflow. An overflow directs water that cannot infiltrate into the subsoil to a specific location like a bioswale, rain garden or storm sewer where it can be stored, infiltrated or conveyed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed permeable pavers can easily be located in series with other GMPs such as bioswales or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a permeable pavers and traditional pavers may not be visible to everyone. To maintain the integrity of the permeable pavers, it is important that those maintaining it, as well as the general public, understand that the permeable pavers are stormwater management features that also provide aesthetic beauty. Training of maintenance staff may be required.

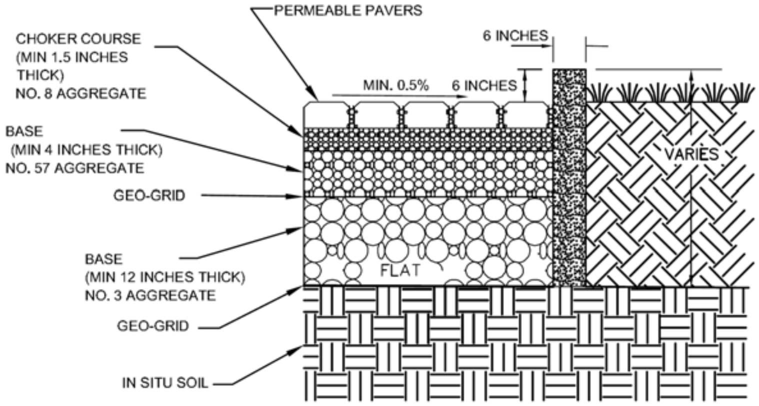


Figure 18.5.9-A. Permeable Pavers Typical Installation

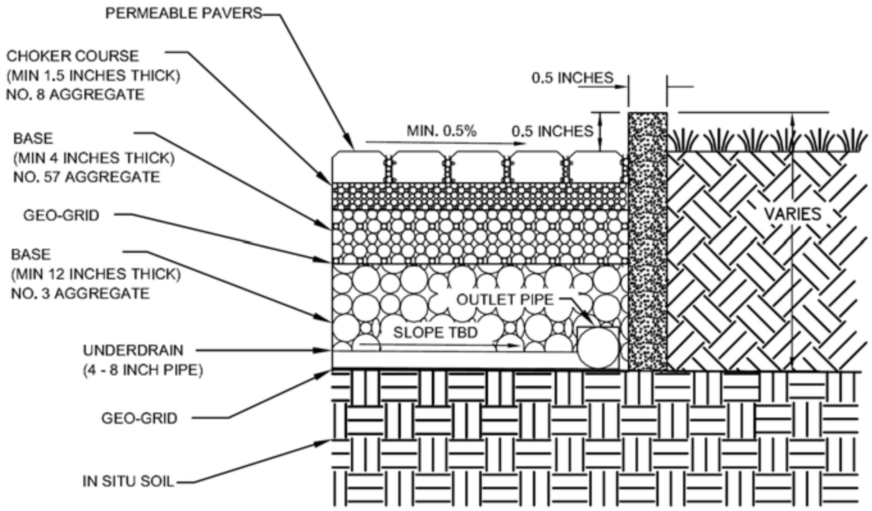


Figure 18.5.9-B. Permeable Pavers with Underdrain System

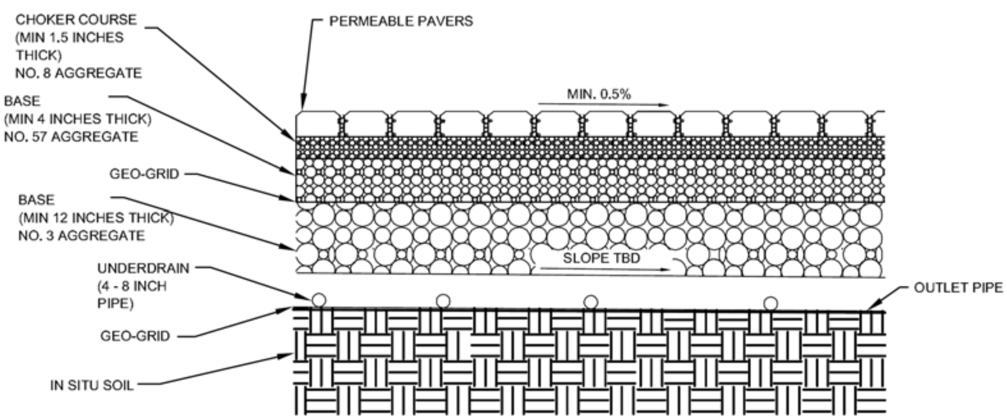


Figure 18.5.9-C. Permeable Pavers with Underdrain System (Profile View)

NOTES

- ALL AGGREGATE WILL BE DOUBLE WASHED
- RAISED HEADER CURB IS OPTIONAL. IT MAY BE CONSTRUCTED AS SHOWN WITH DRAIN SLOTS OR FLUSH. THE USE OF HEADER CURB IS SITE SPECIFIC.
- PAVER THICKNESS SHALL BE AT A MINIMUM 2-3/8 INCHES FOR PEDESTRIAN USE AND 3-1/2 INCHES FOR VEHICULAR USE
- ALL CONCRETE SHALL B CLASS "A" CONCRETE

Permeable Pavers Application and Site Feasibility Criteria

Table 18.5.9-B.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: WQv (ft^3) provided=(A) [(p1)(d1)+(p2)(d2)] *Note: this formula only applies if the paver surface and sub soil have a 0% slope. • A = area of permeable pavers (ft^2) • p1 = porosity of base layer 1 (% void) • d1 =depth of base layer 1 (ft) • p2 = porosity of base layer 2 (% void) • d2 = depth of base layer 2 (ft)
Location	• The natural water table should be a minimum of 3 feet below the subsoil surface • There should be a minimum separation of 15 feet from buildings
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	• The site should be inspected by an Engineer with geotechnical experience • Geo-grid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the permeable paver system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.
Storage Capacity	The storage capacity of the base layers should produce a WQv provided that is equivalent to the required WQv. WQv required = $(^1/_{12})(RE_{WQV})(R_V)(A)$, where • WQv required = Required WQv (ft3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3) • R_V = 0.05+0.009 (I) where ♦ I = Impervious cover of the contribution drainage area in percent • A = Contributing drainage area to the permeable pavers (ft^2)

Permeable Pavers Construction of Permeable Pavers

Table 18.5.9-C.

Step No.	Description
Step 1: Layout the Site	Mark the area of the site where permeable pavers will be placed, to minimize soil disturbance and compaction.
Step 2: Erosion Control/ Base Protection	Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that stormwater runoff does not enter the construction site during construction of the aggregate bases.
Step 3: Excavate to Subsoil	Excavate the site to the depth shown in the design. Extra care should be taken not to compact the subsoil.
Step 4: Soil Stabilization	Geo-grid will be placed on the subsoil as a soil stabilization device. Only approved geo-grid that meets the minimum specifications may be used. Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.
Step 4a: Outlet Design	If the design calls for an underdrain system to be used with permeable pavers, the outlet pipes shall be placed on the soil stabilization device and connected to the appropriate outlet.
Step 5: Install Edge Restraint	The edge restraint serves as a barrier around the perimeter of the permeable pavers. This restraint provides lateral stability to the pavers. The restraint prevents the pavers from shifting due to settlement and increases amounts of stormwater runoff during large storms.
Step 6: Install Base	Install the base consisting of two layers. The bottom layer made of No. 3 washed aggregate that has a minimum thickness 12 inches (18.5 inches where frost heave is a concern). The top layer is made of No. 57 washed aggregate that has a minimum thickness of 4 inches. It is recommended that a second layer of geo-grid be placed on the first base layer.
Step 7: Install Choker Course	The choker course is placed on top of the base layer and is comprised of washed No. 8 aggregate. The minimum thickness of the choker course is 1.5 inches. This course serves as a leveling surface to place the pavers on.
Step 7: Install Permeable Pavers	The installation of the pavers can either be done by hand or by machine, and should be completed by someone experienced in installing the pavers. The manufactures' guidelines should be followed for spacing of the pavers. The voids between the pavers shall be filled as specified (likely with No. 8 or No. 9 stone) and compacted.

Permeable Pavers Step By Step Design Procedures

Step 1: Determine Storage Capacity

The base layers of the permeable paver system which provide storage capacity should be sized to store the WQv. To find the WQv in ft³, the storage capacity equation from Table 18.5.9-B can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12)$$

The WQv provided by the designed permeable paver system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

$$WQv\ (ft^3)\ \text{provided} = (A)\ [(p1)(d1)+(p2)(d2)]$$

*Note: this formula only applies if the paver surface and sub soil have a 0% slope.

Step 2: Determine Slopes

Permeable paver sites should have a subsoil slope of zero and a surface slope 0.5%, if possible. If underdrain systems are installed, permeable paver sites may have a slope up to 5%.

Step 3: Soil Stabilization

Geo-grid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and shall be placed on the aggregate as a second layer if the aggregate depth exceeds twelve inches in depth. Geo-textile fabric may be used in conjunction with the geo-grid if recommended by the engineer.

Step 4: Edge Restraint

The edge restraint should be placed around the perimeter of the permeable pavers, if they are not placed adjacent to another paved surface. The concrete edge restraint should extend to the lesser of: the bottom of the base layer or 18 inches below the surface of the permeable pavers.

Step 5: Base Design

The base layer is made up of two layers. The bottom layer is made of washed No. 3 aggregate that is a minimum thickness of 12 inches (18.5 inches where frost heave is a concern). The top layer is made of washed No. 57 aggregate that is a minimum thickness of 4 inches. The entire base layer will be a minimum of 16 inches thick (22.5 inches where frost heave is a concern) and will be placed on the soil stabilization device.

Step 6: Choker Course

The choker course is made of washed No. 8 aggregate that is a minimum thickness of 1.5 inches and will be placed on the base layer.

Step 7: Selection of Paver Type

The permeable paver will be chosen based on the specific site conditions and the pavers will be placed on top of the choker course.

Step 8: Outlet Design

There are two types of outlet designs used with permeable pavers in areas that complete infiltration is not possible:

Underdrain Systems

- Series of perforated pipes that run longitudinal with the pavers to remove stormwater runoff

Overflow Systems

- Direct water that cannot be infiltrated into the subsoil to an appropriate location to be captured and removed from the pavers (bioswales, storm sewer systems, etc.)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.5.10 Pervious Concrete

Installation of Pervious Concrete (Photo: Louisville & Jefferson County MSD)

Typical Implementation Areas:

- Parking lot parking pads
- Low volume roads (5000 > ADT)
- Crosswalks, sidewalks, bicycle paths, bicycle lanes, multi-use paths
- Medians

Key Considerations:

- Soil type and stability
- Traffic volume
- Type of desired drainage

Cost: Medium
Maintenance: Medium

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◩
Phosphorus	□
Nitrogen	□
Metals	◩
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	□
Stream Channel Protection	◩
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	■

Key: ■ Significant Benefit
◩ Partial Benefits
□ Low or Unknown Benefits

Pervious concrete is a permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and base layers. Pervious concrete is designed without any "fine" material resulting in a gap-graded mixture with high void space. The drainage of the stormwater through the pavement reduces the volume of stormwater entering the storm sewer system.

Advantages/Benefits:

- Reduces volume of stormwater runoff
- Reduces impervious areas
- Reduces amount of catch basins and cross pipes
- Easily installed
- May eliminate the need for detention ponds on site

Disadvantages/Limitations:

- Geotechnical exploration required
- Increased maintenance requirements
- Not applicable for high volume roadways or heavy traffic because of decreased design life
- Not desirable for small jobs that may have to be done by hand
- Not safe for skateboards
- More costly than traditional asphalt or concrete

Application and Site Feasability

Pervious concrete is an alternative to traditional concrete and asphalt that allows stormwater to infiltrate into the soil below. A Professional Engineer (Engineer) with geotechnical experience shall evaluate the soil in the site being considered for pervious concrete. The Engineer shall determine what type of soil is present and the percolation rate of the soil. Soils shall be tested at a depth of four feet below the base subsoil surface. Soils having a permeability of at least 0.05 in/hr are suitable for subsoil material.

Physical Site Considerations

Minimum feasibility requirements:

- Areas should have permeable soils (minimum 0.05 in/hr permeability)
- The natural water table should be a minimum of three feet below the subsoil surface
- Maximum slope of surrounding topography should be 20%
- Minimum separation of fifteen feet from buildings
- Site should have a low volume of traffic and not support construction vehicles

Design Criteria

The design of pervious concrete includes several elements to ensure proper drainage and infiltration of the stormwater by the system. For a summary of the design parameters, see Table 18.5.10-A on page 6.

Design Criteria to consider includes:
- Storage Capacity
- Slopes (Subsoil and Pavement)
- Soil Stabilization
- Base Design
- Frost Heave Considerations
- Pavement Design
- Outlet Design (Complete Infiltration, Over Flow Design or Underdrain System)
- Maintenance

Storage Capacity

The base layer of the pervious concrete system should be designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The base layer provides a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The Engineer will design the base layer, or the appropriate outlet system, to provide a depth that will accommodate required WQv (refer to Chapter 18.3).

Installation of pervious concrete (Photo: Louisville & Jefferson County MSD)

The WQv provided by the designed pervious concrete system can be calculated using the equation in Table 18.5.10-A. The WQv provided should meet or exceed the required WQv.

Slopes

If a large slope is applied to either the pavement surface or subsoil, the depth of the base and/or the effective subsoil must be increased to account for the loss of capacity. If the base depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the subsoil have a 0% slope and the surface have a 0.5% slope or less if at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with pervious concrete as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns geo-grid shall be placed on the subsoil surface before any of the aggregate layers are placed. If the aggregate layer is greater than twelve inches it is recommended to place a second layer of geo-grid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geo-grid. The selection of geo-grid will be based on the size of aggregate used in the pavement system. The geo-grid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads the deformation/failure of the soil and pavement are greatly decreased resulting in less failure to the pavement system over time. Any geo-grid used in conjunction with the permeable pavers shall include the following specifications, at a minimum:

Geo-Grid Specifications

- Manufactured from a punched polypropylene sheet
- Triangular geo-grid shall be used
- 100% resistant to weathering and chemical degradation

Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Base Design

The base of the pervious concrete pavement system will act as the storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The base is made up of double washed No. 57 aggregate (producing 40% void space) that is uniformly graded and washed. The entire subbase should have a thickness of 12 inches (22 inches if frost heave is a concern) at a minimum, which will be structurally sufficient for the design ESAL of the pervious concrete. The base thickness may be increased based on storage capacity as discussed in the previous sections. If maintained properly, the base layer should drain completely after a design storm event.

Frost Heave Considerations

As with any type of pavement, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the subsoil layer should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average of 3 feet frost depth). Also, as will be discussed later, air-entrained admixtures can be added to the concrete to reduce freeze-thaw concerns.

Pervious Concrete Parking Spaces at Dixie Highway Kroger in Louisville KY. (Photo: Erin Wagoner, URS)

Pavement Design

The pavement design is the design of the surface layer of concrete that will be exposed to the elements. The pavement is made up of aggregate, water and cement that bonds together to create a durable surface having 18%-21% voids. See Figures 18.5.10-A through 18.5.10-D on page 5 for typical sections of pervious concrete pavement.

Aggregate

No. 8 and/or No. 9 washed stone are typically used in aggregate for pervious concrete. Gravel and crushed stone are both acceptable forms of aggregate. All aggregate used should conform to ASTM D 448 and ASTM C 33.

Water Content

Water content with pervious concrete differs from the water content used with typical concrete. Typical water/cement ratios of 0.29-0.32 are used with chemical admixtures. Unlike impervious concrete, it is not desired to produce the paste-like bond between the cement and water that gives concrete its dense, smooth finish. Water content in pervious concrete should be closely monitored. As a general rule, the water should give the concrete a sheen but not flow off of the aggregate.

Admixtures

Due to the lessened amount of water and increased void space, pervious concrete has a lower workability and an increased setting time. As a result, retarders or hydration-stabilizing admixtures are used. As mentioned previously, air-entrained admixtures are also commonly used in areas where freeze-thaw is a concern to reduce the effects of frost heave. ASTM C 494 and ASTM C 260 should be used when adding admixtures to the cement.

Outlet Design

If the site prevents the subsoil of the pervious concrete from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the use of trenches or an underdrain system must be implemented.

Trenches

Trenches may be dug across the slope (perpendicular) at intervals determined from the stormwater capacity analysis being drained into the pervious concrete. The trenches shall be filled with rock that will guide water from the subsoil to pipes that will empty into a retention area or a storm sewer system. Filter fabric is recommended in these instances to prevent the washing out of the subsoil. See Figure 18.5.10-C for a typical section of pervious concrete with a trench outlet design.

Underdrain Systems

If the recommended CBR value for the subsoil does not yield the desired porosity for the water to percolate or to capture and reuse the runoff, then an underdrain system should be used. Underdrain systems are a series of pipes that run longitudinal with the pavement. The pipes used in the underdrain system are perforated pipes that tie into a non-perforated outlet. The size of the pipe is determined by the storm sewer capacity analysis. See Figure 18.5.10-D for a typical section of pervious concrete with an underdrain system.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Combination and Location in Series With Other GMPs: Treatment Trains

Constructed pervious concrete can easily be located in series with other GMPs such as bioswales, bio-retention areas or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a pervious concrete and traditional concrete pavement may not be visible to everyone. To maintain the integrity of the pervious concrete, it is important that those maintaining it, as well as the general public, understand that the pervious concrete pavement is a stormwater management feature. Training of maintenance

Pervious concrete surface (Photo: Kentucky Concrete Pavement Association)

Pervious concrete at Louisville Fire Station (Photo: Kentucky Concrete Pavement Association)

Green striping is a public education tool at this "green" parking lot (Photo: Kentucky Concrete Pavement Association)

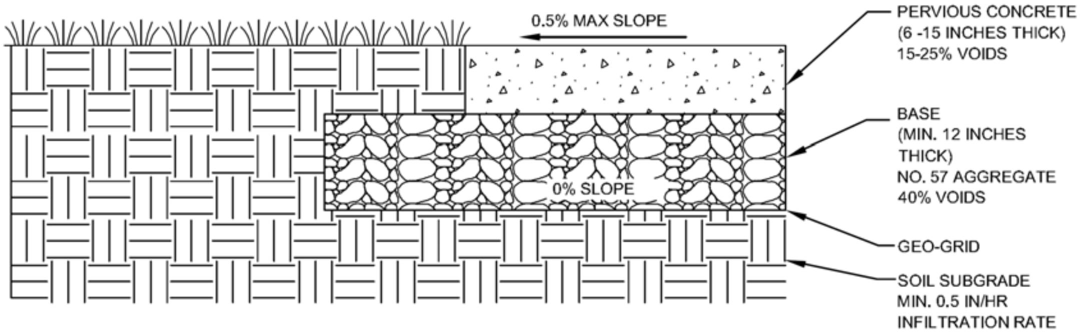


Figure 18.5.10-A. Pervious Concrete Typical Installation

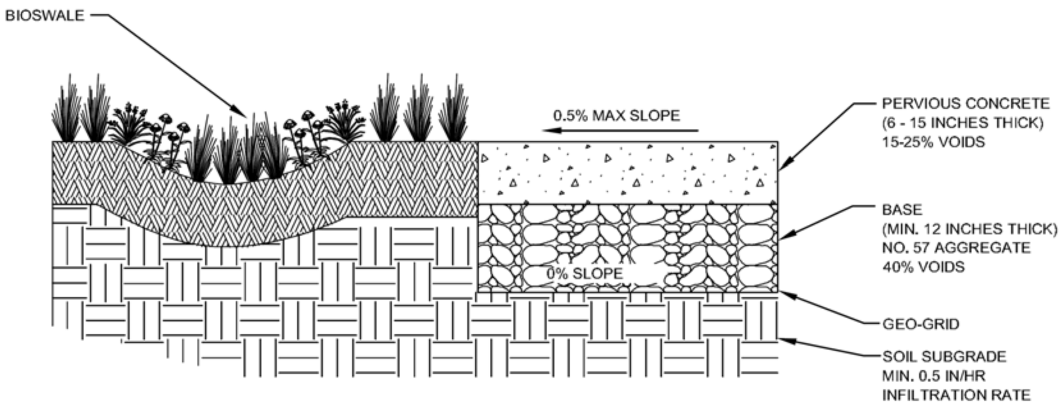


Figure 18.5.10-B. Pervious Concrete with Bioswale Outlet

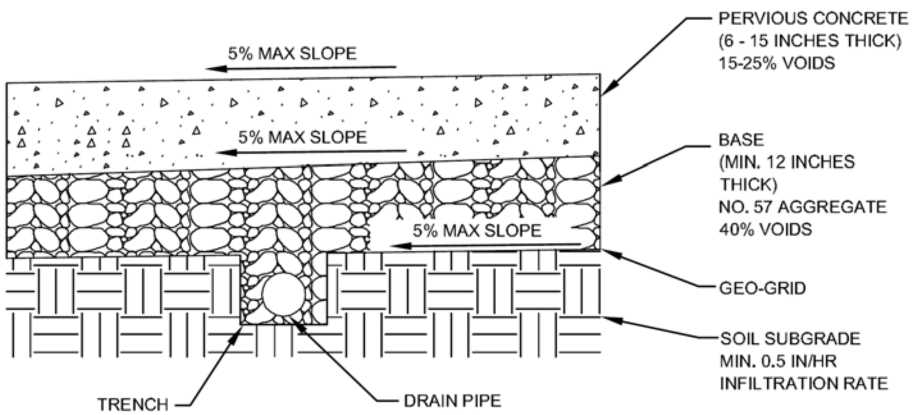


Figure 18.5.10-C. Pervious Concrete with Trench Outlet

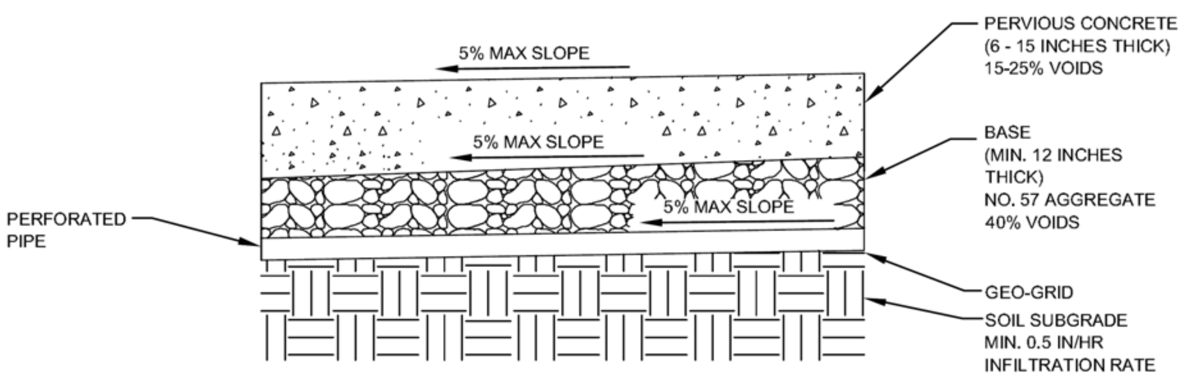


Figure 18.5.10-D. Pervious Concrete with Underdrain System

Pervious Concrete Application and Site Feasibility Criteria

Table 18.5.10-A.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: WQv (ft^3) provided = (A) [(p1)(d1)] *Note: this formula only applies if the concrete surface and sub soil have a 0% slope. • A = area of pervious concrete (ft^2) • p = porosity of base layer (% void) • d = depth of base layer (ft)
Location	The natural water table should be a minimum of 3 feet below the subsoil surface. There should be a minimum separation of 15 feet from buildings
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	The site should have permeable soils (minimum 0.05 in/hr permeability) The site should be inspected by a Civil Engineer with geotechnical experience Geo-grid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the pervious concrete system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.
Storage Capacity	The storage capacity of the base layer should produce a WQv provided that is equivalent to the required WQv. • WQv required = ($^1/_{12}$) (RE_{WQV}) (R_V) (A), where • WQv required = Required WQv (ft^3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3) • R_V = 0.05+0.009 (I) ♦ I = Impervious cover of the contribution drainage area given as percent • A = Contributing drainage area to the pervious concrete (ft^2)

Pervious Concrete Steps to Construct Pervious Concrete

Table 18.5.10-B.

