


GREEN INFRASTRUCTURE

STRATEGIES TO MANAGE STORMWATER IN OUR COMMUNITY

MSD DESIGN MANUAL
CHAPTER 18

EFFECTIVE JUNE 30, 2016

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Safe, clean waterways

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Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

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18.1 Introduction

Green roof at the University of Louisville School of Business

Louisville & Jefferson County MSD published the Green Infrastructure chapter of the design manual in 2013 pursuant to Municipal Separate Storm Sewer System permit requirements to establish and enforce a water quality treatment standard and to promote clean, safe waterways in our community. Green infrastructure reduces the volume of stormwater that flows untreated through drainage conveyances, storm sewers and to creeks and streams by capturing, filtering and infiltrating stormwater.

Louisville and Jefferson County
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18.1.1 Definitions

Louisville skyline

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
EPA	Environmental Protection Agency
EPSC	Erosion Prevention & Sediment Control
ESAL	Equivalent Single Axle Load
Fps	Feet per second
GMP	Green Management Practice
H:V	Horizontal: Vertical
IOAP	Integrated Overflow Abatement Plan
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
KRS	Kentucky Revised Statutes
KYTC	Kentucky Transportation Cabinet
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
PVC	Polyvinyl Chloride
RE_{WQV}	Required Water Quality Volume Rain Event
RRV Capacity	Runoff Reduction Volume Capacity
RWQv	Remaining Water Quality Volume
TMDL	Total Maximum Daily Load
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.
Bioswale	Stormwater conveyance features that mimic ecological function of a landscape, often serving as replacements to open ditches or underground pipes.
Buffer Strip	Undisturbed natural areas that treat stormwater runoff.
Catch Basin Insert	Space saving devices installed underneath the grate of an inlet to remove sediment, debris, oils or metal from stormwater inflow.
Check Dam	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.
Cistern	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.
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 stormwater runoff, treat pollutants and create habitat.
Credit	A credit is a long-term financial incentive. Every MSD customer is charged a monthly fee for drainage.
Cultivar	A plant cultivated for its desirable characteristics and often used in ornamental or landscaped gardens.
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.
Exfiltration	A method for managing stormwater runoff whereby stormwater enters and travels through green infrastructure from the surface and drains into subsurface soils.
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.
Financial Incentive Program	Louisville & Jefferson County's Rates, Rentals and Charges Policy, also referred to as the Stormwater User Fee Credits Program, includes financial incentives to encourage commercial, industrial and institutional property owners to implement green infrastructure as a way to manage the stormwater runoff generated by impervious surfaces on their property.
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.
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.
Green Dry Basin	Stormwater management practices that are similar to standard dry basins, except that they contain 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. 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 various 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 tree boxes.
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 aquatic benches provide water quality benefits.
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.
Hotspot	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.
Infiltration	The process through which stormwater runoff penetrates into the soil from the ground surface.
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 Trench	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, engineered 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.
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.
Louisville & 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 Permit Program	Municipal Separate Storm Sewer System; operated by MSD with its co-permittees including Louisville Metro and the Cities of Anchorage, Jeffersontown, St. Matthews and Shively.
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 pollution that degrades waterways. Nutrients including 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.
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; and 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.
Porous Asphalt	A permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and stone reservoir.
Pretreatment	The process removing pollutants from stormwater before entering green infrastructure and either infiltrating into subsurface soil or exiting into waterways or water bodies.
Proprietary Water Quality Units	Space effective stormwater management structures that typically have 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 functions of a natural landscape. Rain gardens contain deep rooted

	vegetation or cultivar species to filter and infiltrate stormwater.
Rainwater Harvesting	The practice of collecting, storing, and using rainwater to supplement onsite water demands.
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.
Retrofit	Refers to the addition of new technology or features to older systems.
Riparian Area	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.
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.
Spillway	See Emergency Spillway.
Stipend	A stipend is a short-term financial incentive for green infrastructure construction cost recovery.
Stormwater	Water runoff that is a result of natural precipitation.
Stream	Defined by the Clean