Step No.	Description
Step 1: Layout the Site	Mark the area of the site where pervious concrete will be placed to minimize soil disturbance and compaction.
Step 2: Erosion Control	Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that no stormwater runoff will enter the construction site during construction of the aggregate base.
Step 3: Subsoil Preparation	Excavate the site to the depth shown in the design that was determined by: storage capacity, the engineer and frost-heave concerns. Make any modifications to the subsoil that have been recommended by the engineer for use of unsatisfactory subsoil.
Step 4: Soil Stabilization	Geo-grid will be placed on the subsoil as a soil stabilization device. Only approved geo-grid that meets the minimum specifications may be used. Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.
Step 5: Outlet Design (If required)	If the design requires an underdrain or trenching system to be used with the pervious concrete, the outlet pipes or trenches shall be placed on the soil stabilization device and connected to the appropriate outlet.
Step 6: Install Base	Install the base made up of No. 57 double washed aggregate. The base layer is at a minimum 12 inches thick (22 inches if frost heave is a concern). The actual thickness will vary from site to site, and will be specified in the design. The base layer will be kept moist to minimize water loss from the pervious concrete during installation and the curing process.
Step 7: Install Concrete	After the soil stabilization device and base layer are installed, the pervious concrete can be placed. Special attention should be given to the hauling of the pervious concrete. The concrete mixture should be completely used within one hour after initial mixing. Another issue with the installation of pervious concrete is the fact that it cannot be pumped, therefore the site must be able to equip the concrete trucks. When testing the concrete on site, the slump test should not be used since the concrete is designed to be stiff. A unit weight test should be used to determine the quality of the mix. When the concrete is placed, it is consolidated with steel rollers, the consolidation process should be completed within 15 minutes after placement.
Step 8: Joint Placement	Joints are not required to be placed in pervious concrete since random cracking does not reduce the structural integrity of the pavement. However, for aesthetic purposes joints may be placed in pervious concrete to control cracking. When joints are placed, they should be placed at 20 ft spacing and be at a depth equal to 1/4 of the surface layer thickness.
Step 9: Curing	As stated previously, the base layer should be moist when the surface layer is placed. Because of the low water content of the pervious concrete, the moist base layer will keep the base from drawing moisture out of the concrete. After the concrete is placed, it will be lightly sprayed with a mist. Plastic sheets secured with lumber or stakes should be placed over the concrete for a minimum of 7 days.

Pervious Concrete Step By Step Design Procedures

Step 1: Determine Storage Capacity

The base layers of the pervious concrete system which provide storage capacity should be sized to store the WQv. To find the WQv in ft^3, the storage capacity equation from Table 18.5.10-A can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12)$$

The WQv provided by the designed pervious concrete system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

$$WQv\ (ft^3)\ \text{provided} = (A)\ [(p)(d)]$$

*Note: this formula only applies if the concrete surface and sub soil have a 0% slope.

Step 2: Determine Slopes

Pervious concrete sites should have a subsoil slope of 0% and a surface slope of 0.5%, if possible. If an underdrain or trench is installed, pervious concrete sites may have a slope up to 5%.

Step 3: Soil Stabilization

Geo-grid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and shall be placed on the aggregate as a second layer if the depth exceeds twelve inches. Geo-textile fabric may be used in conjunction with the geo-grid if recommended by the Engineer.

Step 4: Base Design

The base design consists of No. 57 double washed aggregate. The base layer will be a minimum of 12 inches thick (22 inches if frost heave is a concern), additional thickness may be based on storage capacity and the base design will be placed on the soil stabilization device.

Step 5: Pavement (Surface) Design

Consider the following:

- Load transfer coefficient
- Drainage coefficient
- ESALs (Equivalent Single Axle Loads)

Step 7: Outlet design

There are two types of outlet designs used with pervious concrete in areas that complete soil infiltration is not possible:

Trenches

- Placed perpendicular to pervious pavement
- Lined with rock that will guide water away from the pavement base and subsoil to pipes

Underdrain Systems

- Series of perforated pipes that run longitudinal with the pavement to remove stormwater runoff

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.11 Porous Asphalt

Iroquois Amphitheater (Photo: Plantmix Asphalt Industry of Kentucky)

Typical Implementation Areas:

- Parking lots (parking pads in high volume parking lots)
- Low volume roads (5000 > ADT)
- Crosswalks, sidewalks, bicycle paths, bicycle lanes, multi-use paths
- Medians

Key Considerations:

- Soil type and stability
- Traffic volume
- Type of desired drainage

Cost: Medium
Maintenance: Medium

Porous asphalt is a permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and stone reservoir. Porous asphalt is different from conventional asphalt mixtures because they primarily utilize one aggregate size which results in a gap-graded mixture and high void space. The drainage of the stormwater through the pavement helps to reduce the volume of stormwater entering the storm sewer system.

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◩
Phosphorus	□
Nitrogen	□
Metals	◩
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	□
Stream Channel Protection	◩
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	■

Key:
■ Significant Benefit
◩ Partial Benefit
□ Low or Unknown Benefits

Advantages/Benefits:

- Reduces volume of stormwater runoff
- Reduces impervious areas
- Reduces amount of catch basins and cross pipes
- Ready to use upon completion
- Easily installed

Disadvantages/Limitations:

- Geotechnical exploration required
- Increased maintenance requirements
- Not applicable for high volume roadways

Application and Site Feasibility

Porous asphalt is an alternative to traditional asphalt pavement that allows water to infiltrate into the soil below. A Professional Engineer (Engineer) with geotechnical experience shall evaluate the soil in the site being considered for porous asphalt. The Engineer shall determine what type of soil is present and the percolation rate of the soil. Soils having a permeability that allow proper drainage in a 72 hour period are suitable for subsoil material.

Physical Site Considerations

When selecting a site as a candidate for porous asphalt pavement, there are many conditions that must be met for the pavement to produce the desired result. The following list contains some of the minimum requirements that must be met to ensure the porous asphalt will work properly:

- Areas should have permeable soils or implement the use of drainage systems (soils should drain completely in a 72 hour period)
- The natural water table, at a seasonal high, should be a minimum of three feet below the subsoil surface
- Surrounding topography should have a maximum slope of 20%
- There should be a minimum separation of fifteen feet from buildings

KY Horse Park, Lexington KY (Photo: Plantmix Asphalt Industry of Kentucky)

KY Horse Park, Lexington KY (Photo: Plantmix Asphalt Industry of Kentucky)

Design Criteria:

The design of porous asphalt includes several elements to ensure proper drainage and infiltration of the stormwater. See Figures 18.5.11-A through 18.5.11-D for asphalt pavement typical section designs. For a summary of design parameters, see Table 18.5.11-B on page 7.

Design Criteria to consider includes:

- Storage Capacity
- Slopes
- Soil Stabilization
- Stone Reservoir
- Frost Heave Considerations
- Pavement Design
- Outlet Design
- Maintenance

Storage Capacity

The stone reservoir of the porous asphalt system is designed to store stormwater until it can infiltrate into the subsoil or drainage system in a timely manner. The stone reservoir provides a holding area for the stormwater runoff to eliminate overflow of drainage systems and subsoil during a rain event. The Engineer should design the stone reservoir to provide a depth that will accommodate required WQv (refer to Chapter 18.3). The WQv provided by the designed porous asphalt system can be calculated using the equation provided in Table 18.5.11-B on page 7.

Slopes

If a large slope is applied to the pavement surface, the depth of the stone reservoir and/or the effective subsoil must be increased to account for the loss of capacity from the slope. If the stone reservoir depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the surface have a 0.5% slope or less and the subsoil have a 0% slope, if at all possible.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with porous asphalt as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns geo-grid shall be placed on the subsoil surface before the stone reservoir is placed. If the stone reservoir is greater than twelve inches it is recommended to place a second layer of geo-grid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geo-grid. The selection of geo-grid will be based on the size of aggregate used in the stone reservoir. The geo-grid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads the deformation/failure of the soil and pavement are greatly decreased resulting in less failure to the pavement system over time. Any geo-grid used in conjunction with the porous asphalt shall include the following specifications, at a minimum:

Park & Ride, Covington KY (Photo: Plantmix Asphalt Industry of Kentucky)

Geo-Grid Specifications

- Manufactured from a punched polypropylene sheet
- Triangular geo-grid shall be used
- 100% resistant to weathering and chemical degradation

Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Stone Reservoir

The stone reservoir layer of the porous asphalt pavement system will act as the main storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The stone reservoir is made up of double washed No. 2 or No. 3 aggregate that is uniformly graded and washed. The entire stone reservoir should have a minimum thickness of 12 inches, (22 inches if frost heave is a concern) which shall be structurally sufficient for the design ESAL of the porous asphalt. The stone reservoir thickness may be increased, based on storage capacity as discussed in the previous sections. The stone reservoir layer should drain completely in 72 hours after a design storm event, if maintained properly.

Frost Heave Considerations

As with any type of pavement, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the stone reservoir should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average 3ft frost depth).

Pavement Design

The pavement design is the design of the surface course of asphalt that will be exposed to elements. The pavement is made up of aggregate and liquid asphalt that bond together and create a durable surface.

Aggregate

Fine aggregates are screened and reduced in porous asphalt to increase the void space. This increased void space allows stormwater to percolate through the asphalt. The porous bituminous surface shall be laid with a bituminous mix of 5.75% to 6% by dry weight aggregate. Aggregate in the asphalt will meet the gradation criteria listed in Table 18.5.11-A below. Total drain down of the binder shall be less than 0.3% in accordance with ASTM D6390.

Liquid Asphalt

Liquid Asphalt is used in all types of asphalt pavement whether it is porous or non-porous. Binders are classified by their PG-performance grade (average high and low temperatures they can withstand). A PG 76-22 binder is recommended for porous asphalt.

Table 18.5.11-A. KYTC Standard Specifications

Porous Bituminous Aggregate Gradation	
U.S. Standard Sieve Size	Percent Passing
1/2 inch	100
3/8 inch	90-100
No. 4	25-50
No. 8	5-15
No. 16	-
No. 200	2-5

Outlet Design

If the site prevents the surface and subsoil of the porous asphalt from having a 0% slope, or if the subsoil is unable to infiltrate the stormwater runoff at the desired rate, the

Drainage Pipes (Photo: CH2M Hill)

Stone Reservoir with Drainage Pipes (Photo: CH2M Hill) use of trenches or an underdrain system must be implemented.

Trenches

Trenches may be dug perpendicular across the slope at intervals determined from the stormwater capacity analysis being drained into the porous asphalt. The trenches will be filled with rock that will guide water from the subsoil to pipes that will empty into a retention area or a storm sewer system. Filter fabric is recommended in these instances to prevent the washing out of the subsoil.

Underdrain Systems

If the recommended CBR value for the subgrade doesn't yield desired porosity for the water to percolate, then underdrains should be considered. Underdrain systems are a series of pipes that run longitudinal with the pavement. The pipes used in the underdrain system are perforated pipes. The size of the pipe is determined by the stormwater capacity draining into the porous asphalt.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Constructed porous asphalt can easily be located in series with other GMPs such as bioswales, bio-retention areas or rain gardens to supplement storage capacity in large storm events.

Educational Awareness

The difference between a porous asphalt and traditional asphalt pavement may not be visible to everyone. To maintain the integrity of the porous asphalt, it is important that those maintaining it, as well as the general public, understand that the porous asphalt pavement is a stormwater management feature. Training of maintenance staff may be required.

University of New Hampshire (Photo: National Asphalt Pavement Association)

University of New Hampshire (Photo: National Asphalt Pavement Association)

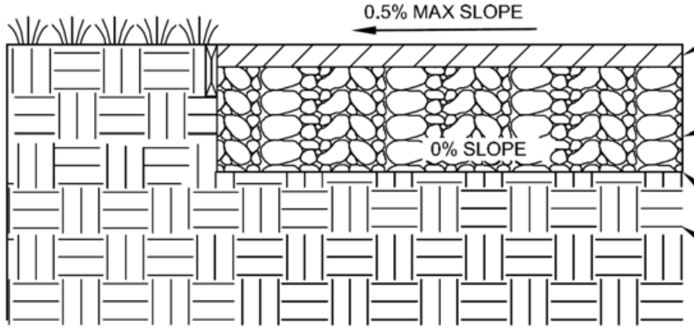


Figure 18.5.11-A. Porous Asphalt Typical Installation

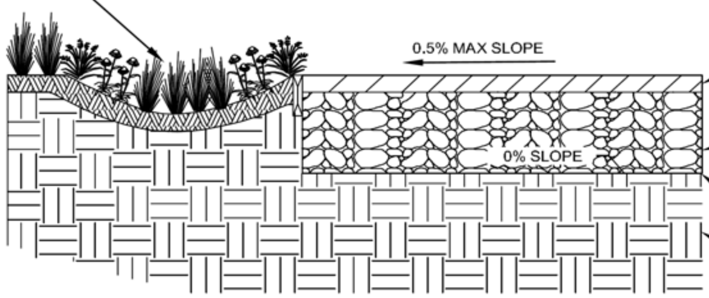


Figure 18.5.11-B. Porous Asphalt with Bioswale Outlet

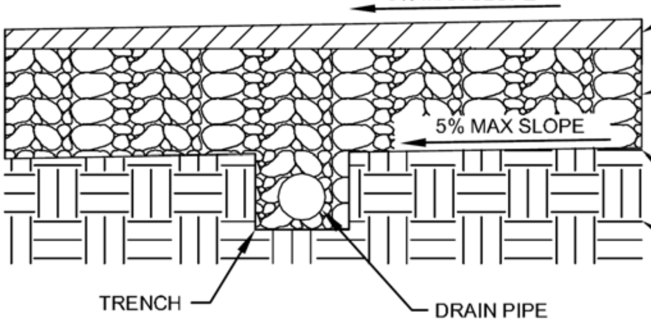


Figure 18.5.11-C. Porous Asphalt Trench Outlet

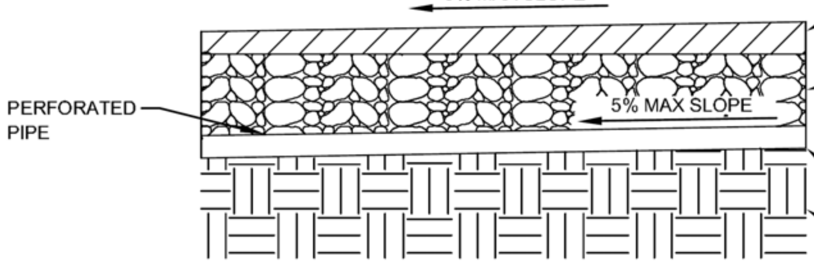


Figure 18.5.11-D. Porous Asphalt with Underdrain System

Porous Asphalt Application and Site Feasibility Criteria

Table 18.5.11-B.

Design Parameter	Criteria
Size (Area & Depth)	Based upon the design storage capacity and the following equation: WQv (ft^3) provided = (A) [(p1)(d1)] *Note: this formula only applies if the asphalt sub soil has a 0% slope and the surface has a 0.5% slope or less. • A = area of porous asphalt (ft^2) • p = porosity of stone reservoir (% void) • d = depth of stone reservoir (ft)
Location	The natural water table should be a minimum of 3 feet below the subsoil surface and there should be a minimum separation of 15 feet from buildings.
Surrounding Slopes	Surrounding topography should have a maximum slope of 20%
Traffic Conditions	The site should have a low volume of traffic
Soils	• The site should have permeable soils (minimum 0.5 in/hr permeability) • The site should be inspected by an Engineer with geotechnical experience • Geo-grid will be placed on the subsoil for stabilization
Profile Grade	The site should have a relatively flat profile grade. In instances where a steep grade is encountered benching may have to be performed on the subsoil to meet the required WQv of the porous asphalt system.
Outlet	The site must have a proper outlet design if the soil in the area does not provide adequate porosity to absorb the WQv.
Storage Capacity	The storage capacity of the stone reservoir should produce a WQv provided that is equivalent to the required WQv. WQv required = ($^1/_{12}$) (RE_{WQV}) (R_V) (A), where • WQv required = Required WQv (ft^3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.3) • R_V = 0.05+0.009 (I) ♦ I = Impervious cover of the contribution drainage area given as percent • A = Contributing drainage area to the porous asphalt (ft^2)

Steps to Construct Porous Ashpalt

Table 18.5.11-C.

Step No.	Description
Step 1: Site Layout	Mark the area of the site where porous asphalt will be placed to minimize soil disturbance and compaction.
Step 2: Erosion Control	Identify stormwater discharges to the construction site and take proper precautions to keep them from eroding the site when construction begins. Ensure that no stormwater runoff will enter the construction site during construction of the stone reservoir.
Step 3: Subsoil Preparation	Excavate the site to the depth shown in the design that was determined by the storage capacity requirements for the site and by the Engineer.
Step 4: Soil Stabilization	Geo-grid will be placed on the subsoil as a soil stabilization device. Only approved geo-grid that meets the minimum specifications may be used. Geo-textile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geo-grid if the Engineer has concerns with soil separation between the aggregate and subsoil.
Step 5: Outlet Design (if required)	If the design requires an underdrain system or trenching system to be used with the porous asphalt, the outlet pipes or trenches shall be placed on the soil stabilization device and connected to the appropriate outlet (storm sewer, retention area, bioswale, etc.)
Step 6: Install Stone Reservoir	Install the stone reservoir made up of No. 2 or No. 3 washed aggregate. The stone reservoir should be placed at a minimum of 12 inches thick (22 inches if frost heave is a concern). The actual thickness will vary from site to site and will be specified in the design.
Step 7: Install Asphalt	After the stone reservoir is installed, the porous asphalt can be placed. The porous bituminous asphalt surface shall be laid in 3½ inches lifts and rolled to a finish depth of 2½ inches. The exact thickness of the asphalt surface will be determined by the Engineer and will be site specific. Compaction of the surface course shall take place when the surface is cool enough to resist a 10-ton roller. One or two passes by the roller are all that is required for proper compaction.

Porous Asphalt Step By Step Design Procedures

Step 1: Determine storage capacity

The stone reservoir of the porous asphalt system which provides storage capacity should be sized to store the WQv. To find the WQv in ft^3, the storage capacity equation from Table 18.5.11-B can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12)$$

The WQv provided by the designed porous asphalt system can be calculated using the equation below. The WQv provided should meet or exceed the required WQv.

WQv (ft3) provided = (A) [(p)(d)]
*Note: this formula only applies if the asphalt surface and sub soil have a 0% slope.

Step 2: Determine slopes

Porous asphalt sites should have a soil subgrade slope of 0% and a surface slope of 0.5%, if possible. If underdrains or trenches are installed, porous asphalt sites may have a slope up to 5%.

Step 3: Soil stabilization

Geo-grid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and geo-textile fabric may be used in conjunction with the geo-grid if recommended by the engineer.

Step 4: Stone reservoir design

Before placing the stone reservoir, the non-woven geotextile fabric should be placed on the subsoil for separation between the two layers. The stone reservoir will have a minimum thickness of 12 inches (22 inches if frost heave is a concern), additional thickness may be added based on storage capacity and consists of No. 2 or No. 3 washed aggregated with 40% voids. The stone reservoir should drain completely in 72 hours.

Step 6: Pavement (surface) design

The Engineer will use the following criteria to determine the appropriate surface design:

- CBR
- ESALs
- Structural Number

Step 7: Outlet design

There are two types of outlet design used with porous asphalt in areas that complete soil infiltration is not possible:

Trenches

- Trenches dug perpendicular to the porous pavement
- Lined with rock that will guide water away from the pavement stone reservoir and subsoil to pipes

Underdrain System

- Series of perforated pipes that run longitudinal with the pavement to carry stormwater away from the pavement

MSD
Metropolitan Sewer District

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.5.12 Planters

Typical Implementation Areas:

- Adjacent to buildings
- Sidewalks, courtyards, plazas and entrance bays
- Connected with rooftop downspouts.
- Redevelopment and retrofit

Key Considerations:

- Proximity of building foundations
- Infiltration rates of soil/media
- Use of deep rooted native vegetation

Cost: Medium
Maintenance: Low

Concept flow-through planter (Photo: Chad McCormick, URS)

Stormwater Management Benefits

Pollutant Reduction

Sediment	■
Phosphorus	◪
Nitrogen	◪
Metals	◪
Pathogens	□
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪

Hydrologic Characteristics

Surface Flow Reduction	◪
Infiltration	◪
Stormwater Conveyance	◪
Stream Channel Protection	◪
Peak Flow Control	□

Runoff Volume Reduction

Runoff Capture	◪

Key: ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Planters, like tree boxes, are very similar to rain gardens and bioretention basins in their design purpose and stormwater management benefits to detain, filter and infiltrate stormwater and ability to utilize plants ranging from native flowers or shrubs to small trees. Planters provide temporary detention and infiltration as stormwater flows through the planter bed and are most often used to promote infiltration of stormwater runoff from rooftop downspouts. Planters improve water quality through:

- ☑ Reduction of runoff volume
- ☑ Treatment of stormwater percolating through soil and filter media
- ☑ Groundwater recharge and detention of stormwater
- ☑ Biological uptake through deep rooted, native plants

Advantages/Benefits

- Visually appealing
- Can be used to address landscaping requirements
- Can provide infiltration and groundwater recharge, reducing runoff volume
- Increases biodiversity by providing urban habitats for wildlife
- Reduces heat island effects

Disadvantages/Limitations

- Building foundations may limit application
- Soil conditions may limit application
- Limited to small drainage areas
- Not recommended for high groundwater level areas
- Erosion potential at downspout inlets

Application and Site Feasibility

Planters are typically applied to manage runoff from rooftop or they can also be submerged at parking lot or street level to manage flow to treat, detain and infiltrate stormwater runoff. Similar to traditional landscapes or hardscapes, the designer can adjust the shape, wall type and plantings used in the planter to fit the character of the site. Planters can be used in urban areas, and are appropriate for use in a wide variety of land use applications including commercial, industrial or residential areas.

Physical Requirements

Key physical considerations are:

- Building foundations—Sufficient space is required from building foundations. Where a gravel infiltration trench is used (in open box design, or infiltration planter), the gravel infiltration trench of the planter must be set back from building foundations. For all applications, buildings and building foundations must be waterproofed with foundation drains to limit seepage into basements or lower levels.
- Space available—Sufficient space is required to plant herbaceous plants, shrubs or trees and allow space for foliage growth above ground and root growth below ground. Plant type and species vary by preferred landscape and aesthetic qualities.
- Soil types—Native soil types affect infiltration and the ability for plant roots to grow and spread. Soils under existing infrastructure around the planter need to be evaluated to determine their ability to allow the plant roots to spread.
- Planting media—The infiltration rate of the media in the planter will dictate how large an area will be required for managing the stormwater runoff.

Design Criteria

The design of an planter includes several elements to manage stormwater infiltration, retention and conveyance to facilitate water quality improvement and reduction of stormwater runoff volumes into the sewer system. Generally, infiltration planters follow the same design approach as a rain garden/bioretention pond. There are some proprietary applications that perform these design calculations or the guidance provided below can be utilitized. For a summary of design parameters, see Table 18.5.12-A on page 4.

Design criteria to consider includes:

- Selection of planter type and size
- Soil composition
- Plant selection
- Maintenance

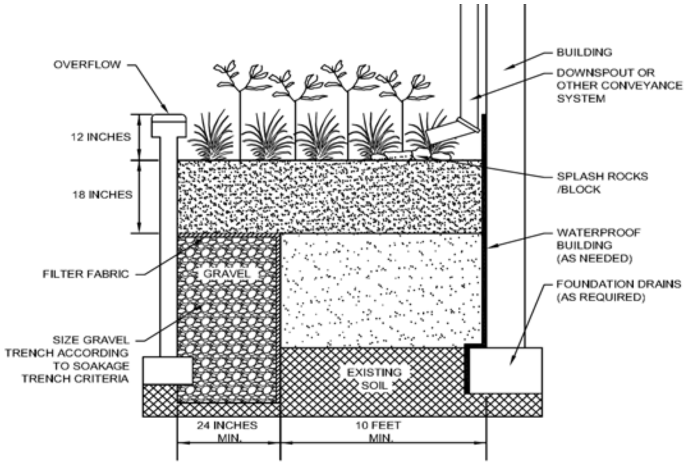


Figure 18.5.12-A. Typical infiltration planter with open box design.

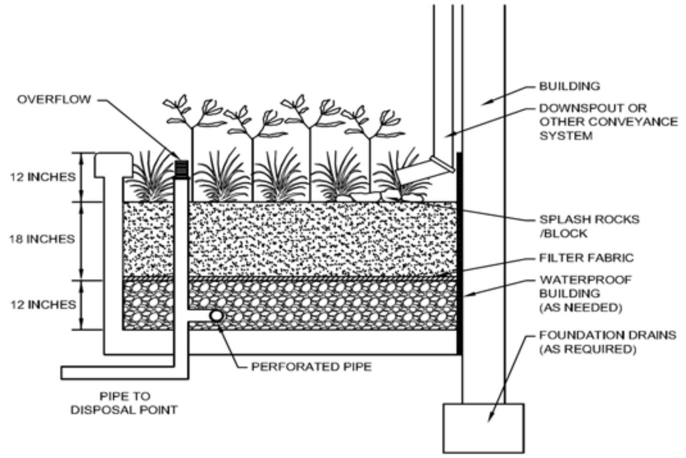


Figure 18.5.12-B. Typical flow-through planter with flow-through closed box design.

Selection of Planter Type and Size

Infiltration planters are designed to capture and infiltrate stormwater runoff through an open box design. If infiltration into native soils is not desired, planters may be designed to capture and retain stormwater runoff with a flow-through closed box design, also called flow-through planters. Flow-through planters include an overflow pipe and underdrain system connected to the storm sewer system. Typical sections of open and closed box designs are shown in Figures 18.5.12-A and 18.5.12-B.

The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil composition in the box and surrounding soils. If an underdrain is needed, storage space can be provided beneath an underdrain system to allow more time for infiltration to occur. In general, a planter should not accept drainage from more than 0.25 acres of impervious area. This is the maximum acreage, but a smaller drainage area is encouraged for better performance.

Sizing of the planter will depend on the infiltration rate of the native soils, the planting media and the drainage volume it receives. The infiltration planter should be sized to capture the WQv. See Table 18.5.12-A for WQv formulas.

Soil Composition

Planters should be designed to drain within 24 hours. Evaluate in situ soil conditions to determine if they meet this criteria for use in the planter. If they do not, consider amending in situ soils with an engineered soil mix, such as a mixture consisting of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

If the primary purpose is infiltration (open box design), it is important that soils are not compacted. If the primary purpose is temporary detention with subsequent drainage to the storm sewer system (flow-through closed box design), then an underdrain system is required. An underdrain system may also be required for open box designs that do not have adequate infiltration rates in the surrounding soils. Underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed No. 57 stone. When grading and soil mix is placed, care should be taken that the soil is not compacted, resulting in a diminished infiltration capacity.

Plant Selection

Planters are typically planted with deep rooted, native trees, shrubs and herbaceous plants. Plants selected should be tolerant of highly variable hydrologic conditions. In selecting trees and shrubs, consider the box and soil depth, space for roots to grow and if the box will retain water for extended periods of time and select species accordingly.

Although deep rooted, native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Flow-through planter application (Photo: Erin Wagoner, URS)

Treatment Trains—Combination and Location in Series With Other GMPs

Planters are typically local practices, but can be located in a series with each other through a highly permeable trench. This series allows greater area for infiltration and root growth and for conveyance of stormwater. Pervious areas above the series also promotes additional stormwater drainage and aeration of the plant roots. Planters may also be preceded in series by a cistern or rain barrel connected to roof downspouts. Planters can also be located as the first GMP in a series with other GMPs, such as rain gardens or bioretention areas to supplement infiltration and volume control.

Educational Awareness

The difference between planters and traditionally landscaped areas may not be visible to everyone. It is important that those maintaining the planters, as well as the general public, understand that its features move beyond aesthetic landscaping to manage and treat stormwater.

Planters Application and Site Feasibility Criteria

Table 18.5.12-A.

Design Parameter	Criteria
Size (Area & Depth)	The minimum surface area of the planter should be determine based upon the design storage capacity and the following equation: A = (WQv)/[(d)(P)+h], where • A = surface area of the ponding area of the planter bed (ft^2) • WQv = required WQv (ft^3) • d = depth of any amended soils (ft) • P = porosity of any amended soils (% void) • h = average height of water above the amended/in situ soils during WQv rain event (ft)
Surrounding Soils	Ideal soils should be sandy loam, loamy sand, or loam texture. If infiltration is desired, soil infiltration should be > 0.5 inches per hour.
Planting Media	Ideal media will contain adequate content for plant growth while maintaining infiltration rates greater then several feet per hour.
Drawdown Time	Infiltration planters should dewater within 24 hours. If necessary, an underdrain system can be added.
Storage Capacity	Planter bed total volume should be equivalent to the Required WQv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the planter (ft^2)

Planters Step by Step Design Procedures

Step 1: Define goals/primary function of the planter

Define the goals/primary function of the planter. Consider whether the planter is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Provide conveyance
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. Where landscaped beds or foundation plantings are proposed at the site, consider using infiltration planters as a substitute for traditional raised landscape beds. Locate roof downspouts and check potential locations/available space for planters. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply.

The design should be based on the restrictions, requirements, goals and primary function(s) of the planter. In conjunction with in situ topographic and soil conditions, this will determine the elements of the planter (engineered soils, underdrain, etc).

Step 2: Determine the peak flow rate and total runoff volume

Planters should be sized to capture and detain or infiltrate the WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.12-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12)$.

Planters also must be designed to safely convey or bypass flow rates produced by larger storm events with adequate freeboard and minimum erosion. Larger storms (2-, 10-, and 100-year) should be checked to size overflow or underdrain structures to convey the flow.

Step 3: Determine if site is appropriate

Based on the defined goals for the planter, determine if the site conditions and drainage area are appropriate for use of an planter. If so, determine whether an open box design or a flow-through closed box design is appropriate. Use Table 18.5.12 -A, especially for the infiltration rate of the surrounding soils.

Step 4: Determine planter dimensions

Calculate the minimum surface area of the planter, assuming a desired depth of filter media and water over the filter bed, using the equation provided in Table 18.5.12-A:

$A = (WQv)/[d(P)+h]$

Based on the required volume, minimum surface area and the site restrictions, including existing trees, utility lines, and other obstructions, calculate the dimensions of the planter. Create a rough layout of the planter.

Step 5: Check freeboard and bypass capability for larger storms

Based on the average infiltration rate of the planter system and projected water surface elevations for all other storm events (shown in Step 2), determine the need for bypass or underdrain systems. This includes allowing a 0.5 foot freeboard between the inlet elevation and water level during the WQv event and determining the need for erosion prevention measures. Modify design as appropriate.

Step 6: Prepare native vegetation

Choose native trees, bushes and/or herbaceous plants based on aesthetic preferences, root depths, plant heights, sun/shade tolerances and the anticipated moisture within the planter.

MSD
Metropolitan Sewer District

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.5.13 Tree Boxes

Tree boxes (Photo: David Dods, URS)

Typical Implementation Areas:
- Sidewalks, courtyards and entrance bays
- Parking lot islands, edges
- Roadway island/median and right-of-ways
- Redevelopment and retrofit

Key Considerations:
- Detain/treat and possibly infiltrate and convey stormwater
- Infiltration rates of soils/ media
- Use deep rooted vegetation
- Drainage area to tree box

Cost: Medium
Maintenance: Low

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◩
Nitrogen	◩
Metals	◩
Pathogens	□
Floatables	◩
Oil and Grease	◩
Dissolved Pollutants	◩
Hydrologic Characteristics	
Surface Flow Reduction	◩
Infiltration	◩
Stormwater Conveyance	◩
Stream Channel Protection	□
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	◩

Key: ■ Significant Benefit
◩ Partial Benefit
□ Low or Unknown Benefit

A tree box is very similar to a rain garden/bioretention basin in its design purpose and stormwater management benefits, except it exclusively uses trees and tall bushes. At a minimum, a tree box temporarily detains the stormwater runoff as it flows through the box prior to discharge into the sewer system. If surrounding soils have adequate permeability, a tree box can also be designed to promote infiltration of the stormwater runoff. A tree box can be used as a single GMP or connected in series through trenches. A tree box improves water quality through:

☑ Reduction of runoff volume through infiltration
☑ Treatment of stormwater percolating through soil and filter media
☑ Temporary detention of stormwater runoff
☑ Biological uptake through deep rooted, native plants

Advantages/Benefits
- Visually appealing
- Can be used to address landscaping requirements
- Provides infiltration, reducing runoff volume
- Increases biodiversity by providing urban habitats for wildlife
- Reduces heat island effects

Disadvantages/Limitations
- Increased maintenance over traditional curb and gutter drainage systems
- Soil conditions may limit application
- Limited to small drainage areas
- Not recommended for high groundwater level areas

Application and Site Feasibility

A tree box is a local feature that is used to treat and detain, and possibly infiltrate stormwater runoff. It may be connected in a series to provide opportunities for enhanced treatment of the stormwater and promote better tree viability. A tree box is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to plant the tree and allow space for its growth both aboveground and belowground.
- Soil types—Soil types affect infiltration and the ability for the tree roots to grow and spread. In addition, soils under existing infrastructure around the tree box need to be evaluated to determine their ability to allow the tree roots to spread.
- Tree box media—The infiltration rate of the media in the tree box will dictate how large a box area will be required for the WQv.

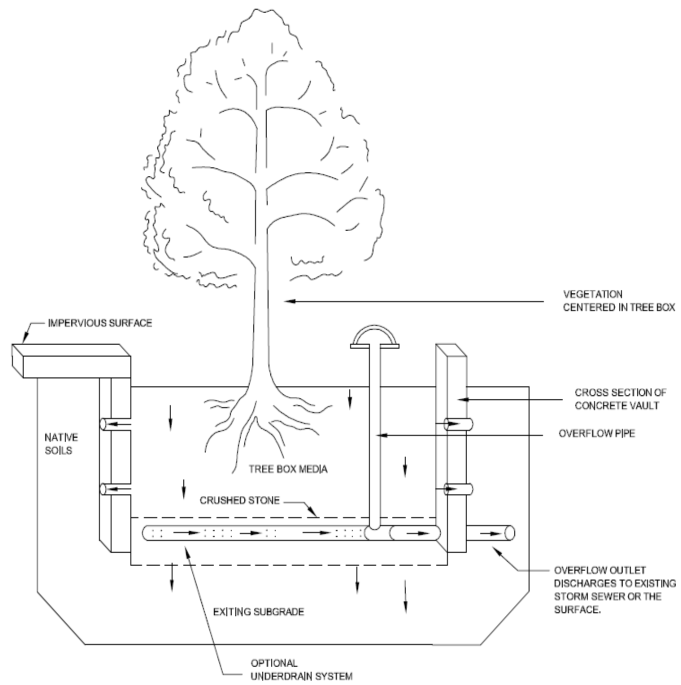


Figure 18.5.13-A: Typical Open Box Design

Design Criteria

The design of a tree box includes several elements to manage stormwater; detention and conveyance to facilitate water quality improvement and infiltration to reduce stormwater runoff volumes into the sewer system. Generally, a tree box follows the same design approach as a rain garden/bioretention pond. There are proprietary tree boxes with standard sizes form the manufacturer. If a proprietary tree box is not chosen, the following guidance can be used to size a tree box. For a summary of design parameters, see Table 18.5.13-A on page 5.

Design criteria to consider includes:

- Selection of tree box type and size
- Soil composition
- Plant selection
- Maintenance

Selection of Tree Box Type and Size

A tree box can be designed to capture and infiltrate the stormwater runoff through an open box design (see Figure 18.5.13-A). If infiltration is not desired, temporary detention of the stormwater runoff can be accomplished using a flow-through sealed box design (see Figure 18.5.13-B). The sealed box design will include an underdrain system connected to the storm sewer system, while the need for an underdrain system in the open box design will depend on the infiltration rate of the surrounding soil. The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil

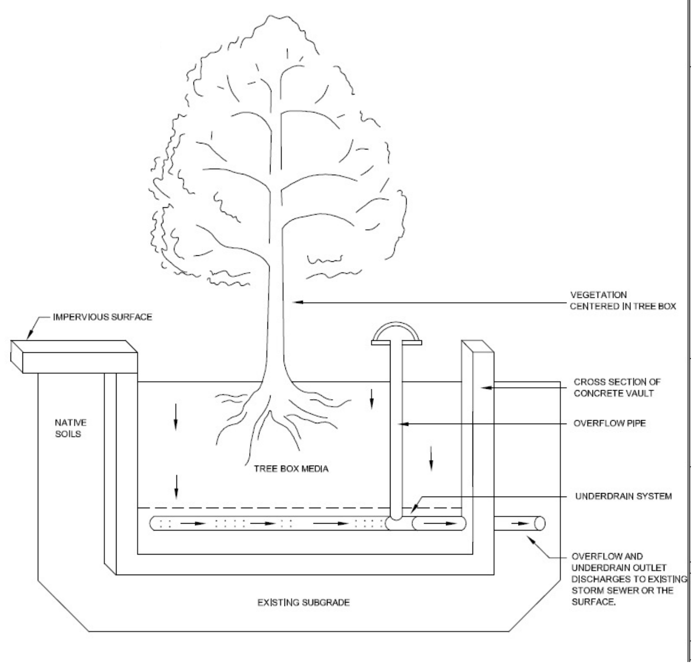


Figure 18.5.13-B: Typical Closed Box Design

composition in the box and surrounding soils. Storage space can be provided under an underdrain system to allow more time for infiltration to occur. As a general guidance, the tree box should not accept drainage from more than 0.25 acres of impervious area. This is the maximum acreage, but a smaller drainage area is encouraged for better performance.

Sizing of a tree box is based on the volume provided by the porosity of the tree box media and in the ponding above the tree box media. The volume should at least be equal to the WQv. See Table 18.5.13-A for WQv formulas.

Evaluate in situ soil conditions to determine if they have the needed infiltration for the tree box. If they do not, consider amending in situ soils with an engineered soil mix, such as a mixture consisting of the following materials, by volume:

- 60% construction sand
- 30% organic compost
- 10% topsoil

Soil Composition

The soils around the tree box are extremely important, especially in an open box design where the tree roots are allowed to expand out past the tree box. If tree roots are allowed to spread, they will typically extend at least as far as the branches. However, if the surrounding soils are too compacted, the tree roots may not be able to penetrate the soil, thus limiting its viability.

The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

If the primary purpose of the tree box is temporary detention with subsequent drainage to the storm sewer system (sealed box design), then an underdrain system is required. An underdrain system may also be required for open box designs that do not have the needed infiltration rates in the surrounding soils. Underdrains should be constructed with perforated pipe or slotted corrugated pipe and bedded in double washed No. 57 stone. Topsoil should be stripped and stockpiled for reuse. When grading and soil mix is placed, care should be taken that the soil is not compacted, resulting in a diminished infiltration capacity.

Plant Selection

A tree box is typically planted with a deep rooted, native tree or shrub. In selecting a tree or shrub, consider the box and soil depth, space for roots to grow, if the box will retain water for extended periods of time and select species accordingly.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Flow through tree box
(Photo: Meg Babani, Taliaferro & Browne, Inc.)

Maintenance

Maintenance is a key component to the long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A tree box is typically a local practice, but it can be located in series with others through a highly permeable trench between the boxes. The series allows greater area for infiltration and root growth and for conveyance of the stormwater. Pervious areas above the series also promote additional stormwater drainage and aeration of the tree roots. Tree boxes can also be located as the first GMP in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

It is important that those maintaining the tree boxes, as well as the general public, understand that its features move beyond aesthetic landscaping to manage and treat stormwater. Training of maintenance staff may be required.

Tree Box Application and Site Feasibility Criteria Chart

Table 18.5.13-A.

Design Parameter	Criteria
Surrounding Soils	Ideal soils are sandy loam, loamy sand, or loam texture. If infiltration is desired, soil infiltration should be > 2.0 inches per hour.
Tree Box Media	Ideal media will contain adequate content for plant growth while maintaining infiltration rates greater than 1 foot per hour.
Drawdown Time	A tree box should dewater within 24 hours. If necessary, an underdrain system can be added.
Storage Capacity	Tree box volume should be equivalent to the Required WQv. Required WQv (ft^3) = ($^1/_{12}$)[(RE_{WQV})(Rv)(A)], where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.3) • Rv = 0.05 + 0.009 (I) ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the tree box (ft^2)
Surface Area	A = (WQv)/[(d)(P)+h], where • A is the surface area of the tree box (ft^2) • WQv = required WQv (ft^3) • d = depth of tree box (ft) • P = porosity of the soil mix in the tree box (% void) • h = average height of water over tree box bed during required WQv storm event (ft)

Tree Box Step by Step Design Procedures

Step 1: Define goals/primary function of the tree box

Define the goals/primary function of the tree box. Consider whether the tree box is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Provide conveyance
- Enhance landscape aesthetic qualities

Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), habitat needs, aesthetic or landscaping requirements, and site access considerations.

The design should be based on the restrictions, requirements, goals, and primary function(s) of the tree box. In conjunction with in situ topographic and soil conditions, this will determine the elements of the tree box (engineered soils, underdrain, etc).

Step 2: Determine the peak flow rate and total runoff volume

A tree box should be sized to capture and detain or infiltrate the required WQv. To find the WQv in cubic feet, the Storage Capacity equation from Table 18.5.13-A can be used in this form:

WQv (ft^3) = (RE_{WQV})(Rv)(A/12).

A tree box also must be designed to safely convey or bypass flow rates produced by larger storm events with adequate freeboard and minimum erosion. Larger storms (2-, 10-, and 100-year) should be checked to size overflow or underdrain structures to convey the flow.

Step 3: Determine if site is appropriate

Based on the defined goals for the tree box, which sets the type of tree box to use (open or closed); determine whether the site conditions and drainage area are appropriate for use of a tree box. Consider Table 18.5.13-A, especially the infiltration rate of the surrounding soils.

Step 4: Determine tree box dimensions

Calculate the required area of the tree box based on the void space of the tree box media so that it can store the WQv using the following equation: A = (WQv)/[d(P)+h].

Based on the required volume, minimum surface area and the site restrictions, including existing trees, utility lines, and other obstructions, calculate the dimensions of the tree box. Create a rough layout of the tree box.

Step 5: Check freeboard and bypass capability for larger storms

Based on the infiltration rate of the soils around the tree box system and projected water surface elevations for all other storm events (shown in Step 2), determine the need for bypass or underdrain systems. This includes allowing a 0.5 foot freeboard between the inlet elevation and water level during the WQv event and determining the need for erosion prevention measures. Modify design as appropriate.

Step 6: Prepare native vegetation

Choose native trees and bushes based on aesthetic preferences, root depths, plant heights, sun/shade tolerances and the anticipated moisture within the tree box.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.5.14 Rainwater Harvesting - Cisterns

Typical Implementation Areas:
- Downspout conveyance
- Exterior reuse—irrigation
- Storage for gray water use
- Interior reuse—non-potable

Key Considerations:
- Beneficial reuse opportunities
- Treatment of stored water
- Storage size and location
- Plumbing codes for using rainwater inside a building

Cost: Medium
Maintenance: Medium—High

Cisterns drain to a bioswale at the Green Building in Louisville (Photo: Erin Wagoner, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Low or Unknown Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Low or Unknown Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Low or Unknown Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Low or Unknown Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Low or Unknown Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

Key: ■ Significant Benefit; ◩ Partial Benefit; □ Low or Unknown Benefit

Rainwater harvesting is the practice of collecting and temporarily storing rainwater. Typically this is limited to rainwater runoff from roofs with the intent for the captured roof runoff to be used following the rain event. Beneficial uses for commercial and industrial applications may include watering nearby landscaping, washing vehicles, toilet flushing water and HVAC or boiler make-up water. Due to the size needed for such applications, a cistern is typically used instead of multiple rain barrels. A cistern is a more permanent structure than rain barrels, typically having a volume over 100 gallons and can be placed aboveground or belowground. Rainwater harvesting improves stormwater management through:

☑ Beneficial use and reduction of stormwater runoff volume
☑ The harvested rainwater needs to be used prior to the next rain event to allow for continued harvesting.

Advantages/Benefits

- May reduce water bill
- Reduces channel/stream bank erosion by reducing number of bankfull events
- Allows beneficial reuse of stormwater

Disadvantages/Limitations

- Need to drain or use captured roof runoff between rain events
- Water may need to be pumped if cistern is belowground
- Not to be used with tar and gravel and asbestos shingled roofs
- May not be aesthetically pleasing
- Plumbing codes for using rainwater inside a building

Application and Site Feasibility

Rain harvesting generally relies on the ability of the rainwater to flow by gravity from the rooftop to the cistern and to the beneficial reuse area. If the cistern is located belowground, pumping will be required. In addition, the overflow needs to discharge to a location that is stable and pervious. Rainwater harvesting is appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space, whether aboveground or belowground is required to locate the required volume of storage.
- Construction of the cistern—The cistern needs to include an inlet for the downspout, overflow port and outlet.
- Slopes—The cistern needs to be located on stable and flat surface to prevent accidental tipping.
- Beneficial reuse area—The cistern needs to be drained or the water used regularly to be able to receive the next roof rainfall runoff. Consideration needs to be given to whether the beneficial reuse can receive/utilize the water volume on a regular basis.
- Interior reuse—Additional plumbing that requires approval pursuant to local building codes and from health departments, as well as a pumping system are required to use cistern water for interior uses such as toilet flush water and HVAC make-up water.

Design Criteria

The design of a cistern includes several elements to properly reduce stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.1-A on page 5.

Design criteria to consider includes:

- Roof runoff discharge locations
- Roof drainage area to each discharge location
- Select number and type of cisterns
- Location of cistern
- Inlet and pretreatment
- Drain or outlet
- Overflow
- Maintenance

Roof Runoff Discharge Locations

Review the building to determine where the roof runoff discharges. Identify the downspouts and determine where these downspouts discharge.

Cistern under construction at Americana (Photo: Louisville & Jefferson County MSD)

Roof Drainage Area to Each Discharge Location

Review the location of the gutter system, the slope of the gutter system and consider the location of the downspouts to determine the roof area that drains to each downspout. When determining the roof area, the aerial extent of the roof should be considered. The slope and pitch of the roof are not critical for determining the area.

Select Number and Type of Cisterns

Calculate the area of the roof draining to each downspout, multiply by the required WQv rain event and convert to gallons to determine the storage volume required for rainwater harvesting. Based on the required number of gallons, space available, water reuse needs and budget limitations, select an appropriate sized and shaped cistern for each downspout. Routing multiple downspouts to one larger cistern should also be considered.

Rainwater harvesting cisterns are available in a variety of different materials and should be selected based on their application. Underground cisterns should have the structural capability to support applicable weight bearing loads.

Location of Cistern

A cistern needs to be located on a firm, level surface to prevent tipping which could cause damage to the cistern and surrounding structures and landscaping. Consideration should be given to strapping the cistern to nearby structures to help prevent tipping and to resist any wind gusts.

Because harvested rainwater is typically used to water vegetation following the rain event, the cistern needs to be located close to the area identified for watering and at an elevation that will allow the harvested rainwater to flow by gravity, unless pumping is provided.

Inlet and Pretreatment

The downspout should form a tight fit with the cistern inlet to prevent harvested rainwater leakage and mosquito access. Using a grated inlet helps prevent leaves and other debris washed from the rooftop from entering the cistern. A fine mesh screen placed over the bottom of the grated inlet is also recommended to prevent mosquito access.

Drain or Outlet

Each aboveground cistern should be equipped with a drain or outlet nozzle located near the bottom, to allow it to be drained or used after the rain event and prior to the next rain event, or if the cistern has to be taken off line for the winter. Belowground cisterns should also be equipped with outlet piping near the bottom to allow for full use of the cistern volume.

Overflow

A cistern needs to be equipped with an overflow port to manage the roof rainwater runoff that is greater than the required WQv rain event. The port opening should be sized to handle the peak runoff from the 100 year, 24-hour rain event. The port on an aboveground cistern should be located to allow about one foot of head space between it and the top of the cistern. The discharge from the outlet should be directed to a pervious, stabilized area that will not be eroded from this concentrated flow.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A cistern is intended to only temporarily store harvested rainwater. Following the rain event, the stored rainwater needs to be drained or used to prepare for the next rain event. Therefore, this GMP should be in series with other GMPs such as rain gardens or bioretention areas to provide infiltration and volume control or some other beneficial reuse.

Rainwater harvesting cisterns at the Green Building (Photo: Erin Wagoner, URS)

Educational Awareness

Signage should be provided at the cistern indicating that the water is not safe for human consumption.

Rainwater Harvesting-Cisterns Application and Site Feasibility Criteria

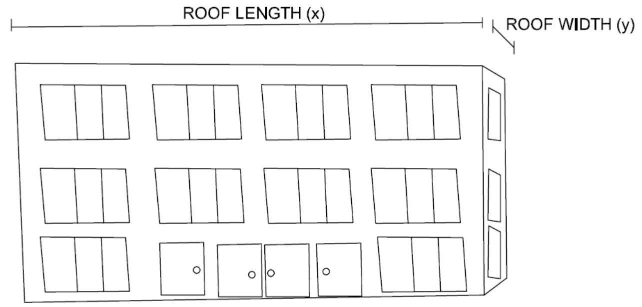
Table 18.5.14-A.

Design Parameter	Criteria
Design Volume and Conveyance Capacity	Store the runoff volume from the Required WQv Rain Event. Calculate runoff to pass the 2-, 10- and 100-year storms.
Pretreatment	Provide grate and fine mesh screen to prevent leaves and debris from entering the cistern.
Overflow Protection	Provide scour protection at the overflow discharge point. The overflow needs to sized to pass the 100-year storm event.
Volume	Cistern volume should be at least equivalent to the Required WQv. WQv (ft^3) = ($^1/_{12}$)[(RE_{WQV})(Rv)(A)] where • RE_{WQV} = Required WQv Rain Event (refer to Chapter 18.3) • Rv = 0.05 + 0.009 (I) ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the cistern (ft^2)
Drawdown Time	Cistern should be emptied prior to the next rain event or continuous simulation model must demonstrate regular use and drainage of captured water.

Rainwater Harvesting-Cisterns Step by Step Design Procedures

Step 1: Determine the roof drainage area and runoff volume

When measuring the area of the roof, the footprint of the roof is required, not the area of each section of the pitched roof. An easy way to measure the roof footprint is to measure the outside of the building at ground level to determine the length and width of the building and then to add the length of any roof overhang, which is the distance that the roof extends past the building. Therefore, the area of the roof can be calculated as follows:



Roof Area (square ft) = x*y, where

x = length of the roof footprint (ft)
y = width of the roof footprint (ft)

A cistern should be sized to capture the required WQv, which is as follows:

$WQv\ (ft^3) = (^1/_{12})[(RE_{WQV})(Rv)(A)]$, where

RE_{WQV} = Required WQv Rain Event
Rv = 0.05 + 0.009 (I);
I = impervious cover in percent;
A = drainage area to the cistern (ft^2); and
0.623 is a conversion factor

Step 2: Determine the roof drainage area and required WQv to each downspout

Evaluate the roof to determine the percentage of the entire roof or the specific area of the roof that drains to each downspout. Use this area along with the WQv calculation in Step 1 to determine the required WQv for each downspout.

Step 3: Determine number and size of cisterns

Based on the required WQv for each downspout calculated in Step 2, site constraints, and cistern costs, determine whether one larger cistern has adequate volume or whether multiple cisterns are needed. Select the combination of cistern(s) that provides the required WQv.

Step 4: Check stormwater reuse opportunities at each downspout

Evaluate the stormwater reuse opportunities at each downspout so that the stored stormwater can be used prior to the next rain event. Consider combining downspouts, as necessary. Follow applicable plumbing codes for using rainwater inside a building.

Step 5: Determine size of overflow

Calculate the peak stormwater roof runoff rate to each downspout for the 2-, 10- and 100-year storm events. Size and locate the overflow port for each cistern so that it can pass these larger storm events. The discharge from the overflow should be stabilized to prevent any scour and erosion.

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18.5.15 Vegetated Buffers

Vegetated buffer strip along a bike path (Photo: David Dods, URS)

Typical Implementation Areas:
- Commercial, industrial, multi-family residential and institutional developments

Key Considerations:
- Provide sheet flow into and across entire vegetated buffer
- Use to treat/infiltrate stormwater
- Applicable with gentle slopes (<6%)

Cost: Low-Medium
Maintenance: Low

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Partial Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Low or Unknown Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Partial Benefit
Infiltration	Partial Benefit
Stormwater Conveyance	Partial Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Partial Benefit

Key: Significant Benefit; Partial Benefit; Low or Unknown Benefit

A vegetated buffer, or filter strip, is a uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff. The vegetation in the buffer works to slow down the stormwater runoff, settling and filtering some pollutants and uptaking others. The stormwater runoff volume can also be reduced by infiltration into the pervious soil, if available, and by absorption and evapotranspiration of the vegetation. For a vegetated buffer to be effective, the stormwater has to enter and flow through the buffer in sheet flow. As a result, a flow spreader is often needed. The slope needs to be between 2 and 6%. The vegetation should consist of native, deep rooted grasses, shrubs and trees. A vegetated buffer can be managed or unmanaged depending on the desired aesthetics. A vegetated buffer improves water quality through:

☑ Settling and filtering pollutants
☑ Reducing stormwater peak flows due to infiltration of stormwater runoff

Advantages/Benefits

- Reduces stormwater runoff volume through infiltration and groundwater recharge
- Can be used as part of conveyance system and provides pretreatment for other GMPs

Disadvantages/Limitations

- Need to provide sheet flow to and throughout the buffer
- Limited applications (i.e. adjacent to trails and sidewalks)
- Not recommended for steep slopes or "hot spot" areas

Application and Site Feasibility:

A vegetated buffer usually receives stormwater runoff from an upstream impervious area and through sheet flow is able to treat the runoff and if the soils allow, infiltrate some of the stormwater runoff volume. For the buffer to be effective, the runoff needs to enter and flow through the entire buffer length in sheet flow. A flow spreader or similar device is typically required to produce sheet flow into the buffer; uniform grading within the buffer is required to maintain the sheet flow throughout the buffer. In addition, the buffer slope needs to be less than 6% to allow the flow to move slow enough for the vegetation to filter and settle out the pollutants and for the runoff to infiltrate. If the slope is less than 2%, then ponding water may be produced, which can lead to mosquito concerns. Often a vegetated buffer is used as preliminary treatment of the stormwater prior to entering another GMP. A vegetated buffer is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to provide the buffer width and length required.
- Slope—The slope of the vegetated buffer should be between 2 and 6%.
- Soil types—Soil types affect the amount of infiltration and the ability for the vegetation to thrive.
- Sheet flow—Sheet flow needs to be provided at the beginning and throughout the vegetated buffer.

Design Criteria

The design of a vegetated buffer includes several elements to manage stormwater treatment and infiltration. For a schematic of a typical vegetated buffer design see Figure 18.5.15-A. For a summary of design parameters, see Table 18.5.15-A on page 4.

Design criteria to consider include:

- Buffer slope and length
- Buffer width
- Soil composition
- Drainage area
- Inlet
- Landscaping plan
- Maintenance

Buffer Slope and Length

The vegetated buffer slope in the direction of flow should be between 2 and 6%, which prevents ponding of the

Typical vegetated buffer (Photo: David Dods, URS)

runoff, but does not promote the formation of concentrated flow. The length of the buffer (parallel to flow) should be a minimum of 25 feet and should be determined using the formula given in Table 18.5.15-A.

Buffer Width

Stormwater runoff must enter the vegetated buffer as sheet flow across its entire width (perpendicular to flow) at a depth no greater than one inch for the required WQv rain event. The buffer width should be determined using the formulas in Table 18.5.15-A on page 4.

Soil Composition

A vegetated buffer should be used on soils that have minimal clays and an infiltration rate greater than two inches/hr. The soils should be able to sustain a dense vegetative growth.

Drainage Area

The vegetated buffer is intended to treat runoff from a small contributing drainage area, typically not to exceed three acres.

Inlet

Stormwater runoff must enter the vegetated buffer in sheet flow across its entire width for it to be effective. A flow spreader or similar device is required to convert the upstream concentrated or overland flow to sheet flow across the entire buffer. The inlet design should also accommodate the passing or diversion of flows greater than the runoff from the required WQv rain event, without damaging the flow spreader and eroding the buffer.

Landscaping Plan

A landscaping plan is recommended for planting the vegetated buffer. The plan should include bedding preparation, identification of the various planting zones and

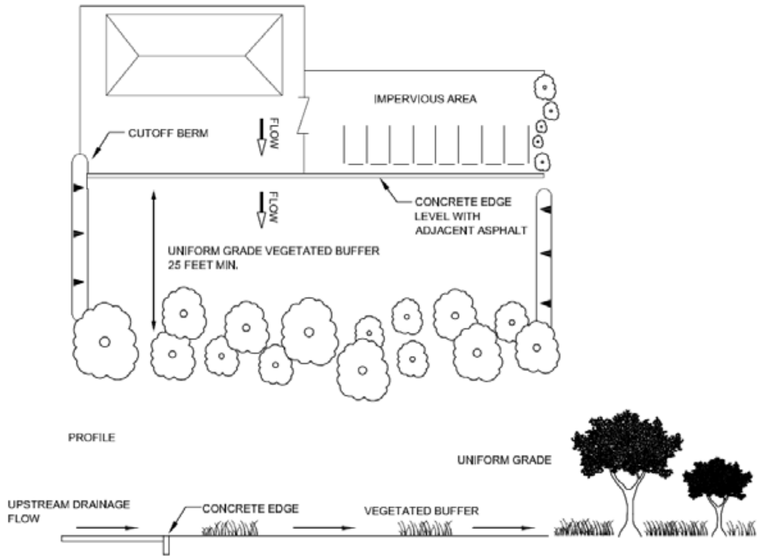

Figure 18.5.15-A. Vegetated Buffer Schematic (Rendering: Shea Powell, Dropseed)

recommended plants for each planting zone. Select plants appropriate for each zone.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Vegetated buffers are typically one of the first in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

The difference between a vegetated buffer and a traditionally landscaped area may not be visible to everyone. It is important that those maintaining it, as well as the general public, understand that its features extend beyond aesthetic landscaping to manage and treat stormwater runoff. Signs indicating "No Mow" areas serve to inform the public and may be required.

Vegetated Buffers Application and Site Feasibility Criteria

Table 18.5.15-A.

Design Parameter	Criteria
Buffer Slope and Length	• Slope in the direction of flow should be between 2 and 6% • Buffer length (parallel to the flow) should be a minimum of 25 feet and be calculated using the following equation: $L=[(T)^{1.25}(P)^{0.625}(S)^{0.5}]/3.34n$, where L = length of the buffer parallel to the flow path (ft) T = travel time through the filter strip (minutes), has to be 10 minutes at a minimum P = required WQv rain event (refer to Chapter 18.3) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient
Buffer Width	• The maximum discharge loading per linear foot of buffer width (perpendicular to flow) should be calculated using the following equation: $q = 0.0237(S)^{0.5}/n$, where q = discharge per foot of width of the filter strip (cfs/ft) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient The minimum width of the buffer should be calculated using the following equation: $W = Q/q$, where W = minimum width of the filter strip (perpendicular to the flow (ft) Q = peak discharge to the buffer from the required WQv rain event (cfs) • Calculate the velocity of the stormwater runoff across the buffer to be sure that it is less than 2.0 fps using the following equation: $V = Q/d*W$, where d = the depth of flow (ft)
Soil Composition	The infiltration rate within the vegetated buffer needs to be at least two inches/hr.
Drainage Area	The area draining to the vegetated buffer needs to be less than three acres.
Inlet	The vegetated buffer needs to have a flow spreader to provide uniform sheet flow across the entire width of the buffer.

Vegetated Buffers Step by Step Design Procedures

Step 1: Determine if site is appropriate

Determine if the site conditions and drainage area are appropriate for use of a vegetated buffer. Consider Table 18.5.15-A, especially the infiltration rate of the underlying soils.

Step 2: Determine the maximum discharge loading per foot of vegetated buffer width

Use the following equation to calculate the maximum discharge loading per foot of vegetated buffer width.

$$q = 0.0237(S)^{0.5}/n$$

Step 3: Determine the peak flow rate

The vegetated buffer should be sized so the depth of flow across the buffer is no more than one inch during the peak runoff from the required WQv rain event (Q). The vegetated buffer also must be designed to safely convey or bypass flow rates produced by larger storm events with minimum erosion. Larger storms (2-, 10-, and 100-year) should be modeled to size overflow or bypass structures to safely convey the flow.

Step 4: Determine minimum buffer width (perpendicular to the flow)

Calculate the minimum buffer width (perpendicular to the flow) using the following equation:

$$W_{min} = Q/q$$

Step 5: Check velocity through vegetated buffer

Check to make sure that the velocity through the vegetated buffer is less than two fps using the following equation:

$$V = Q/d*W$$

Should the velocity be too high, consider decreasing the slope or increasing the buffer width.

Step 6: Inlet design and bypass capability for larger storms

For the vegetated buffer to be effective, it needs to have uniform sheet flow into it and all along its length. A flow spreader should be designed at the entrance to the vegetated buffer to provide sheet flow. Consideration should be given for minimizing erosion at the beginning of the buffer once the flow leaves the flow spreader. In addition, the flow spreader and vegetated buffer should be designed to bypass or pass runoff from the larger storm events (2-, 10-, and 100-year) without causing erosion within the vegetated buffer.

Step 7: Prepare landscaping plan

Choose native plants to incorporate into the vegetated buffer based on aesthetic preferences, plant heights and sun/shade tolerances. The plan should include the following information:

- Different planting zones
- The species to be planted within each planting zone, plant material types (seed, bare-root, potted), plant sizes and planting plan
- Plant spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

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18.5.16 Vegetated Swales

Typical Implementation Areas:

- Natural or manmade shallow drainage ways in commercial, industrial, multi-family residential and institutional developments

Key Considerations:

- Drain within 24 hours after a rain event
- Large storm velocity <4.5 fps
- Only applicable with gentle slopes (preferably <2%)

Cost: Low
Maintenance: Low

Vegetated swale (Photo: David Dods, URS)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial
Phosphorus	Low or Unknown
Nitrogen	Low or Unknown
Metals	Low or Unknown
Pathogens	Low or Unknown
Floatables	Partial
Oil and Grease	Low or Unknown
Dissolved Pollutants	Low or Unknown
Hydrologic Characteristics	
Surface Flow Reduction	Low or Unknown
Infiltration	Partial
Stormwater Conveyance	Significant
Stream Channel Protection	Low or Unknown
Peak Flow Control	Low or Unknown
Runoff Volume Reduction	
Runoff Capture	Partial

Key: ■ Significant Benefit; ◩ Partial Benefit; □ Low or Unknown Benefit

A vegetated swale is a shallow, open-channel concentrated flow feature that contains a dense growth of vegetation, typically tall grass, that partially treats and can infiltrate stormwater runoff. The vegetation in the swale slows down the stormwater runoff, settling and filtering out some pollutants and uptaking others. The stormwater runoff volume can also be reduced by infiltration into the pervious soil, if available. A vegetated swale can enhance the local landscaping and be used as a good pre-treatment for other GMPs. A vegetated swale improves water quality through:

- ☑ Settling and filtering pollutants
- ☑ Reducing stormwater peak flows due to infiltration of stormwater runoff

Advantages/Benefits

- Can provide infiltration of runoff from smaller rain events (provided underlying soils allow)
- Can be used as part of conveyance system and provides pretreatment for other GMPs
- Can reduce cost of typical curb/gutter and storm sewer pipe infrastructure

Disadvantages/Limitations

- Low pollutant removal ability
- Need to be at lower slopes (<2%)
- May contain wet spots leading to maintenance and mosquito concerns
- Potential for erosion in bottom of swale while vegetation is becoming established

Application and Site Feasibility

A vegetated swale typically receives stormwater runoff from an area less than 20 acres. The vegetated swale slope needs to be less than 5%, and preferably in the 1-2% range to allow the flow to move slow enough for the vegetation to filter and settle out the pollutants and for the runoff to infiltrate, should the soils allow. With slopes less than 2%, ponding water may occur, which can lead to mosquito and maintenance concerns. An underdrain system can be added to help remove ponding water. In addition, the bottom of the swale should be at least 1 foot above the seasonal high water table to promote drainage of the swale.

The flatter swale slope is also important to prevent scouring of the swale bottom and sides and to allow time for the soil particles to be filtered out and any infiltration to occur. The runoff velocity within the swale should be kept to less than 4.5 fps during large rain events and 1.0 fps during the required WQv rain event. The swale length should be at least 100 feet long and provide a minimum of 5 minutes of residence time.

A vegetated swale is appropriate for stormwater conveyance in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/high density residential areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to provide the swale width and length required
- Slope—should be between 1 and 2%, and not to exceed 5%
- Channel length—should provide at least five minutes of residence time
- Soil types—affect the amount of infiltration and the ability for the vegetation to thrive
- Conveyance—Should be able to convey the required flows at acceptable velocities

A schematic of a vegetated swale is provided in Figure 18.5.16-A on this page.

Design Criteria

The design of a vegetated swale includes several elements to manage stormwater treatment and infiltration. For a summary of design parameters, see Table 18.5.1-A. Note that vegetated swale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

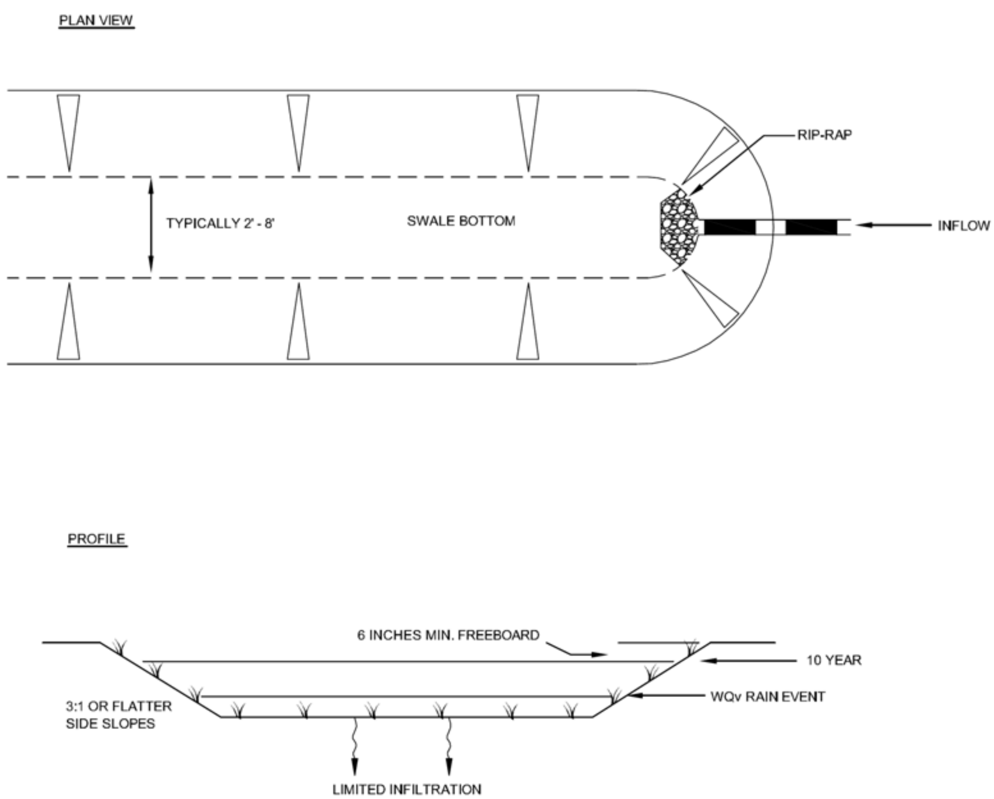

Figure 18.5.16-A. Schematic of vegetated swale

Design criteria to consider include:

- Flow capacity, velocity and freeboard
- Erosion prevention
- Slopes
- Swale length
- Soil composition
- Maintenance

Flow Capacity, Velocity, and Freeboard

Since swales are conveyance features, they are designed to slow and detain small storm events while also safely passing large storms with adequate freeboard. Flow velocity calculations for evaluating erosion protection needs are typically done assuming new or short vegetation. Flow conveyance and freeboard calculations for large storms typically assume taller, denser vegetation. The flow velocity for the peak runoff from the required WQv rain event should not exceed 1.0 fps, while that for the 100-year rain event should not exceed 4.5 fps or the limit for the vegetation to be used, whichever is lower.

A minimum of 6 inches of freeboard should be provided in the swale for runoff from the 100-year, 24-hour rain event. The maximum flow depth for the peak runoff from the required WQv rain event should be four inches.

The swale should be sized to have a bottom swale width of between two and eight feet. The width can be calculated using the formula in Table 18.5.16-A. Vegetated swales along the roadway should have adequate flow conveyance and maintain adequate freeboard to avoid flooding or overtopping the pavement. When swales are in close proximity to pavement structure, they should have enough flow capacity to provide positive subgrade drainage.

Erosion Prevention

Vegetated swales should be lined with biodegradable erosion control matting for erosion prevention during the vegetation establishment period. Selection should be based on shear stress of flowing water. In addition, velocities should be maintained within the limits noted in the previous section.

Slopes

Site topography should be considered in the vegetated swale design, including main channel slope and side slope to maintain non-erosive velocities. Typically, main channel slopes (parallel to the flow) should be 1 to 2%. Where there are poor soils, an underdrain should be used, to prevent ponding water. In areas with slopes between 2 and 5%, check dams or weirs should be placed perpendicular to the flow to extend time for infiltration and filtration and reduce the effective slope of the swale. Placement of check dams or weirs should include scour protection to limit erosion.

The side slopes of the swale should be a minimum of 3:1, with 4:1 preferred. These flatter slopes prevent scour from runoff entering the channel from the sides and from the concentrated flow in the swale.

Swale Length

The vegetated swale length should be sized to provide a minimum of 5 minutes of residence time and should be a

Vegetated swale installation using turf reinforcement mats
(Photo: David Dods, URS)

minimum of 100 feet. The swale length can be calculated using the equations provided in Table 18.5.16-A.

Soil Composition

A vegetated swale should be used on soils that have minimal clays and an infiltration rate greater than 0.5 inches/hr. The soils should be able to sustain a dense vegetative growth.

Landscaping Plan

A landscaping plan is recommended for planting the vegetated swale. The plan should include bedding preparation, identification of the various planting zones and recommended grasses for each planting zone considering flow velocity and wet and dry fluctuations. Select grasses appropriate for each zone.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A minimum of three different types of grasses are recommended. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

A vegetated swale is typically one of the first in a series with other GMPs, such as rain gardens or bioretention areas, to supplement infiltration and volume control.

Educational Awareness

The difference between a vegetated swale and a traditionally landscaped area may not be visible to everyone. To maintain the integrity and effectiveness of the vegetated swale, it is important that those maintaining it understand that its features move beyond aesthetic landscaping to manage and treat stormwater runoff. Signs indicating that the vegetated swale is a stormwater management feature will provide outreach to the general public and may be required.

MSD staff re-grade a vegetated roadside swale (Photo: Louisville & Jefferson County MSD)

Vegetated Swales Application and Site Feasibility Criteria Chart*

Table 18.5.16-A.

Design Parameter	Criteria
Longitudinal Slope	• Less than 5% • 1 - 2 % preferred • Use check dams to achieve slopes as needed
Bottom Width	• 2 - 8 feet typical • The width can be calculated using the following equation: $W = (n*Q)/(1.49*D^{5/3}*S^{1/2})$, where W = minimum bottom swale width (ft) n = Manning's roughness coefficient Q = peak runoff (cfs) D = flow depth (ft) S = slope (%)
Swale Length	• The swale length can be calculated using the following equations: V = Q/(W*D) L = 60*V*R, where V = velocity (fps) L = swale length (ft) R = residence time (minutes)
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Maximum Permissible Velocity	• 1.0 fps for peak flow from required WQv rain event • 4.5 fps for peak flow from the 100-year, 24-hour rain event
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm
Soils	Underlying soils should have an infiltration rate of 0.5 inches per hour or greater.
Residence Time for the Required WQv Rain Event	• Minimum of 5 minutes • Preferably greater than 9 minutes
Drawdown Time	Vegetated swale should dewater within 24 hours.
WQv	Calculate WQv (ft^3) $=(^1/_{12})[(RE_{WQV})(Rv)(A)]$, where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter18.3) • Rv = 0.05 + 0.009 (I) where ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the swale (ft^2)

* Note that vegetated swale design requirements differ from conventional conveyance requirements, as provided in Chapter 10.3.5 (Conventional Channels and Ditches) of the MSD Design Manual.

Vegetated Swales Step by Step Design Procedures

Step 1: Determine if site is appropriate

Determine if the site conditions and drainage area are appropriate for use of a vegetated swale. Consider Table 18.5.16-A.

Step 2: Determine the peak flow rate

Swales should achieve the residence time shown in Table 18.5.16-A for the runoff from the required WQv rain event. Swales must be designed to safely convey flow rates produced by larger storm events with adequate freeboard and minimum erosion.

Larger storms (2–, 10– and 100-year) should be checked to size the swale to carry them. For each culvert/drainage area, model or calculate the peak flow rate for the following storm events:

- Required WQv rain event
- 2-year, 24-hour
- 10-year, 24-hour

Step 3: Determine swale dimensions

Size bottom width, depth, length and slope necessary to achieve the residence time and freeboard per Table 18.5.16-A. The following equations can be used:

$$W = (n*Q)/(1.49*D^{5/3}*S^{1/2})$$

$$L = 89.4*D^{2/3}*S^{1/2}*R/n$$

Step 4: Check velocities for required WQv rain event

Based on the average swale cross-section and slope, check flow velocities and water depth for the peak runoff from the required WQv rain event. Check that the velocity is 1 fps or less to promote sedimentation and filtration as well as reduce erosion potential. Check that the water depth is 4 inches or less.

Step 5: Check velocities and freeboard for larger storms

Based on the average swale cross-section and slope, check flow velocities and water surface elevations for the 2- , 10- and 100- year, 24-hour storm events for the swale to pass safely. Check that the velocity is 4.5 fps or less to promote sediment drop out and filtration as well as reduce erosion potential. Check that the water depth provides 6 inches of freeboard. Modify design as appropriate.

Step 6: Select erosion control measures

Compare peak flow velocities calculated for the required WQv rain event, 2-, 10– and 100-year, 24-hour storm events to maximum permissible velocities for the soil types present at the site and determine the need for biodegradable erosion control materials. For most swales, a biodegradable erosion control mat will be needed to limit soil erosion while the vegetation is becoming established. Choose biodegradable erosion control mat based on the manufacturer's specifications that meet the peak flow velocities.

Step 7: Prepare vegetation and landscaping plan

Choose deep rooted, native grasses based on aesthetic preferences, grass heights, and the anticipated moisture zones within the swale. In general, the sides of the swale will be well drained and the vegetation on the sides will need to tolerate dry conditions as well as occasional wet conditions. The bottom of the swale will have more moist conditions, so vegetation will need to tolerate longer periods of saturation. Choose grasses appropriate for the conditions that will be created in the swale.

The plan should include the following information:

- Different planting zones
- Species to be planted within each planting zone and planting plan
- Planting density for each species
- Planting bed preparation and planting methods

- Establishment, maintenance and care requirements
- Acceptable sources for the vegetation

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18.5.17 Underground Storage

Typical Implementation Areas:

- Underneath paved areas in commercial, industrial, multi-family residential and institutional developments
- Highly urbanized areas where land is expensive or limited

Key Considerations:

- Temporarily detains stormwater
- Access for maintenance

Cost: High
Maintenance: Medium

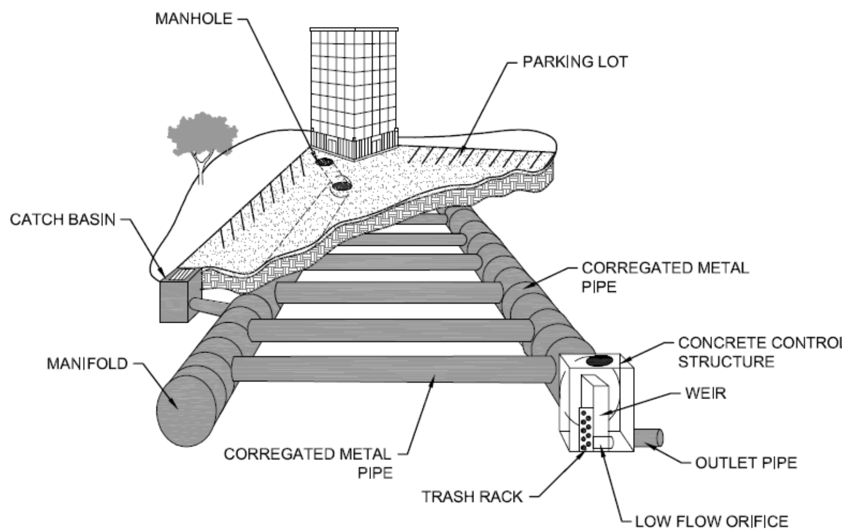

Figure 18.5.17-A. Typical underground stormwater storage system (Source: Montgomery County, MD)

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Low or Unknown Benefit
Pathogens	Low or Unknown Benefit
Floatables	Partial Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Low or Unknown Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Low or Unknown Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Low or Unknown Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

Key: ■ Significant Benefit; ◪ Partial Benefit; □ Low or Unknown Benefit

Underground storage is the practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures. The collected stormwater runoff is intended to be released back to the surface drainage system or storm sewer system at a reduced rate and completely drained prior to the next rain event, similar to a green dry detention pond. Some underground storage systems may also infiltrate the stormwater into the underlying soils, provided the surrounding soils have the necessary permeability. An underground storage system may be constructed of concrete, steel or plastic with many proprietary products in the market. These systems provide very little water quality benefit, so additional GMPs or pretreatment devices are required where water quality improvements are needed. Underground storage improves stormwater management through:

- ☑ Detention of stormwater runoff, reducing peak flows
- ☑ Possible reduction of stormwater runoff volume through infiltration to surrounding soils

Advantages/Benefits

- Reduces channel/stream bank erosion by reducing the number of bankfull events
- Less installation time than other GMPs
- Adapts to unusual shaped property
- Increased public safety compared to surface GMPs

Disadvantages/Limitations

- Not intended for water quality benefit
- Requires pretreatment to reduce maintenance efforts or to infiltrate
- Not to be used in areas with high groundwater table

Application and Site Feasibility

Underground storage is applicable in areas where water quantity control is desired and land is not available or is too expensive for aboveground GMPs. Underground storage needs to be located such that the stormwater runoff gravity feeds into and out of the storage system. Underground storage should be located in areas that can be excavated in the future, should the need arise. Underground storage is appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/ high density residential areas, typically in ultra-urban areas.

Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to locate the required storage volume and provide access for maintenance vehicles.
- Material selection—Select the material of construction for the underground storage system based on desired useful life, earthwork requirements, overburden support and potential for the system to float.
- Access—Several manholes/access ports need to be provided to allow for maintenance and inspection of the system.
- Slopes—The bottom of the underground storage system should be sloped no more than 2% to allow for complete draining.

Design Criteria

The design of underground storage includes several elements to properly reduce stormwater runoff volumes and reduce peak flow rates into the sewer system. See Figure 18.5.17-A for a schematic drawing of a typical underground storage system. For a summary of design parameters, see Table 18.5.1-A on page 3.

Design criteria to consider includes:

- Inlet and pretreatment
- Outlet
- Overflow and bypass
- Infiltration
- Overburden support
- Drain time
- Maintenance

Inlet and Pretreatment

Inlets need to be provided in the quantity and size needed for the desired stormwater runoff to enter the underground storage system. Pretreatment, focused on the removal of floatables and sediment, should be provided at the inlets to reduce maintenance efforts and prevent any groundwater contamination, if infiltration is provided. Pretreatment may include catch basin inserts or proprietary water quality units.

Outlet

The outlet orifices need to be sized to prevent clogging, typically no smaller than 8 inches, but provide the required retention of the stormwater runoff.

Overflow and Bypass

The underground storage system needs to have an emergency overflow to allow for safe passage of the larger storm events. In addition, a bypass system should be provided to allow the underground system to be taken out of service should it become inoperable.

Infiltration

Should the underground storage system intend to infiltrate the stormwater runoff into the surrounding soils, the soils need to have a permeability rate of at least 0.5 inches/hr. Pretreatment of the stormwater runoff should be provided to prevent groundwater contamination.

Overburden Support

When selecting the underground storage system material, consider the loading coming from above. The loading will include backfill, pavement, and possibly vehicular traffic.

Drain Time

The stormwater runoff WQv collected in underground storage should drain out to a surface drainage or sewer system or infiltrate into the surrounding soils within 48 hours.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. Provide an adequate number of access points, a minimum of two, to allow for maintenance activities. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Underground storage mostly provides water quantity benefits and not water quality benefits. Therefore, this GMP will typically be in series with other GMPs. It may follow proprietary water quality units or catch basin inserts or may precede other GMPs such as bioswales or green detention ponds to provide infiltration and additional volume control.

Educational Awareness

Underground storage is confined space, so special precautions, protective equipment and training are required for personnel entering the storage system.

Underground Storage Application and Site Feasibility Criteria

Table 18.5.17-A.

Design Parameter	Criteria
Pretreatment	Provide BMPs to prevent leaves, trash and sediment from entering the underground storage system.
Overflow Protection	The overflow needs to be sized to pass runoff from storms greater than the 100 -year, 24-hour event.
Conveyance	Pass the runoff from the 2-, 10- and 100-year, 24-hour storms.
Volume	Underground storage volume should be at least equivalent to the Required WQv. WQv (ft^3) = ($^1/_{12}$)[(RE_{WQV})(Rv)(A)] where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.3) • Rv = 0.05 + 0.009 (I) where ♦ I = impervious cover of the contributing drainage area in percent • A = drainage area to the underground storage system (ft^2)
Infiltration Rate	For underground storage to infiltrate the stormwater runoff into the surrounding soils, the soils need to have a permeability of at least 0.5 inches/ hour.
Drawdown Time	Underground storage should be drained within 48 hours of the end of the required water quality rain event.

Underground Storage Step by Step Design Procedures

Step 1: Define goals/primary function of underground storage

Define the goals/primary function of the underground storage system, especially whether it will provide infiltration into the surrounding soils. Also define supplemental project goals, such as regional water quality limitations (e.g. TMDLs), and site access considerations.

Step 2: Determine the peak flow rate and total runoff volume

Underground storage should be sized to capture and temporarily store the required WQv created from the runoff from the required WQv rain event. The underground storage system should drain in no more than 48 hours. Larger storms (2-, 10- and 100-year) should be checked to size outlet, bypass and overflow structures to convey these flows. For each inlet, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Required WQv Rain Event
- 2-year
- 10-year
- 100-year

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of underground storage. Consider Table 18.5.17-A. Create a rough layout of the underground storage system including existing utilities, topography and other obstructions.

Step 4: Determine outlet, bypass and overflow design

Based on the underground storage system configuration, check water surface elevations for all storm events (shown in Step 2) so the system can pass these flows safely and drain within 48 hours. Determine the need for erosion prevention and energy dissipation measures at the outlet. Modify design as appropriate.

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Green Management Practice (GMP)

18.5.18 Catch Basin Inserts

Typical Implementation Areas:
- Retrofit areas
- Pretreatment upstream of other GMPs
- Inlet protection

Key Considerations:
- Media type/manufacturer
- Size of drainage area

Cost: Low-Medium
Maintenance: High

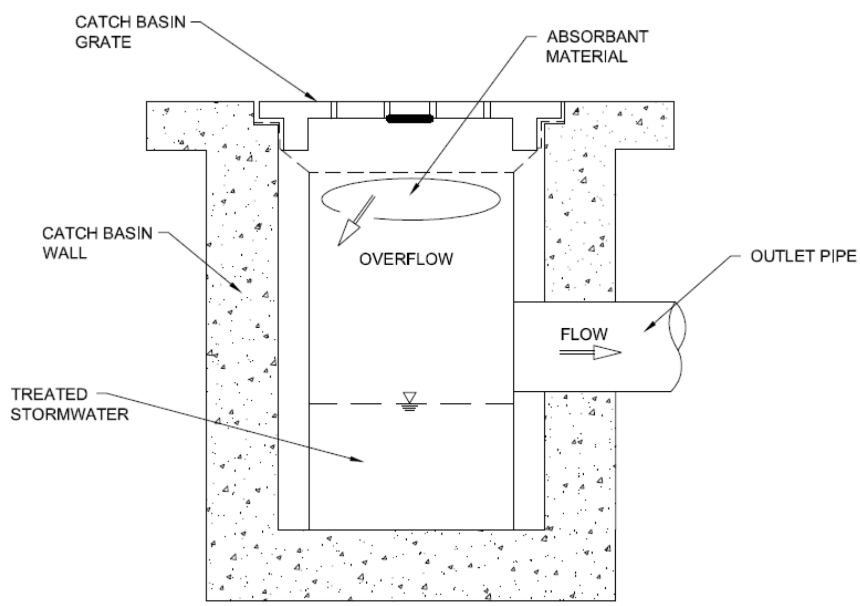


Figure 18.5.18-A. Catch basin insert schematic

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Partial Benefit
Oil and Grease	Partial Benefit
Dissolved Pollutants	Low or Unknown Benefit
Hydrologic Characteristics	
Surface Flow Reduction	Low or Unknown Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Low or Unknown Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Partial Benefit

Key:
- Significant Benefit
- Partial Benefit
- Low or Unknown Benefit

Catch basin inserts are space saving devices installed underneath the grate of an inlet to remove sediment, debris, oils or metals from stormwater inflow. This can be achieved through filtering, settling or absorbing pollutants. Catch basin inserts are beneficial because they install easily in retrofit systems and work well in a treatment train as they minimize clogging in downstream water quality features. Catch basin inserts improve water quality through:

☑ Filtering sediment, debris and oils
☑ Effective form of pretreatment

Advantages/Benefits:

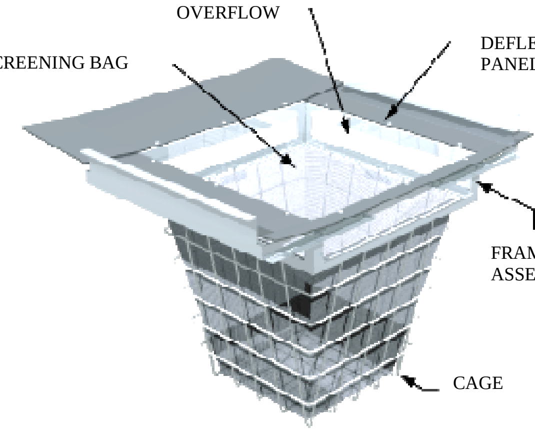
- Typically easy installation
- Appropriate for sites with space limitations and where infiltration is not an option
- Appropriate for retrofit applications
- No aboveground or underground storage is needed beyond the typical storm sewer system

Disadvantages/Limitations:

- Not effective as a stand-alone water quality treatment source
- Susceptible to clogging and not suitable for accepting runoff from areas with heavy sediment flow
- May require more frequent maintenance or could become a source of pollutant depending on volume of flow received
- Does not effectively capture dissolved pollutants and fine particles

Application and Site Feasibility:

Catch basin inserts are an effective way of filtering stormwater before it enters a rain garden, dry basin or some other form of GMP. Since the inserts trap sediment and debris, they minimize the potential of clogging for downstream water quality features. They can also be installed as an additional source of water quality improvement and receive filtered water from a GMP. However, they are not suitable for receiving runoff from areas with heavy sediment flow because of their minimal storage capacity for captured sediment. Catch basin inserts are suitable for use in unpaved areas with minimal erosion or in parking lots with a small drainage area. Catch basin inserts are also beneficial for retrofit areas because of their ability to be installed easily into existing systems.



Catch basin insert with a metal screen to catch sediment and debris (Source: Enviropod, Stormwater 360)

Physical Requirements:

Catch basin inserts performance ability and size vary based on the manufacturer and/or project need. Inserts should be designed and installed based on the manufacturer's recommendations. Recycled and reusable products are available for some types of insert media. The following types of material are generally used in combination with the catch basin inserts:

- Metal/Plastic Screens—typically effective in the removal of sediment and other debris (See schematic to the right)
- Fabric—typically effective in the removal of oil and grease (See photo to the right)
- Filter inserts—designed to remove metals or other types of pollutants (See graphic page 3)

Catch basin insert with an oil-absorbent fabric (Source: Enpac)

Design Criteria:

The design of catch basin inserts should be based on manufacturer's recommendations. Some typical design considerations for choosing the type and manufacturer include:

- Location of Catch Basin
- Overflow (Bypass)
- Location of Filter Media
- Pollutant Removal
- Installation
- Maintenance

Location of Catch Basin

The catch basin should be located in an area that is accessible for maintenance at any time. Special consideration should be given during the design phase to ensure that the basin will not be blocked for maintenance by vehicles or other obstructions.

Overflow (Bypass)

Catch basin inserts should be designed to bypass stormwater flow in excess of the water quality design volume into another system or inlet. This prevents overflow of the catch basin if it becomes clogged or when there is excessive rainfall.

Location of Filter Media

The bottom of the filter media should be located above the crown of the outlet pipe (See Figure 18.5.18-A on page 1). This will ensure that the water quality design volume is filtered through the media.

Pollutant Removal

Catch basin inserts can be designed to remove various types of pollutants based on the media inserts discussed under physical requirements. Care should be taken to ensure that the insert type chosen has the necessary performance capabilities based on the manufacturer's recommendations.

Installation

Inserts should be installed based on manufacturer's recommendations. Generally, the construction site should be stabilized before the insert in installed into the basin to prevent clogging from excess sediment.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

As stated previously, catch basin inserts are not stand-alone features because of their small storage capacity and are recommended to be located in series with other GMPs.

Educational Awareness:

Some catch basin inserts collect pollutants that could be harmful to human health, so appropriate personal protective equipment is recommended.

Catch basin insert incorporates a specialized filtration fabric and a mesh lining to remove various types of pollutants (Source: CleanwayUSA)

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Green Management Practice (GMP)

18.5.19 Proprietary Water Quality Units

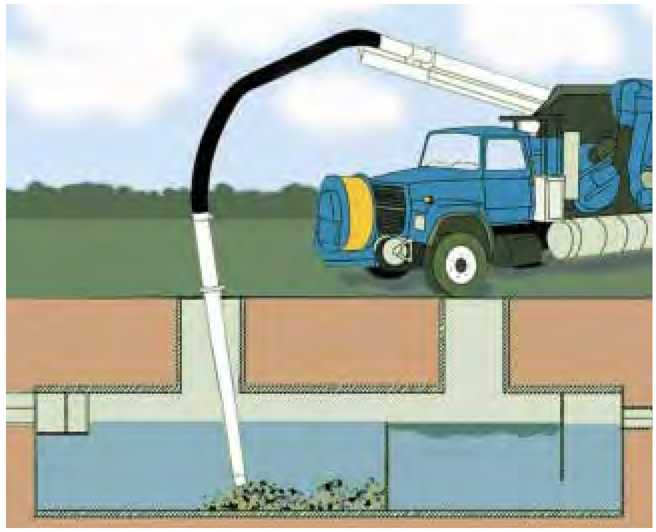
Typical Implementation Areas:

- Parking lots and roadways
- Hazardous substance facilities
- Curb and inlet runoff
- Retrofit areas

Key Considerations:

- Unit type

Cost: Medium-High
Maintenance: Medium



Water quality units are typically equipped with access risers for easier inspection and maintenance. (Graphic: Advanced Drainage Systems)

Stormwater Management Benefits

Pollutant Reduction

Sediment	varies
Phosphorus	varies
Nitrogen	varies
Metals	varies
Pathogens	varies
Floatables	varies
Oil and Grease	varies
Dissolved Pollutants	varies

Hydrologic Characteristics

Surface Flow Reduction	Low or Unknown Benefit
Infiltration	Low or Unknown Benefit
Stormwater Conveyance	Partial Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Runoff Volume Reduction

Runoff Capture	Partial Benefit

Key: Significant Benefit / Partial Benefit / Low or Unknown Benefit

Proprietary water quality units vary based on manufacturer, but are typically underground treatment systems installed at inlet structures. These systems are a space effective design that creates a swirling vortex or contains multiple chambers to separate sediments and floatables, such as oil/grease, from stormwater inflow. Proprietary water quality units improve water quality through:

☑ Effective removal of heavy sediment
☑ Effective removal of oil/grease
☑ Removal of hazardous substances before they have a chance to infiltrate into the soil
☑ Works well in a treatment train

Advantages/Benefits

- Typically easy installation
- Appropriate for sites with space limitations and where infiltration is not an option
- Appropriate for retrofit applications
- Good for impervious area runoff that may clog other types of GMP's
- Can be designed to be suitable for hazardous substance runoff

Disadvantages/Limitations

- Not effective as a stand-alone water quality treatment source
- May require more frequent maintenance depending on size of structure and quantity of flow and pollutants
- Cannot effectively remove dissolved pollutants and fine particles
- Potential source of pollutants if maintenance is neglected

Application and Site Feasibility

Proprietary water quality units can provide water quality benefits for sites with limited area for infiltration opportunities. The units typically will need to be used in conjunction with other GMPs as they do not provide removal of fine or soluble particles. Some systems are suitable for areas with impervious runoff or hazardous materials because they provide treatment of water before it is infiltrated into the soil. The water quality units are also implemented in retrofit areas because of their ability to meet space requirements.

Physical Requirements

Key physical considerations:

- Unit Type—Proprietary water quality units vary based on the manufacturer, however there are two main types of units: hydrodynamic and chambered

Hydrodynamic Devices

Hydrodynamic designed units allow flow to enter the system where the water will move in a swirling motion inside the unit to allow particles of sediment and debris to separate and fall to the bottom. There may also be a separate filter inside the water quality unit to absorb oil and grease. Hydrodynamic devices are generally effective in treating smaller storms and are typically designed to pass flow from larger storm events to prevent re-suspension of captured sediment and debris. Additional GMP's used in conjunction with the units could be effective in meeting water quality requirements for larger storms. A schematic section of a hydrodynamic water quality unit is shown on Figure 18.5.19 -A below.

Chambered Devices

Chambered devices allow water to flow into a sump-like structure with weir or baffle plate walls located vertically, thus dividing the structure into separate chambers. (See schematic below). These chambers allow sediment and debris to settle and oil and grease to be separated from the outflow. As with hydrodynamic units, these structures are typically designed to pass larger storms so additional GMP's are recommended in conjunction with the chambered device. A schematic section of a chambered device is shown on Figure 18.5.19-B on page 3.

Design Criteria

Design for water quality units should be based on manufacturer's recommendations. Some typical design criteria to consider when choosing a type and manufacturer are:

- Location
- Sizing
- Installation
- Pollutant Removal
- Maintenance

Location

Water quality units should be installed upstream of additional GMPs as pretreatment devices. Refer to manufacturer's recommendations for maximum drainage area for each type of device.

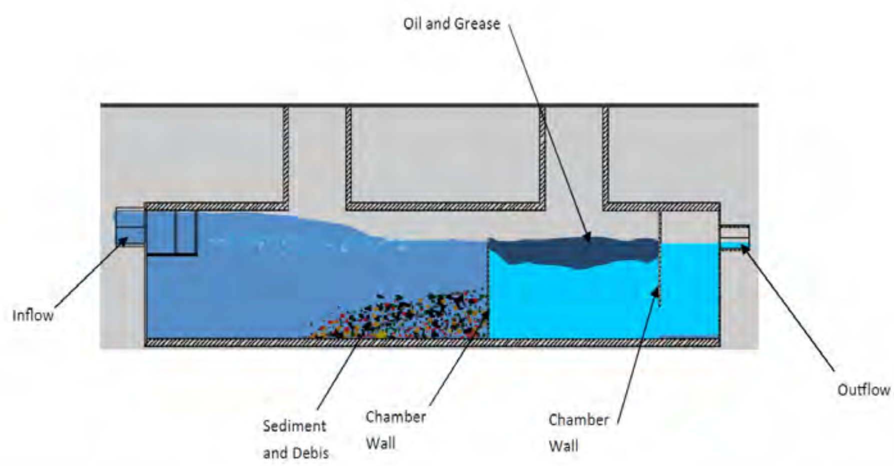


Figure 18.5.19-A. Schematic section of a chamber device (Graphic: Advanced Drainage Systems)

Sizing

At a minimum, the water quality unit should be sized to treat the peak flow associated with the WQv in order to be an effective pretreatment device.

Installation

Installation should always occur per manufacturer's recommendations. A manufacturer's representative should be present on-site during the installation of the water quality unit to ensure that it is installed properly. Based on the water quality unit chosen, screens may also need to be installed to prevent mosquitos and rodents from entering the unit.

Pollutant Removal

Pollutant removal varies based on the individual design of the water quality unit and can be customized per manufacturers' recommendations. If the unit will be accepting flow from a hazardous substance facility or has any other special pollutant removal requirements, care should be taken to ensure that the unit chosen has the necessary performance capabilities.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

As stated previously, water quality units are not typically stand-alone treatment sources because of their inability to remove dissolved sediment and fine particles and are thus most effective located in series with other GMPs.

Educational Awareness

Some proprietary water quality units are confined space, so special precautions, personal protective equipment and training are required for personnel entering the unit.

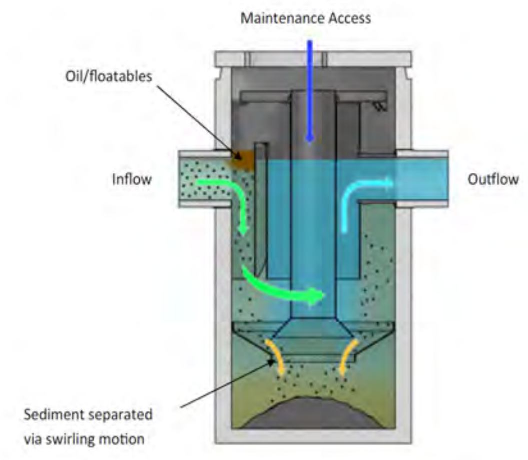


Figure 18.5.19-B. Schematic section of a hydrodynamic device (Graphic: Hydro International)

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18.5.20 Infiltration Trenches

Typical Implementation Areas:
- Parking lot perimeters
- Small sites
- Medians between drive lanes

Key Considerations:
- Surface dimension vs. depth
- Requires pretreatment
- Infiltration
- Proximity to building foundations
- Slopes

Cost: Medium
Maintenance: Medium-High

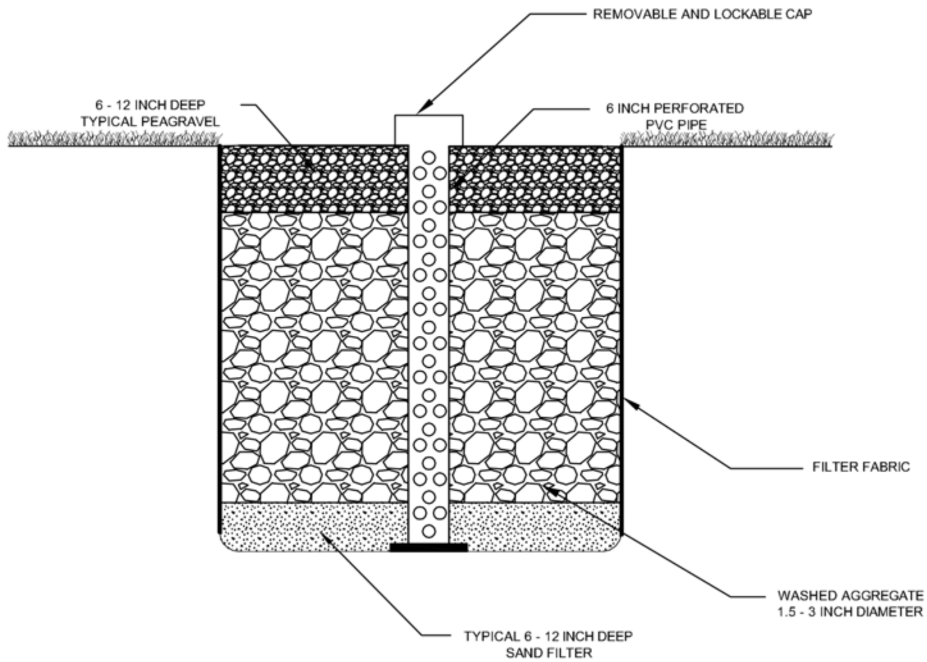

Figure 18.5.20-A. Typical cross-section of an infiltration trench

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	◪
Floatables	◪
Oil and Grease	◪
Dissolved Pollutants	◪
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	■
Stream Channel Protection	◪
Peak Flow Control	◪
Runoff Volume Reduction	
Runoff Capture	■

Key: ■ Significant Benefit
◪ Partial Benefit
□ Low or Unknown Benefit

Infiltration trenches are shallow, excavated areas that receive stormwater. They are typically filled with aggregate and contain no outlet structure. Overland flow or a perforated inlet pipe allows stormwater to infiltrate through the aggregate and into the underlying soil promoting groundwater recharge. Incoming stormwater should have some form of pretreatment before entering the infiltration trench to ensure the trench does not become clogged by large sediment and debris. Infiltration trenches improve water quality through:

☑ Treatment of stormwater percolating through soil
☑ Groundwater recharge
☑ Effective removal of light sediment and pollutants

Advantages/Benefits

- Provides WQv for sites with limited space available
- Reduces volume of stormwater runoff and provides peak flow control
- Appropriate for small sites (< 5 acres)
- Provides infiltration, groundwater recharge and filtering pollutants
- Works well with other GMP's in series

Disadvantages/Limitations

- May not be suitable for locations impacting utilities, shallow groundwater, bedrock, sinkholes, buildings/basements, etc.
- Not suitable for steep slopes (>15%)
- Requires pretreatment to prevent clogging
- Potential for groundwater contamination
- Generally not appropriate for large sites (> 5 acres)
- EPA regulations

Application and Site Feasibility

Infiltration trenches are appropriate for use in series with other GMPs. They require a pretreatment device be used to filter large sediment and debris before entering the trench to prevent clogging. Infiltration trenches are applicable for a wide variety of uses such as the perimeter of parking areas or medians between drive lanes. They can also be applicable for sites with limited space available for water quality features.

Physical Requirements

Key physical considerations are:

- Surface dimension vs. depth—if an infiltration trench is designed so that the trench is deeper than it is wide, then it meets the EPA definition of a Class V Injection Well. See the Design Criteria on this page for more information.
- Infiltration—Infiltration trenches should drain in 24 to 48 hours. Native soils shall have an infiltration rate of 0.5 inches per hour or greater.
- Slopes—Slopes affect flow rates, infiltration rates, and erosion.

Design Criteria

The design of an infiltration trench includes several elements to manage stormwater infiltration as well as stormwater conveyance to facilitate water quality improvement and offloading of stormwater runoff volumes into the sewer system. For a summary of design parameters, see Table 18.5.20-A on page 6.

Design criteria to consider includes:

- Location
- Size
- Storage capacity
- Slopes
- Pretreatment
- Native soils
- Storage media
- Overflow
- Observation well
- Erosion prevention
- Mosquito Control
- Maintenance

Location

Since infiltration trenches are retention structures, they are designed to effectively capture stormwater runoff. When finding the most appropriate location for the infiltration trench, it is best to find a location with a small drainage area (approximately less than 5 acres). For larger drainage areas, it is recommended that more than one infiltration trench or another GMP be established in series.

An improved sinkhole can be considered a Class V Injection Well by the EPA (Photo: Sabak, Wilson and Lingo)

These structures should be built where the groundwater table is at least 4 feet lower than the lowest point of the infiltration trench to promote affective infiltration. Areas with heavy sediment flow or a significant pollutant load are not suitable locations for infiltration trenches because the aggregate may become clogged or the groundwater contaminated. In addition, infiltration trenches should be placed at least 10 feet from building foundations and underground utilities. See Figures 18.5.20-C & D for typical infiltration trench design layouts.

Size

Infiltration trenches are generally long, narrow stormwater quality features that capture stormwater. However, an infiltration trench can be classified as a Class V Injection well by the EPA if it meets the following criteria (see the Class V wells page at www.epa.gov):

- "A bored, drilled, or driven shaft, or a dug hole that is deeper than it is wide,"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system."

If the infiltration trench designed meets any of the above criteria, all applicable EPA regulations should be followed. Other terms including well, injection well, improved sinkhole or drywell will trigger requirements by the EPA.

The surface storage parameter should be designed to retain/ capture the volume produced by the rainfall events specified in Table 18.5.20-A on page 6. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. Ponding depth should be limited to 6 inches or less. An overflow feature should be installed to move excess water during a large storm event or in case of clogging.

Sizing of the infiltration trench is based on the volume provided by the porosity of the media in the trench and in the ponding above the trench media. The volume should at least be equal to the WQv. See Table 18.5.20-A on page 6 for the WQv formulas.

Storage Capacity

Infiltration trenches are designed to detain small storm events while also safely passing large storms with adequate freeboard. Infiltration trenches in the medians between the roadway should have an adequate overflow system and maintain adequate freeboard to avoid flooding or overtopping the pavement

Slopes

Site topography should be considered in infiltration trench design. Typically, natural slopes of areas providing stromwater drainage flow to the infiltration trench should be less than 15%. This prevents excessive scouring of the vegetated area due to high velocities from the stormwater inflow. See Figure 18.5.20-B for a typical profile of an infiltration trench.

Pretreatment

Pretreatment should be used for all applications to prevent clogging and ease maintenance, especially in land use areas with high sediment loads. The use of a forebay, level spreader, or vegetated strip at the inlet facilitates maintenance and removal of accumulated sediment.

Native Soils

Infiltration trenches typically contain no outlet structure. The native soils underneath the trench should have an infiltration rate of 0.5 inches per hour or greater and should be designed to drain in 24 to 48 hours. Should the infiltration trench have in-situ soils that are Hydrologic Soils Group A or field determined to be equivalent, then the infiltration ability of the soils can be factored into the sizing of the infiltration trench. Modeling and analysis showing how a smaller infiltration trench can manage the required WQv can be prepared by the design professional and submitted to MSD for review and concurrence.

Storage Media

Infiltration trenches should be installed using a washed aggregate, pea gravel, sand, and filter fabric. A 6 inch to 12 inch layer of sand should be installed on the bottom of the trench to promote infiltration and to prevent compaction of the native soils. Filter fabric can also be installed on the sides of the trench to aid in compaction of the native soils. A 6 inch to 12 inch layer of pea gravel as the top layer of the trench will help to filter large sediment and debris before it enters the storage layer. See Figure 18.5.20-A on page 1.

Overflow

A high flow bypass or diversion structure should be included to safely convey high flows from large storm events. This may be achieved by installing a vegetated berm around the perimeter of the trench or by designing the trench so the overflow flows downhill. The planning and

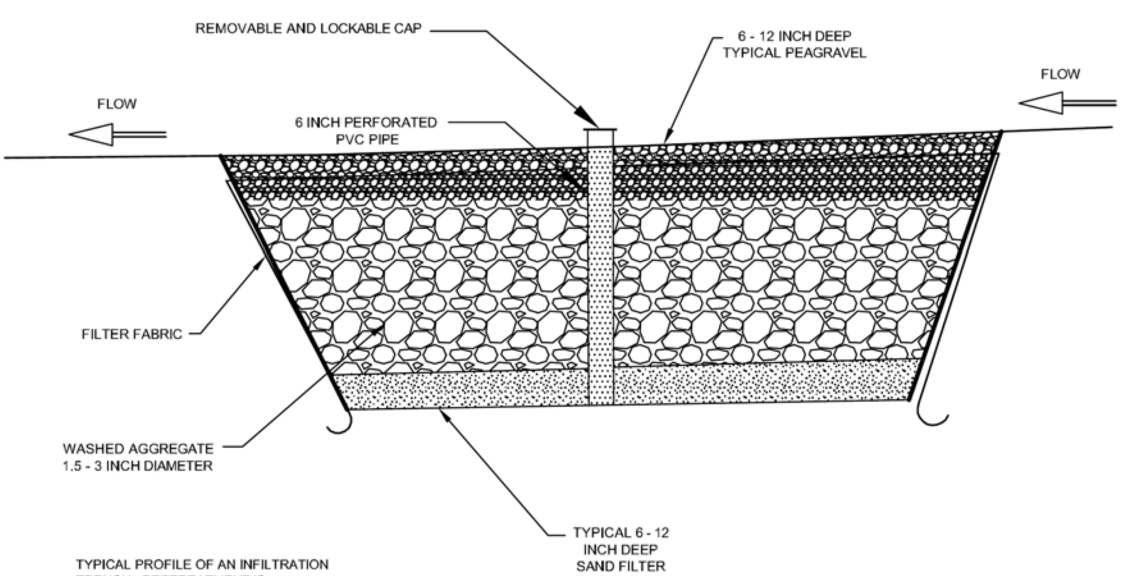

Figure 18.5.20-B. Typical profile of an infiltration trench

installation of the high flow bypass or diversion structure will be largely based on each site design.

Observation Well

An observation well should be installed in the center of the trench to monitor the water level of the trench and check for clogging. The observation well should be a 6-inch perforated PVC pipe with a removable and lockable cap.

Erosion Prevention

Infiltration trenches receiving stormwater by means of sheet flow through a vegetated area may require the use of level spreaders, turf reinforcement mats, or other enhanced erosion protection. This may be necessary in locations of concentrated flow or to protect against high stormwater velocities produced by large storm events. Mat selection should be based upon anticipated flow velocities, vegetation planting requirements, and longevity needs.

Mosquito Control

By their design, infiltration trenches are not in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining infiltration trench, the chances of providing mosquito habitat are virtually eliminated. If the infiltration trench holds enough water for mosquitoes to successfully breed, there is a problem with the aggregate or overflow structure that should be addressed.

Maintenance

Maintenance is a key component to long-term stormwater management effectiveness of GMPs. See Chapter 18.7 Operation & Maintenance for maintenance activities and schedules specific to each GMP.

Treatment Trains—Combination and Location in Series With Other GMPs

Infiltration trenches can be located in series with other GMPs such as green roofs, forebays, or vegetated swales to prevent clogging as well as supplement erosion prevention sediment control and infiltration.

Educational Awareness

The difference between infiltration trenches and traditional areas with landscaped stone may not be visible to the general public. It is important that those maintaining the infiltration trenches, as well as the public, including customers, visitors or staff understand that its features move beyond aesthetic landscaping to manage and treat stormwater. At a minimum, signage and edging should be used to delineate the infiltration trench and its pretreatment features. Signage should include awareness information that the infiltration trench and its surrounding pretreatment is for purposes of carrying and treating stormwater runoff. Raised edging can help to delineate the infiltration trench from surrounding landscape, however care should be taken to ensure edging does not inhibit the flow of drainage into the infiltration trench. For information on educational credits, see MSD's Stormwater User Fee Credits Program.

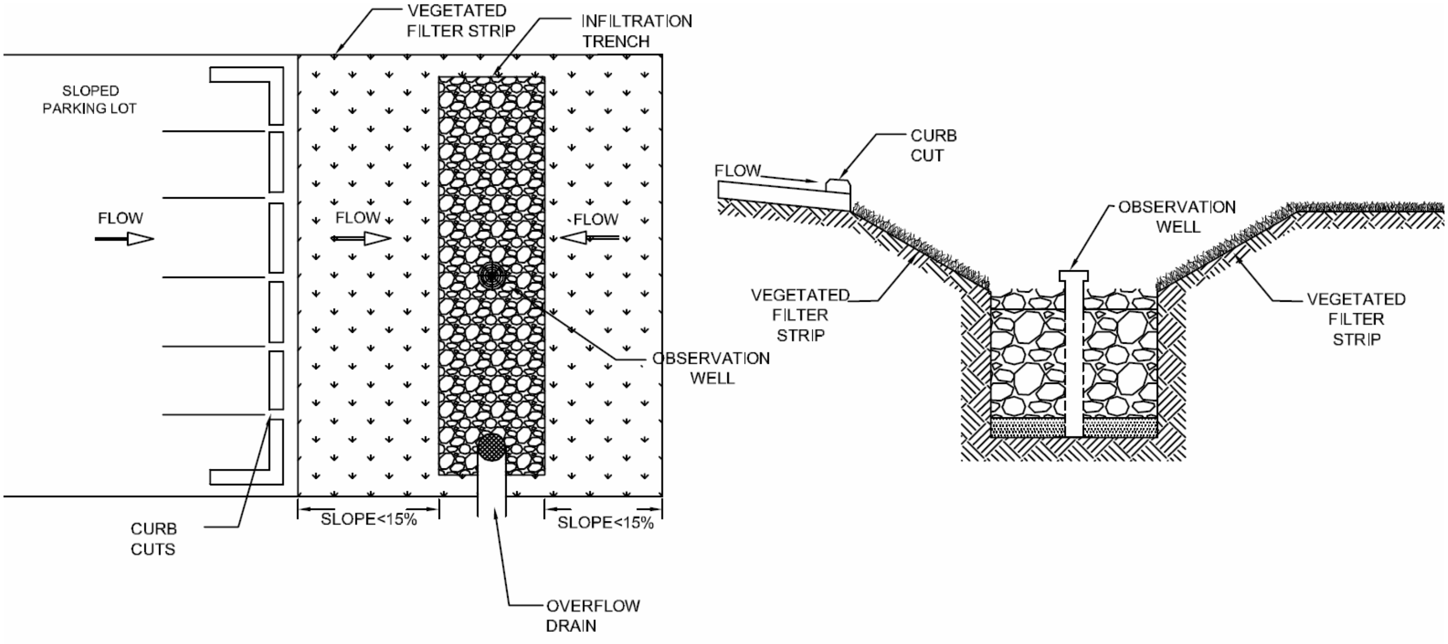

Figure 18.5.20-C. Plan and cross-sectional view schematic of typical implementation of an infiltration trench accepting parking lot runoff

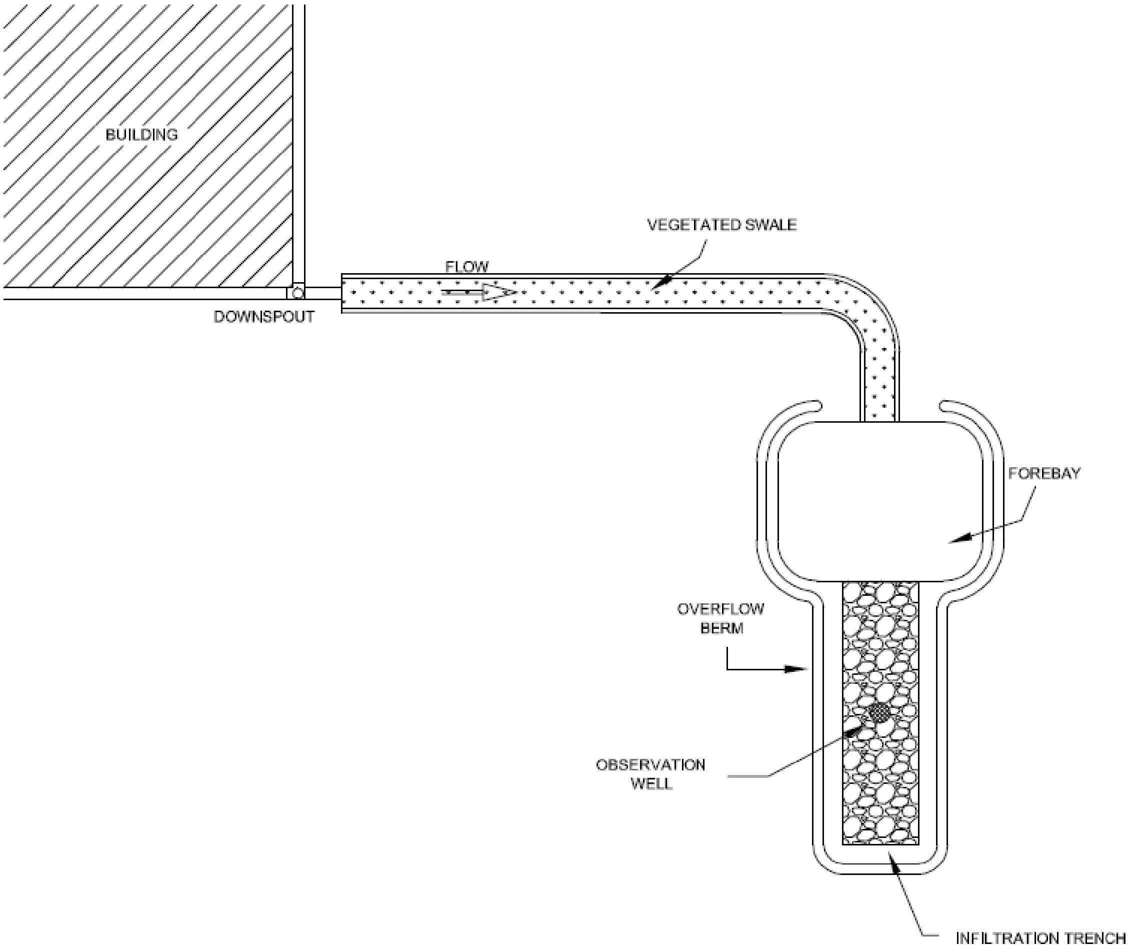

Figure 18.5.20-D. Schematic of a typical implementation of an infiltration trench accepting rooftop drainage

Infiltration Trenches Application and Site Feasibility Criteria Chart

Table 18.5.20-A.

Design Parameter	Criteria
Size (Area & Depth)	The minimum surface area of the infiltration trench should be determined based upon the design storage capacity and the following equation: A = (WQv)/[d(P)+h], where A = surface area of the ponding area of the infiltration trench (ft^2) WQv = required WQv (ft^3) d = depth of infiltration trench (ft) P = porosity of the media in the infiltration trench (% void) h = the average height of water above the infiltration trench during the WQv rain event (ft) If the infiltration trench is deeper than it is wide, then it will fall under the EPA classification of a Class V Injection Well. All applicable EPA regulations should be followed.
Longitudinal Slope	No greater than 15%.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Design Flows and Conveyance Capacity	• Pass the 2- and 10-year, 24-hour storms • Pass the 100-year, 24-hour storm • Meet 6 inches freeboard
Native Soils	Native soils should have an infiltration rate of 0.5 inches per hour or greater. It should be noted that 0.5 inches per hour is the minimum infiltration rate, however higher infiltration rates are recommended.
Pretreatment (optional)	Size pretreatment forebay to hold 10% to 15% of the WQv.
Inlet/Outlet protection	Scour protection required at inlet and discharge point, dependent upon individual designs.
Maximum Drainage Area	Contributing drainage area should be no larger than 5 acres.
Drawdown Time	Dewatering of the rain garden should occur within 24-48 hours.
Storage Capacity	Infiltration trench total volume should be equivalent to the required WQv. Required WQv (ft^3) = ($^1/_{12}$)(RE_{WQV})(Rv)(A) where • RE_{WQV} = required WQv rain event (refer to Chapter 18.3) • Rv = 0.05 + 0.009(I) where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the infiltration trench (ft^2)

Infiltration Trenches Step by Step Design Procedures

Step 1: Define goals/primary function of the infiltration trench

Define the goals/primary function of the infiltration trench. Consider whether the infiltration trench is intended to:

- Meet a regulatory criteria or water quality goal
- Promote infiltration and improve water quality
- Promote infiltration and improve water quality while limiting standing water
- Provide a fix to an excess drainage problem
- Enhance landscape aesthetic qualities

Consider any special site-specific design conditions/criteria. Determine if there are any site restrictions and/or surface water or watershed requirements that may apply. Determine if the infiltration trench will be an improved sinkhole or a subsurface fluid distribution system. If the infiltration trench will be achieving either of these goals, then all applicable EPA regulations will need to be followed for a Class V Injection Well.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the infiltration trench. Since infiltration trenches do not typically contain underdrains, in situ topographic and soil conditions should be considered when planning an infiltration trench.

Step 2: Determine the total runoff volume and infiltration trench footprint

Infiltration trenches should be sized to capture and retain the WQv. To find the WQv in cubic feet, the Storage Capacity equation from the Table 18.5.20-A can be used in this form: WQv (ft3) = $(RE_{WQV})(Rv)(A/12)$. The minimum surface area of the infiltration trench should be determined using the following formula:
$A = (WQv)/[d(P)+h]$ (see Table 18.5.20-A).

Larger storms (2-, 10-, and 100-year) should be modeled to size outlet overflow structures and drainage pipes. For each culvert/drainage area, model or calculate the peak flow rate and total runoff volume for the following storm events:

- Water Quality
- 2-year, 24-hour
- 10-year, 24-hour
- 100-year, 24-hour

Step 3: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of an infiltration trench. Consider Table 18.5.20-A. Create a rough layout of the infiltration trench dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

It may be desired to use pretreatement to reduce flow velocities or facilitate sediment removal, maintenance and clogging of the infiltration trench. A forebay or other pretreatment system is recommended for infiltration trenches. Size the forebay per Table 18.5.20-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations. Splash blocks or level spreaders should be considered to dissipate the concentration of stormwater runoff at the inlet and overflow to prevent scour.

Step 5: Determine infiltration trench parameters

Size bottom width, depth, and length necessary to achieve the WQv per Table 18.5.20-A.

Step 6: Determine overflow location

Consider site specific design considerations when determining the type of overflow system installed. The site topography may dictate the best option for each application.

Step 7: Select erosion control measures

Compare peak flow velocities and water levels calculated for the 2-year to 100-year storm events to maximum permissible velocities for the soil types present at the site and determine the need for erosion control materials. A biodegradable erosion control mat may be needed to limit soil erosion while the vegetation surrounding the trench is becoming established. Choose an erosion control mat or other erosion controls based on the manufacturer's specifications that meet the project requirements.

Inspection Checklist

GMP Post-Construction Checklist

Project Name:	______________________	Contractor:	______________________
Work Order No.:	______________________	Phone Number:	______________________
Street Address:	______________________	Email:	______________________
Inspector:	______________________	Mailing Address:	______________________
Date:	______________________	Date Construction Started:	______________________
Time:	______________________	Date Construction Ended:	______________________
		Phase of Construction:	______________________

Type of GMP(s) Onsite	Check all that apply	Comments/Description
Bioswale	❑	
Rain Garden	❑	
Constructed Wetland	❑	
Wet Basin	❑	
Dry Basin	❑	
Extensive Green Roof	❑	
Intensive Green Roof	❑	
Blue Roof	❑	
Permeable Pavers	❑	
Pervious Concrete	❑	
Porous Asphalt	❑	
Planters	❑	
Tree Boxes	❑	
Rainwater Harvesting	❑	
Vegetated Buffer	❑	
Vegetated Swale	❑	
Underground Storage	❑	
Catch Basin Insert	❑	
Proprietary Water Quality Unit	❑	
Infiltration Trench	❑	

Post-Construction Tasks	Yes	No	N/A	Explanation
1. Are GMP(s) installed according to plans/specifications?	❑	❑	❑	
2. Is the site/GMP(s) in a condition that is accessible for maintenance?	❑	❑	❑	
3. Is the site free of trash/debris upstream of the GMP(s)?	❑	❑	❑	
4. Are inlets/outlets/other structures free of trash/debris?	❑	❑	❑	
5. Is the site free of excessive erosion upstream of the GMP(s)?	❑	❑	❑	
6. Is signage (no mow, safety, etc.) installed as needed/designed?	❑	❑	❑	
7. Is the area in and around the GMP(s) free of erosion?	❑	❑	❑	

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.7 Operation & Maintenance

Weeding and maintenance of a rain garden.
(Photo: Louisville & Jefferson County MSD)

Overview of Maintenance Procedures

Routine inspections will help to maintain function of the GMP systems and prevent problems from arising. As most GMP systems are largely affected by the seasonal changes and storms, inspections should typically be conducted at the beginning of each season as well as after significant rain events.

In general the inspection and maintenance of the systems includes:

- Removal of sediment buildup
- Removal of debris from the inflow and outflow points
- Local erosion prevention and sediment control
- Routine inspection of the structural integrity of the GMP to ensure function
- Replacement of filter media (if needed)

In general vegetation maintenance includes:

- Irrigation and weeding during the first few months of planting to ensure species establishment
- Maintenance of the health and abundance of native or cultivar species and plantings;
- Annual mowing, trimming or pruning to prevent woody species growth
- Removal of any invasive species

This section provides detailed operation and maintenance procedures for each GMP.

Bioswales

Bioswale maintenance will primarily consist of routine inspections of the drainage surface to remove debris, obstructions or sediment buildup; repair of erosion or other surface damage; replacement and care of plant materials; removal of invasive, non-native plants; and regular irrigation during dry periods. Inspections and repairs should be scheduled prior to the first seasonal rains as well as during and after each major storm to ensure proper function of the bioswale and prevent possible flooding, sediment buildup and erosion.

In addition to these general maintenance procedures, the bioswale should be trimmed every year or two to prevent woody species from establishing. Mowing or cutting the vegetation usually reduces evapotranspiration and therefore reduces the amount of pollutant uptake, so this should be done minimally. If the bioswale is built in an area that receives heavy stormwater runoff consisting of chemical fertilizers, chemical pesticides and/or oil and grease from cars, plant clippings may need to be disposed of at a land fill rather than composted.

For the Bioswales Maintenance Schedule, see Table 18.7-A on the next page.

Inspect plant health and replace as necessary (Photo: Louisville & Jefferson County MSD)

"No Mow" maintenance signs installed at a bioretention cell in Louisville Metro Parks (Photo: Louisville & Jefferson County MSD)

Rain Gardens

Maintenance should be routinely conducted to ensure that the area is functioning properly. Initially, the landscape may require more intensive maintenance to ensure proper species establishment and function, but will require less maintenance over time. Maintenance of the system will primarily consist of monthly inspections of the soil; removal of accumulated debris or sediment buildup; erosion repair; watering of the garden during periods with no rain, replacement of dead or diseased vegetation; and weeding of invasive, non-native species. Plant material should be cut back and removed from the garden during the winter months when plants are dormant. Mulch should be added to the garden every 1-2 years; shredded hardwood mulch is preferred.

After rainstorms, it is important to regularly inspect the cell and make sure that drainage paths are clear and that the pooling water dissipates within 24-48 hours; for well-drained soils, pooling water dissipates over 4-6 hours. Note that water may pool for longer times during the winter and early spring. If the rain garden is not functioning properly, solutions could include aerating or cultivating the soils or repairs to the under drain, as well as inflow and outflow structures.

By their design, rain gardens and bioswales are not in danger of becoming a breeding ground for mosquitoes. It takes 24 to 48 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining rain garden or bioswale, the chances of providing mosquito habitat are virtually eliminated. If the rain garden or bioswale holds enough water for mosquitoes to successfully breed, there is a problem with the soil or outflow structure that should be addressed.

For the Rain Garden Maintenance Schedule, see Table 18.7-A on the next page.

Table 18.7-A. Bioswales & Rain Gardens Maintenance Schedule

Schedule	Activity
Monthly during the growing season	• Prune and control weeds • Remove and replace dead or damaged plants • Mow perimeter areas as needed
Semi-annually in spring and fall	• Remove sediment, trash and debris from inlets/forebays • Inspect inflow points for clogging and remove any sediment • Inspect for erosion, rills or gullies and repair • Herbaceous trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from rain garden to prevent clogging and replace dead plants • Develop/adjust plant maintenance plan for trimming and dividing perennials to prevent overcrowding and stress and to achieve desired aesthetic qualities; remove any non-native, invasive species • Inspect plants for health and signs of stress; if plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe infiltration rates after rain events; rain gardens should drain within 24-48 hours of a storm event • Mulching depth should be inspected and additional mulch added, if necessary • Evaluate areas containing low flow stone or gravel; replace if necessary
2-3 years	• Replace/repair inlets, outlets, scour protection or other structures as needed • Implement plant maintenance plan to trim and divide perennials to prevent overcrowding and stress • If the rain garden is not meeting desired infiltration rates or over time soil has compacted, check soil infiltration rates by performing a percolation test • Re-aerate or replace soil and mulch layers as needed to achieve infiltration rate of 0.5 inches per hour • When removing soil for replacement, take to landfill

Constructed Wetland

Constructed wetlands should be visited monthly and following major storms during the first year after construction. Inspections should evaluate the success of the native plantings, establishment of invasive non-native plants, inlet/outlet conditions and sediment/debris accumulation. Repairs, replacements and maintenance should be conducted as problems arise to maintain the functionality of the wetland. Maintenance will consist of repairs to improve the structural integrity of the outlet and containment edges; erosion and burrow repair; monitoring and removal of debris and sediment buildup with special attention to their effect on water storage capacity; invasive non-native species control; and replacement of native plant material as needed. Visits to the site can be reduced to 4 times per year in the second and third years after establishment.

A high level of quantitative monitoring should occur during the first five years after the wetland is installed to ensure proper function and establishment of the constructed wetland. Monitoring should focus on successful establishment of native wetland plants, water storage capacity and pollutant removal. Sediment markers may be used in the wetland to determine how frequently sediment buildup/debris should be removed. Over time, large wetlands that are heavily loaded will require more frequent monitoring than smaller less loaded wetlands.

Vegetation assessment should be conducted utilizing transect plots that bisect the wetland. Randomly spaced quadrants (square plots, usually 3 ft x 3 ft) should be selected within the wetland and monitored seasonally to determine species composition and concentration. Changes of concern include an increase in the numbers of aggressive non-native species, a decrease in the density of the vegetative cover and signs of disease. Maintenance should also be conducted regularly to enhance natural mosquito control and not allow water to stand more than 24 hours.

For the Constructed Wetland Maintenance Schedule, see Table 18.7-B below.

No mow buffer surrounding wetland at Buechel basin (Photo: Erin Wagoner, URS)

Table 18.7-B. Constructed Wetland Maintenance Schedule

Schedule	Activity
Monthly during the first year after construction	• Remove and replace dead, severely diseased vegetation, or damaged plants • Remove or control weeds and invasive species • Monitor wetland after major storm events to ensure structures are functioning properly and inspect for erosion
Semi-annually in spring and fall	• Inspect inflow points for clogging • Inspect for erosion, rills or gullies along the embankments and repair • Remove fallen, clipped or trimmed plant material from wetland to prevent outlet clogging Harvesting of seasonally dead plant material in the fall may be needed if high nutrient level treatment is desired • Inspect vegetation for health and signs of stress; If plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe water levels to confirm that they are as designed • Mow maintenance access areas around wetland • Maintain signs in "no mow" areas
5 years or as needed	• Remove sediment, trash and debris from inlets/forebays when one-quarter of the forebay volume has been lost
10 plus years	• Monitor sediment accumulation in the wetland cell and remove when one-quarter of the wetland volume has been lost

Green Wet Basin

A wet basin should be inspected at the beginning and end of the rainy season as well as after any storm or heavy rain event. The basin should be maintained for structural stability and proper inflow and outflow discharge. Accumulated sediment and debris should be removed from the basin as well as the inflow area to prevent future clogging during rain events. Overall health and abundance of the native vegetation should be maintained, replacing dead or diseased plants as necessary. In addition, seasonal or yearly management should be conducted to remove or control invasive non-native vegetation from the site as well as to remove woody vegetation from all embankment areas.

Inspection of the buffer zone, downstream of the outflow point, should be conducted regularly to make sure that the wet basin is functioning properly and the outflow is not negatively impacting downstream habitats. This includes inspection for any erosion along the embankment of the basin.

For the Green Wet Basin Maintenance Schedule, see Table 18.7-C below.

Green Dry Basin

The seasonal maintenance of a dry basin consists primarily of the inspection of the inlet and outlet pipes for structural integrity; the clearing of sediment and debris from the inlet and outlet pipes as well as the basin; and the removal of debris from upstream areas to prevent it from washing into the basin. It is important to note that improperly maintained basins can reduce the storage volume of the pond as well as create breeding areas for mosquitoes.

Native vegetation should be maintained seasonally and after large rain events. Maintenance consists of the replacement of dead or diseased plants, replanting of eroded areas and invasive species control. The basin should also be trimmed or burned annually to prevent the growth of woody species.

For the Green Dry Basin Maintenance Schedule, see Table 18.7-C.

Table 18.7-C. Green Wet & Green Dry Basin Maintenance Schedule

Schedule	Activity
Monthly during the first growing season	• Remove and replace dead or damaged plants • Remove or control weeds and invasive species • Inspect for erosion • Water as needed to keep plants alive
Semi-annually in spring and fall	• Inspect inflow/outflow points for clogging • Remove any trash and debris from forebay • Inspect for erosion, rills or gullies along the embankments and repair • Vegetation should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from basin to prevent outlet clogging • If plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Inspect for plant root damage to piping and mammal burrows; remove/repair when discovered • Mow maintenance access areas around green wet/dry basins; for green wet basins, do not mow close the to the water's edge which will discourage the habitation • Observe infiltration rates of the basin to ensure storage volume is being maintained • Clean pond of debris and trash • For dry basins, remove any sediment accumulation
5-10 years	• Remove sediment from inlets/forebays when one-quarter of the forebay volume has been lost
10 plus years	• Monitor sediment accumulation in green wet basins and remove when one-quarter of the green wet basins volume has been lost

Extensive Green Roof

Extensive green roofs will require irrigation or natural precipitation, at least once a week until the plants have fully established. Once the plants have matured, extensive green roofs no longer need to be irrigated except in cases of extreme drought. Weeding the rooftop will follow the same natural pattern- the roof will require regular weeding during the establishment phase and only seasonal weeding thereafter. Vegetation should be monitored seasonally to maintain overall health and plants should be replaced or re-sown as needed. Plants should be fertilized annually or as recommended by the source nursery.

The severe consequences of drainage backups, root punctures and leaks in the waterproofing membrane system make seasonal inspections crucial. Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil. Debris and dead vegetation should be removed along with any woody vegetation.

For the Extensive Green Roof Maintenance Schedule, see Table 18.7-D below.

Remove sediment, trash, weeds and debris (Photo: Louisville & Jefferson County MSD; Concept Rendering: Shea Powell, Dropseed Nursery)

Intensive Green Roof

The increased weight and the addition of more intensive plantings tend to increase the maintenance requirements of intensive green roofs. The same overall maintenance noted for an Extensive Green Roof should be followed, but on a more frequent basis. Plantings will need additional care and maintenance due the increased soil depth and the likelihood of additional invasive plants becoming established.

For the Green Dry Basin Maintenance Schedule, see Table 18.7-D below.

Table 18.7-D. Extensive Green Roof & Intensive Green Roof Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
Semi-annually in spring and fall	• Remove sediment, trash, weeds and debris • Implement landscaping maintenance plan for trimming to achieve desired aesthetic qualities • Inspect landscaping for health and signs of stress • If vegetation begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect underneath roof system • Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil • Observe infiltration rates after rain events; green roof should drain within 24 hours of a storm event
10-25 years	• Remove trees/shrubs and replace with smaller specimen

Blue Roofs

Blue roofs require repair and replacement of piping and other structural features. Piping and weirs around the roof drain should be periodically checked for clogging attributed to sediment build-up and debris or obstructions. It is also important to ensure that the captured water is filtering through the system as designed and that the waterproofing membrane is still functioning properly.

For the Blue Roof Maintenance Schedule, see Table 18.7-E below.

Blue roof adjacent to green roof (Photo: New York City Blue Roof and Green Roof Comparison Study)

Table 18.7-E. Blue Roof Maintenance Schedule

Schedule	Activity
Monthly	• Inspect weirs around roof drains/outlets and any valving for proper operation and remove debris and leaves from the rooftop, especially from around the roof drains, weirs and valving
Semi-annually in spring and fall	• Inspect under roof system for any potential leaks • Check weirs around roof drains and valving for proper operation, including ponding depth and detained water drain time; repair as needed
7 plus years	• Inspect weirs, roof drains and valving for failure; replace as needed

Permeable Pavers

Permeable pavers require the surface be kept clean of organic materials and debris through periodic vacuuming and low-pressure washing. Cleaning should be conducted seasonally with certain sites requiring additional maintenance due to the local conditions and the frequency of storm events. Such cleaning will help to maintain the pavement's flow capacity and restore permeability. After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damage and repaired as needed.

Permeable pavers should be inspected for trash, debris and dirt (Photo: Bethany Shain, URS)

Areas should be routinely inspected for settling and loss of water flow through the system and maintenance should be conducted as problems arise. Regular maintenance should help to prevent these issues.

Vegetation surrounding the pavers will initially require irrigation and weeding until the plants have become established. Once the plants have matured, maintenance can be conducted spring and fall with additional irrigation during periods of extreme drought.

In times of winter snow, permeable pavers can be plowed similarly to any other unpaved road, requiring the blade to be lifted about a half inch above the turf. The use of sand, ash, salt or other deicing products should be avoided, as they will adversely affect all concrete and turf materials.

For the Permeable Pavers Maintenance Schedule, see Table 18.7-F below.

Table 18.7-F. Permeable Pavers Maintenance Schedule

Schedule	Activity
Monthly during the growing season	• Inspect the pavers for trash, debris and dirt • Keep weeds and grass out of the paved area (unless concrete grid pavers are being used) • Mow/trim adjacent vegetation and remove clippings from the area • Visually inspect the pavers after large storms to ensure the overflow drainage system is working • After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damage and repaired as needed
Semi-annually in spring and fall	• Sweep or vacuum the pavers with a street sweeper or street vacuum • If the pavers are installed in an area that is subject to higher than normal amounts of sediment (i.e. an area with large trucks traveling on it daily) it may need to be cleaned more often • Replace any joint material that may have eroded • Observe the system during a rain event • Areas should be routinely inspected for settling and loss of water flow through the system
As needed in winter	• Organic deicers may be used to melt ice and snow • Snow plows may be used when necessary under the following conditions: ♦ The edges of the plow are beveled ♦ The blade of the snow plow is raised 1 to 2 inches ♦ The snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces

Pervious Concrete and Porous Asphalt

Pervious pavements should be observed monthly and between storms to ensure the successful operation of the system. Maintenance activities including vacuuming and jet washing of the pavement surface to remove debris and sediment should be conducted at least annually and more frequently if build-up of runoff material is observed. Upland and adjacent areas should be kept vegetated to reduce erosion and sediment flow onto the pavement area. Pervious pavement is intended for areas of low traffic; heavy traffic use and large vehicles should be prohibited.

Test and observe infiltration on pervious pavements (Photo: Kentucky Concrete Pavement Association)

In winter months, non-toxic, organic deicers are recommended. Potholes in porous asphalt are not common, however small damaged areas can be patched with either a porous or a standard asphalt mix. If the damaged area is greater than 10% of the total area, a repair patch type must be approved by the Engineer.

For the Pervious Concrete and Porous Asphalt Maintenance Schedule, see Table 18.7-G below.

Table 18.7-G. Pervious Concrete and Porous Asphalt Maintenance Schedule

Schedule	Maintenance Activities
Preventative measures	• Keep trucks carrying dirt, mulch or sand off the pavement • Route drainage of surrounding landscaping away from the pervious pavements
As needed	• Potholes and cracks may be patched with traditional methods as long as no more than 10% of the total area is effected
Monthly during the growing season	• Keep the asphalt pavement clear of trash, debris and dirt • Keep weeds and grass out of the paved area • Mow/trim adjacent vegetation and always remove any clippings from the area • Monitor infiltration after large storms to ensure the drainage system is working
Semi-annually in spring and fall	• Sweep or vacuum pavement with a street sweeper or street vacuum • Pavement washing systems and compress units are not recommended for **asphalt pavements**, however clogged pores/voids in **concrete pavements** can be pressure washed • If the pavement is located in an area that is subject to higher than normal amounts of sediment, it may need to be cleaned more often
As needed in winter	• Organic deicers may be used to melt ice and snow (sand and gravel are not permitted for the use of deicing) • Snow plows may be used when necessary if the snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces

Tree Boxes & Planters

Tree boxes and planter boxes should be kept free of debris and trash and periodic cleaning should be conducted to clear the inflow and outflow mechanisms. The vegetation in the boxes will require more intensive maintenance over the first several months after installation, but this demand will decrease as the plants become established. Boxes should be kept free of invasive species and the overall health of the plants should be maintained. If periodic observations indicate a potential presence of contaminants, the soil and mulch in the boxes should be tested to avoid the build-up of pollutants that may harm the vegetation. Any mulch used should be replaced biannually.

Tree boxes require regular irrigation during dry periods. If an under-drain system is used, maintenance of inflow and outflow structures will require periodic inspection and removal of sediment and debris, if necessary. In addition to general maintenance procedures, the tree/shrub should be trimmed or pruned according to an established maintenance plan.

For the Tree Boxes and Planters Maintenance Schedule, see Table 18.7-H below.

Series of tree and planter boxes accept stormwater runoff from a roadway and should drain within 24 hours after the rain event (Photo: David Dods, URS)

Table 18.7-H. Tree Boxes and Planters Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
Semi-annually in spring and fall	• Remove sediment, trash, weeds and debris • Implement vegetation maintenance plan for trimming to achieve desired aesthetic qualities • Inspect vegetation for health and signs of stress • If tree/shrub begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Observe infiltration rates after rain events. The tree box or planter should drain within 24 hours of a storm event • Replace mulching
10-25 years	• Remove tree/shrub and replace with smaller specimen

Rainwater Harvesting

Rainwater harvesting cisterns will require routine maintenance in the spring and fall. Roof downspouts should be disconnected before the first significant freeze and the cistern will need to be drained. Rainwater harvesting cisterns should be drained and removed or kept at half capacity with the spigot open during the winter months to prevent ice damage.

Overall maintenance consists of regular inspection of the unit with replacements and repairs being conducted as needed. In addition, gutters and downspouts should be kept clean and free of leaks. Vegetation receiving the rainwater should be inspected for health and signs of stress and replaced if necessary.

For the Rainwater Harvesting Maintenance Schedule, see Table 18.7-J below.

Three cisterns capture and store excess runoff from rooftop surfaces at the Green Building and are drained between rain events to water the bioswale and rain garden. (Photo: Ted Wathen)

Table 18.7-J. Rainwater Harvesting Maintenance Schedule

Schedule	Activity
Before first significant freeze (late fall)	• Disconnect aboveground cistern from the roof downspouts and direct downspouts to a stabilized, pervious surface • Drain and clean out aboveground cistern
After last significant freeze (early spring)	• Connect cistern to roof downspout
Regularly during the rainwater harvesting season	• Drain harvested rainwater to vegetated, pervious area or utilize beneficially • Inspect health of vegetation receiving harvested rainwater to determine watering needs
Semi-annually in spring and fall	• Remove leaves and debris from grated and screened inlet • Inspect aboveground cistern for tight connections at the inlet and drain valve. • Inspect for erosion around the overflow discharge and repair as necessary • Check for algae growth inside the cistern; if found, treat the water to remove the algae and then coat cistern so sunlight is not allowed to penetrate it • Check pumping systems to ensure it is working properly • Flush piping as necessary and consult the owner's manual or a professional for further troubleshooting.
Annually	• Check accumulated sediment and remove when it is more than 5% of the volume of the cistern

Vegetated Buffer & Vegetated Swale

Initially, vegetated buffers and swales should be inspected after rain events to ensure proper draining. They should maintain desired slope, length and width and bare spots or eroded areas should be repaired to ensure they are functioning according to design specifications. Vegetation should be mowed regularly according to maintenance plans and "No Mow" areas should be clearly defined. Inspections should consist of replacement and care of plant materials and irrigation during dry periods. Accumulated sediment or other trash and debris should be removed and the buffer should be checked for erosion.

For the Vegetated Buffer and Vegetated Swale Maintenance Schedule, see Table 18.7-K below.

Inspect vegetation for health and signs of stress (Photo: Louisville & Jefferson County MSD)

Table 18.7-K. Vegetated Buffer and Swale Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions • Mow or trim vegetation in accordance with nursery recommendations
Semi-annually in spring and fall during first year and annually thereafter	• Inspect grading of vegetative buffer to ensure sheet flow across the entire buffer length and width • Inspect vegetation for health and signs of stress; if tree/shrub/grass begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect buffer for erosion and bare spots and repair
Following significant rain events (>10 yrs)	• Inspect and repair eroded or damaged areas to maintain sheet flow to and across the vegetative buffer

Catch Basin Inserts

Catch basin inserts will require very frequent sediment removal as their volume is very limited in comparison to the volume of the catch basin sump. It is necessary to routinely remove sediment, trash and debris and to replace the inserts if they are damaged. Inspections of catch basin inserts should be scheduled, at a minimum, prior to the first seasonal rains as well as during and after each major storm event.

The site should also be checked for excessive erosion or sediment flow upstream of the catch basin. It may also be necessary to periodically check the catch basin to ensure stormwater is flowing through the filter system and not bypassing it. In addition to general maintenance procedures, the catch basin inserts should be replaced annually.

For the Catch Basin Insert Maintenance Schedule, see Table 18.7-L below.

Catch basins should be kept free of sediment, trash and debris. (Photo: Dauphin County Conservation District, Pennsylvania)

Table 18.7-L. Catch Basin Inserts Maintenance Schedule

Schedule	Activity
Preventative Measures	• Inflow should flow through the filter system and not bypass it
Regularly	• Inspect catch basin inserts for clogging and remove sediment, trash or debris
Semi-annually in spring and fall	• Visit site to ensure there is not excessive erosion or sediment flow upstream of the catch basin insert
Annually	• Replace catch basin inserts

Proprietary Water Quality Units & Underground Storage

Proprietary water quality units and underground detention should be inspected seasonally and after major storm events or per manufacturer's recommendations to ensure proper function. Manufacturer's guidelines should be followed and an individual maintenance plan should be developed for all systems based on routine inspections. Maintenance will include pumping and pressure washing the unit and cleaning blockage or sediment buildup with use of vacuum trucks or boom trucks. Drainage areas should be regularly maintained to prevent the flow of trash, sediment and debris into the system. Note that the system may need additional cleaning in the event that a spill of a foreign substance enters the unit. Drainage areas should be regularly maintained to prevent the flow of trash, sediment and debris into the system.

Inspections should be conducted after the first rain event and also after major storms. Repairs to inlets, outlets, control valves or other structures should be performed periodically. Safety and maintenance practices for confined spaces should be followed when appropriate.

For the Proprietary Water Quality Units and Underground Storage Maintenance Schedule, see Table 18.7-M below.

MSD employees use a vacuum truck to cleanout existing structures (Photo: Louisville & Jefferson County MSD)

Table 18.7-M. Proprietary Water Quality Units & Underground Storage Maintenance Schedule

Schedule	Activity
As needed	• Inspect drainage areas for trash, erosion and debris • Perform cleanout if hazardous or foreign substances are spilled in the drainage areas • Repair inlets, outlets, control valves or other structural features as needed • Inspect system after major rain events to ensure it is draining properly
Quarterly	• Inspect system for blockage or sediment buildup and perform cleanout if necessary • Follow manufacturer's guidelines and develop/adjust maintenance plan for the system
Annually	• Perform cleanout of the system with vacuum or boom trucks • Clean any sediment or oil chambers • Inspect inlets, outlets and other structural features; repair as needed

Infiltration Trenches

Infiltration trenches are characterized as having a surface dimension (length or width) greater than their depth and do not have a subsurface fluid distribution system (i.e. below-grade perforated piping to enhance infiltration).

Infiltration trenches will require maintenance inspections at least semi-annually, and more frequently if pre-treatment is not used. It is necessary to check the observation well for clogging on an as needed basis. All pretreatment systems and other structures installed should be routinely checked for clogging. If the pea gravel layer becomes clogged with sediment and debris, it may be necessary to remove the layer and replace it with new pea gravel. It may also be necessary to check the observation well after large storm events to ensure the trench is draining properly. The top of the trench and all pretreatment devices should be cleared of leaves and other debris routinely. It is necessary to mow the area around the pretreatment devices, as well as the perimeter of the trench to clear access for maintenance. If the entire system appears to be clogged with sediment and is no longer functioning properly, this may trigger the removal of the GMP and replacement with unwanted material.

For the Infiltration Trench Maintenance Schedule, see Table 18.7-O below.

Table 18.7-O. Infiltration Trench Maintenance Schedule

Schedule	Activity
As needed	• Monitor the trench and observation well after large rain events and check for any ponding water • Mow or trim the perimeter of the trench and any pretreatment devices; grass clippings should be removed to prevent clogging • Check observation well for clogging
Semi-annually in spring and fall during first year and annually thereafter	• Check pretreatment systems and other structures for clogging; remove sediment and debris as necessary • Inspect the top layer of the trench for ponding water, leaves, grass clippings or other debris • Inspect any piping or other structural devices for damage; replace as necessary
Upon Failure	• If the entire system becomes clogged, remove and install clean, washed trench aggregate; • it may also be necessary to replace piping, filter fabric, etc.

Maintenance Inspection Checklist

Site License Number:	______	Maintenance Contact Person:	______
Date/Time	______	Phone Number:	______
Street Address of Site:	______	Email:	______
Inspector:	______	Mailing Address:	______
Site Description:	______	Schedule for Maintenance:	______

Type of GMP(s) Onsite	Check all that apply	Comments/Description
Bioswale	❑	
Rain Garden	❑	
Constructed Wetland	❑	
Wet Basin	❑	
Dry Basin	❑	
Extensive Green Roof	❑	
Intensive Green Roof	❑	
Blue Roof	❑	
Permeable Pavers	❑	
Pervious Concrete	❑	
Porous Asphalt	❑	
Planters	❑	
Tree Boxes	❑	
Rainwater Harvesting	❑	
Vegetated Buffer	❑	
Vegetated Swale	❑	
Underground Storage	❑	
Catch Basin Insert	❑	
Proprietary Water Quality Unit	❑	
Infiltration Trench	❑	

Post-Construction Tasks	Yes	No	N/A	Explanation
1. Do all GMP(s) on-site appear to be functioning?	❑	❑	❑	
2. Is the site/GMP(s) in a condition that is accessible for maintenance?	❑	❑	❑	
3. Is the site free of trash/debris/erosion upstream of the GMP(s)?	❑	❑	❑	
4. Is the area in and around the GMP(s) free of erosion?	❑	❑	❑	
5. Are water levels as designed (i.e. wet basin, constructed wetland, etc.) or is the area free of standing water as designed (i.e. tree boxes, dry basins, etc.)?	❑	❑	❑	
6. Is the mulch/stone/gravel evenly distributed and is the depth of mulch/stone/gravel sufficient?	❑	❑	❑	
7. Are inlets/outlets/forebays/other structures free of trash/debris?	❑	❑	❑	
8. Is the site free of bare/exposed soil?	❑	❑	❑	
9. Are inlets/outlets/other structures in proper working condition and not in need of repair?	❑	❑	❑	
10. Is the overflow drainage system functioning properly?	❑	❑	❑	
11. Is scour protection, rip rap, etc. functioning properly?	❑	❑	❑	
19. Is the area free of evidence of animal burrows?	❑	❑	❑	
12. Are level spreaders, check dams, etc. in proper working condition?	❑	❑	❑	

Post-Construction Tasks	Yes	No	N/A	Explanation
13. Have plants been pruned/weeded and is the area free of fallen, clipped and trimmed plant material?	❑	❑	❑	
14. Have dead or damaged plants been removed and replaced and is the planted area free of invasive plants?	❑	❑	❑	
15. Has the plant maintenance plan been adjusted, if necessary?	❑	❑	❑	
16. Does the slope of the GMP(s) or the grade of the area draining to the GMP(s) still meet the desired purpose? (i.e. sheet flow, positive drainage, etc.)	❑	❑	❑	
17. Does the top layer of the infiltration trench appear to be free of sediment and debris?	❑	❑	❑	
18. Are the gutters free of leaves and other debris as applicable?	❑	❑	❑	
20. Does the forebay/wetland/wet basin have less than one quarter of the volume filled with sediment?	❑	❑	❑	
21. Is pervious pavement free of trash/debris/dirt/weeds/grass as applicable?	❑	❑	❑	
22. For pervious pavement, is adjacent vegetation free of grass clippings or other debris?	❑	❑	❑	
23. For pervious pavements, is the joint material in good condition?	❑	❑	❑	
24. For rainwater harvesting cisterns, are grated and screened inlets free of leaves and other debris?	❑	❑	❑	
25. For rainwater harvesting cisterns, are there tight connections at the inlet and drain valve?	❑	❑	❑	
26. For rainwater harvesting cisterns, is the pumping system working properly?	❑	❑	❑	
27. Is the rainwater harvesting cistern free of algal growth inside the cistern?	❑	❑	❑	
28. Is the accumlated sediment in the rainwater harvesting cistern less than 5% of the volume of the cistern?	❑	❑	❑	
29. For catch basin inserts, does the inflow flow through the filter system and not bypass it?	❑	❑	❑	
30. Are catch basin inserts unclogged and free of sediment, trash and other debris?	❑	❑	❑	
31. Is the roof system free of any leaks underneath the rain garden or blue roof?	❑	❑	❑	
32. Are weirs around roof drains operating properly?	❑	❑	❑	

33. Do you recommend approval of GMP(s) assessed on-site?	❑ Yes	❑ No
If **yes**, retain stormwater credit?	Full amount ❑ ________	Partial amount ❑ _________
If **no**, explain why:		

Acronyms

ASTM	American Society of Testing and Materials
BMP	Best Management Practice
CBR	California Bearing Ratio
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EPSC	Erosion Prevention & Sediment Control
ESAL	Equivalent Single Axle Load
FEMA	Federal Emergency Management Agency
Fps	Feet per second
GMP	Green Management Practice
H:V	Horizontal: Vertical
I/I	Inflow and Infiltration
IOAP	Integrated Overflow Abatement Plan
KAR	Kentucky Administrative Regulations
KDEP	Kentucky Department of Environmental Protection
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
KRS	Kentucky Revised Statutes
KYTC	Kentucky Transportation Cabinet
LEED	Leadership in Energy and Environmental Design
LF	Linear Feet
LOJIC	Louisville Jefferson County Information Consortium
MEP	Maximum Extent Practicable
mg/L	Milligrams per Liter
MS4	Municipal Separate Storm Sewer System
MSD	Metropolitan Sewer District
MWQv	Managed Water Quality Volume
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
O&M	Operation & Maintenance
PE	Professional Engineer
PIO	Public Information and Outreach
PLS	Pure Live Seed
PVC	Polyvinyl Chloride
RE_{WQV}	Required Water Quality Volume Rain Event
ROW	Right-of-way
RRV Capacity	Runoff Reduction Volume Capacity
RWQv	Remaining Water Quality Volume
SSO	Sanitary Sewer Overflow
SSS	Sanitary Sewer System
SWPPP	Stormwater Pollution Prevention Plan
SWQMP	Stormwater Quality Management Plan
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
WQv	Water Quality Volume

Definitions

Aquatic bench	Shallow areas around the edge of a wet basin that sustains vegetation and that provide water quality benefits.
Beneficially Used	Utilizing stormwater runoff for vegetative irrigation or non-potable uses; not allowing stormwater runoff to directly discharge onto impervious surfaces and into pipes and culverts.
Best Management Practice (BMP)	Schedules of activities, prohibitions of practices, treatment requirements, operating procedures, and other various protocols used to prevent or reduce the discharge of pollutants to the waters of the United States.
Bioaccumulation	The uptake of toxic substances, including pesticides and absorbs the toxic substance at a rate greater than it is lost.
Bioswale	Stormwater conveyance features that mimic ecological function of a landscape, often serving as replacements to open ditches or underground pipes.
Blue Roof	A stormwater management practice that detains 1 to 4 inches of rainfall in the roof and slowly releasing the water to a storm sewer system generally over a 24 hour period.
Buffer Strip	Undisturbed natural areas that treat stormwater runoff.
Catch Basin Inserts	Space saving devices installed underneath the grate of an inlet to remove sediment, debris, oils or metal from stormwater inflow.
Channel Stabilization	Erosion prevention and stabilization of velocity distribution in a channel using drops, revetments, vegetation and other measures.
Check Dams	Small dam built across minor channels, swales, bioswales, or drainage ditches; used to reduce erosion and allow pollutants/sediments to settle.
Choker Course	Aggregate layer placed above the base layer in permeable pavement design for leveling of the surface material.
Cisterns	A permanent structure typically having a volume over 100 gallons and can be placed aboveground or belowground.
Class V Injection Well	Defined by EPA as a bored, drilled or driven shaft or a dug hole that is deeper than it is wide, an improved sinkhole or a subsurface fluid distribution system.
Clean Water Act	An act by which congress mandated that the EPA address non-point source pollution in stormwater runoff.
Combined Sewer Overflow	An outfall which MSD is authorized to discharge during wet weather, as defined by MSD's KPDES permit for the Morris Forman WWTP.
Combined Sewer System	The portion of MSD's Sewer System designed to convey municipal sewage (domestic, commercial, and industrial wastewaters) and stormwater runoff through a single-pipe system to MSD's Morris Forman WWTP or CSOs.
Compost	Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.
Consent Decree	Judicial decree expressing a voluntary agreement between parties to a suit; often an agreement by a defendant to cease illegal activities in exchange for an end to criminal charges.
Conservation Subdivision	An alternative to conventional subdivision adopted by the Louisville Metro Planning Commission and Louisville Metro Council, to balance residential development open space conservation and natural resource protection.
Constructed Wetland	Stormwater management practices that are generally shallow, except for pool areas and contain dense native aquatic vegetation. Constructed wetlands temporarily store storm-

	water runoff, treat pollutants and create habitat.
CSS Sewersheds	Drainage area of man-made sewers and storm drains.
Cultivars	A plant cultivated for its desirable characteristics and often used in ornamental or land-scaped gardens.
Design Life	The period of time for which a facility is expected to perform its intended function.
Detention	Managing stormwater runoff or sewer flows through a temporary holding and controlled release.
Dry Well	See Class V Injection Well.
Emergency Spillway	Gates or structures that regulate the passage of flood flows around the dam or containment structure.
Energy Dissipater	A mechanism to break up and slow the flow of water.
Erosion	Detachment and movement of soil or rock fragments by water, wind, ice or gravity.
Evapotranspiration	The combined loss of water from a given area and during a specific period of time, by evaporation from the soil and by transpiration from plants.
Excess Rainfall	Direct runoff at the place where it originates.
Extensive Green Roof	A stormwater management practice comprised of a roofing system consisting of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive roofs have soil depths of six inches or less that is designed to support dense, low growing, drought tolerant vegetation.
Filter Fabric	A woven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.
Filter Strip	See Vegetated Buffer.
First flush	The first portion of runoff generated by rainfall event and containing the main portion of the pollutant load resulting from the storm.
Floatable	A type of litter pollution that floats on the surface of stormwater, typically bottles, cans, styrofoam containers or other trash.
Flood Peak	The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.
Forebay	A manmade pool of water in front of a larger body of water, often used for flood control.
Foundation Drain	A pipe or series of pipes which collects groundwater from the foundation or footing of structures and discharges this water into sewers or other points of disposal.
Freeboard	A vertical distance between the elevation of the design high water and the top of a dam, levee or diversion ridge.
Frost Heave	Uplift of soil or pavement surface due to expansion of groundwater upon freezing.
Geogrid	Manufactured soil reinforcement products that stabilize subsurface conditions through a multi-directional load distribution grid.
Gray Infrastructure	Constructed structures such as treatment facilities, sewer systems, stormwater systems, or storage basins. The term "gray" refers to the fact that such structures are typically made of, or involve the use of concrete.
Gray Infrastructure	Constructed structures such as treatment facilities, stormwater systems, storage basins, sewer systems, etc. "Gray" referencing that most of these structures are made from concrete.

Green Dry Basin	Stormwater management practices that are similar to standard dry basins, except that they contain a forebay for capturing the heavier sedient and floatables, non-turf frass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm evetns and no low flow channel so sheet flow can be promoted. Water quality benefits include uptake and filtering through deep rooted, native plants; sediment settling; temporary stormwater detention; and a slower rate of release.
Green Infrastructure	An adaptable term used to describe an array of materials, technologies, and practices that use natural systems—or engineered systems that mimic natural processes— to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. Examples of green infrastructure include green roofs, porous pavement, rain gardens, and vegetated swales.
Green Management Practice (GMP)	Term used to describe best management practices within green infrastructure.
Green Wet Basins	Stormwater management practices that are similar to standard wet basins, except that they contain an aquatic bench along the perimeter of the pond just below the normal pool level and possibly other plantings above the normal pool elevation in the extended portion of the basin. The aquatice benches provide water quality benefits.
Greenway Trails	Multi-use paths or trails constructed for pedestrian and/or bicycle traffic and recreational use often through scenic natural areas or along waterways and connect neighborhoods with parks, schools and recreational areas.
Hardscape	Areas where the upper soil profile is no longer exposed to the actual surface of the Earth (e.g., paved areas, business complexes and housing developments, industrial areas).
Heat Island Effect	Causes an area to be consistently warmer than its surrounding rural area, often due to urban development. Affects communities by increasing energy demand, air pollution, and water quality.
Hotspots	A land use or activity that generates higher concentrations of pollutants including but not limited to hydrocarbons, sediments, and trace metals that are found in stormwater near the land use.
Impaired Waters	Surface water that is negatively impacted by pollution, resulting in decreased water quality. Kentucky Division of Water publishes impaired waters in its 303(d) list.
Impervious surface	Surfaces that do not allow water to permeate or infiltrate through the material, such as paved roadways, sidewalks, rooftops, etc.
Incentives Policy	Louisville & Jefferson County's Rates, Rentals and Charges Policy, also refered to as the Stormwater User Fee Credits Program, includes financial incentives to encourage commercial, industrial and institutional property owners to implement green infrastruture as a way to manage the stormwater runoff generated by impervious surfaces on their property.
Infiltration	Groundwater that enters a wastewater system through such means as defects in pipes, pipe joints, connections, or manholes.
Infiltration Rate	A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions including the presence of an excess of water.
Infiltration Trenches	Shallow, excavated areas that receive stormwater that are typically filled with aggregate and contain no outlet structure.
Inlet	Narrow body of water between islands or leading inland from a larger body of water, often leading to an enclosed body of water.
Intensive Green Roof	A stormwater management practice comprised of a waterproof layer, drainage system, engi-

neered soils and vegetation. Intensive green roofs have soil depths greater that six inches to support the root growth of larger vegetation, including: plants, shrubs and trees.

Invasive Species — A non-native species that adversely affect the habitats that they invade by disrupting the natural balance of the habitat either by dominating resources, habitat or native species.

KAR — Administrative regulations published by the Kentucky Legislative Commission. An unofficial posting of the KAR is available via the Commission's website at www.lrc.ky.gov.

Kentucky Pollutant Discharge Elimination System Permit — Any National Pollutant Discharge Elimination System permit issued to MSD by the Cabinet pursuant to the authority of the Clean Water Act and Kentucky Revised Statues (KRS) Chapter 224 and the regulations promulgated thereunder..

Leadership in Energy and Environmental Design (LEED) — A rating system that is administered by the US Green Building Council (USGBC) and is currently the most accepted benchmark for the design, construction, and operation of high performance green buildings and neighborhood developments in the U.S. The five key areas include sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.

Louisville and Jefferson County Metropolitan Sewer District — The agency responsible for providing wastewater, stormwater, and flood protection services in Jefferson County. MSD is also responsible for response, mitigation, notification, and reporting of overflows, including unauthorized discharges.

MS4 Program — Municipal Separate Storm Sewer System; operated by MSD in Anchorage, Jeffersontown, St. Matthews and Shively, as well as operated by the Kentucky Transportation Cabinet.

Mulch — A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover and minimizes temperature fluctuations.

National Pollutant Discharge Elimination System — A national program under the Clean Water Act that regulates discharges of pollutants from point sources to Waters of the United States. Discharges are illegal unless authorized by an NPDES permit.

Nonpoint Source Pollution — The EPA defines this term as any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground and carrying with it pollutants that are eventually deposited in lakes, rivers, wetlands, coastal waters and ground water.

Nutrients — A type of water contamination including nitrogen and phosphorous that degrades waterways. Excess nitrogen and phosphorous lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that make people sick.

Outfall — The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.

Outlet — The mouth of a waterway, where water flows into a larger body of water.

Overflow — Any release of wastewater from MSD's sanitary or combined sewer system at locations not specified in any KPDES permit. This includes any Unauthorized Discharge and releases to public or private property that do not reach Waters of the United States, such as basement backups. However, wastewater backups into buildings caused by blockages, flow conditions, or malfunctions in a building lateral, other piping or conveyance system that is not owned or operationally controlled by MSD are not overflows for the purposes of the IOAP.

Overland Flow — Surface runoff that occurs when soil is saturated and excess water from rain or snowmelt flows over the land.

Pathogen	An organism capable of causing disease, including disease-causing bacteria, protozoa, and viruses.
Peak Flow	The maximum flow that occurs over a specific length of time (e.g., daily, hourly, instantaneous).
Permeable Pavers	Pavement surfaces that promote infiltration of stormwater that consist of individual concrete or stone shapes that are placed adjacent to one another over a sub-base.
Permeable/Pervious/Porous	Allows water to pass through.
Pervious Concrete	A permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and base layers.
Phosphorus	Phosphorous pollution is a type of nutrient pollution that causes degradation of waterways. See Nutrients.
Planters	Are similar to rain gardens and bioretention basins in that they detain, filter and infiltrate stormwater; nad are suitable for plants ranging from native flowers to shrubs or small trees. They are most commonly used as infiltration of stormwater runoff from rooftop downspouts.
Pollutants of Concern	Pollutants that are identified as current and/or future problems for local waterways. This list will be re-evaluated as monitoring data becomes available and conditions change. Factors to consider when listing a pollutant of concern include potential violation NPDES permit violation, pollutants that pose a threat to local waterways, potential pollutant impact on human health. Any pollutant that has been documented via analytical data as a cause of impairment in any waterbody.
Porous Asphalt	A permeable pavement that allowes the water to infiltrate into the subsoil through the pavement surface and stone reservoir.
Pretreatment	The process of wastewater traveling through municipal wastewater treatment plants before exiting into waterways or water bodies, reducing water pollutants.
Proprietary Water Quality Units	Space effective stormwater management structures that typically underground treatment systems installed at inlet structures.
Rain Garden	A stormwater management practice, sometimes referred to as bioretention cells, bioinfiltration cells, or biofiltration cells which are shallow stormwater basins that mimic the ecological funtions of a natural landscape. Rain gardens contain deep rooted vegetation or cultivar species to filter and infiltrate stormwater.
Rainwater Harvesting	the practice of collecting and temporarily storing rainwater.
Reasonable Engineering	As a legal term of art, this is the statutory and regulatory standard for judgment evaluating engineering practices.
Recharge	Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.
Required Water Quality Volume	This is the third step in the GMP selection process. During this step, the volume for treating the water quality rain event is calculated.
Required Water Quality Volume Rain Event	This is the second step in the GMP selection process. During this step, the rain event for calculating the water quality volume for the site is selected. RE_{WQV} depends on the location of the project site. If the project site is in the Combined Sewers System, then the 92 percentile storm (1.00") is used. If the project site is in the MS4 area, then the 80 percentile storm (0.60") is used.
Retrofit	Refers to the addition of new technology or features to older systems.
Riparian Areas	Ecosystems that occur along waterways or bodies of water.

Sanitary Sewer	A pipe or conduit (sewer) intended to carry wastewater or water-borne wastes. from homes, businesses, and industries to the publicly owned treatment works.
Sanitary Sewer Overflow	Any discharge of wastewater to waters of the United States from MSD's Sewer System through a point source not authorized by a KPDES permit, as well as any release of wastewater from MSD's Sewer System to public or private property that does not reach Waters of the United States, such as a release to a land surface or structure that does not reach Waters of the United States; provided, however, that releases or wastewater backups into buildings that are caused by blockages, flow conditions, or malfunctions in a building lateral, or in other piping or conveyance system that is not owned or operationally controlled by MSD are not SSOs.
Sanitary System	The portion of MSD's sewer system designed to convey only municipal sewage (domestic, commercial, and industrial wastewaters) to MSD's WWTPs.
Sensitive Areas	Areas of particular environmental significance or sensitivity as determined by the KPDES permitting authority in coordination with State and Federal agencies, that include Outstanding National Resources Waters, waters with threatened or endangered species and their habitats, waters with primary contract recreation, public drinking water intakes or their designated protection areas.
Sewer System	The wastewater collection, retention, and transmission system that MSD owns or operates, that are designed to collect, retain and convey municipal sewage (domestic, commercial and industrial wastewaters) to MSD's WWTPs or CSOs which is comprised of the CSS and the SSS.
Slope	Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plan with a 90 degree slope being vertical (maximum) and a 45 degree being a 1:1 or 100 percent slope.
Spillway	See Emergency Spillway.
Stormwater	Water runoff that is a result of natural precipitation.
Stormwater Pollution Prevention Plan	A plan for stormwater discharge that when implemented will decrease stormwater discharge.
Stormwater Quality Management Program	All activities undertaken that improve the quality of stormwater runoff into the waters of Louisville Metro.
Stream	Surface water channel having well-defined banks and bed, either constantly or intermittently flowing. "Ephemeral stream" means a watercourse which only flows in direct response to precipitation in the immediate watershed, or in response to the melting of a cover of snow and ice, and which has a channel bottom that is above the local water table. An ephemeral stream is a water of the United States, provided it has an OHWM. "Intermittent stream" means a steam or part of a stream that does not flow continuously throughout the calendar year; but that has a bed below the local water table for at least one (1) month of the calendar year during which it obtains its flow from both surface water and ground water discharge. The term does not include an ephemeral stream. "Perennial stream" means a stream or part of a stream that flows continuously during all of the calendar year as a result of ground-water discharge or surface runoff. The term does not include "intermittent stream" or "ephemeral stream".
Surface Waters	Those waters having well-defined banks and beds, either constantly or intermittently flowing; lakes and impounded waters; marshes and wetlands; and any subterranean waters flowing in well-defined channels and having a demonstrable hydrologic connection with the surface.

Total Dissolved Solids	The fine particles that are suspended in water as measured by a laboratory analysis. TDS are typically small enough to pass through a sieve size of two micrometers.
Total Maximum Daily Load	A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.
Treatment Train	The use of multiple GMPs in series on a site to meet the water quality volume requirement for stormwater management.
Tree Box	provides similar benefits as a rain garden/bioretention basin in its design purpose and stormwater benefits by infiltrating, treatment, temporary detention, and biological uptake using trees and tall bushes.
Turbidity	The cloudiness of a fluid caused by microscopic particles suspended in the fluid.
Underdrain Surface	A series of pipes that run longitudinal with pavers that can be used to capture and reuse storwmater runoff; or to reach the desired porosity.
Underground Storage	The practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures with the intent of releasing the stormwater runoff to the surface drainage system at a reduced rate and completely drained prior to the next rain event, similar to a green dry detention pond.
United States Army Corps of Engineers	A branch of the US Government, made up of civilians and military members with a wide diversity of disciplines. From biologists, engineers, geologists, hydrologists, natural resource managers, to other professionals needed within this entity. The Corps plans, designs, builds, operates, and regulates water resources projects that are crucial to the citizens of the United States.
United States Environmental Protection Agency	The federal agency responsible for enforcing the Clean Water Act, Safe Drinking Water Act and other federal environmental regulations.
United States Geological Survey	A division of the United States Government, Department of Interior. USGS is the sole science agency for the Department of Interior.
Urbanization	The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.
Vegetated Buffer	Uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff, generally consisting of native, deep rooted grasses, shrubs and trees.
Vegetated Swale	a shallow, open-channel concentrated flow feature that contains a dense growth of vegetation, generally tall grass, that partially treats and infiltrates stormwater runoff.
Water	From KRS 224.01 (33) "Water" or "waters of the Commonwealth" means and includes any and all rivers, streams, creeks, lakes, ponds, impounding reservoirs, springs, wells, marshes, and all other bodies of surface or underground water, natural or artificial, situated wholly or partly within or bordering upon the Commonwealth or within its jurisdiction; Effluent ditches and lagoons used for waste treatment which are situated on property owned, leased, or under valid easement by a KPDES-permitted discharger are not considered to be waters of the Commonwealth.
Water Quality	A term used to describe the chemical, physical and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water Quality Standards	Standards that set the goals, pollution limits, and protection requirements for each waterbody. These standards are composed of designated (beneficial) uses, numeric and narrative criteria, and antidegradation policies and procedures.
Water table	The upper surface of the free groundwater in a zone of saturation; locus of points in subsurface water at which hydraulic pressure is equal to atmospheric pressure.

Waters of the United States	As defined in 40 CFR I22.2: (a) All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide; (b) All interstate waters, including interstate “wetlands,” (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, “wetlands,” sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters: (1) Which are or could be used by interstate or foreign travelers for recreational or other purposes; or (2) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (3) Which are used or could be used for industrial purposes by industries in interstate commerce; (d) All impoundments of waters otherwise defined as waters of the United States under this definition; (e) Tributaries of waters identified in paragraphs (a) through (d) of this definition; (f) The territorial sea; and (g) “Wetlands” adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (a) through (‘1) of this definition.
Watershed	Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.
Watershed Approach	A flexible framework used for managing water resources within a specified drainage area, or watershed. This approach includes stakeholder involvement and management actions supported by sound science and appropriate technology.
Weir	Device of measuring or regulating the flow of water.
Wet Weather Flow	A combination of dry weather flows and infiltration, inflow and/or runoff, which occurs as a result of rainstorms.
Wetlands	A region of land whose soil is saturated with moister permanently or seasonally.

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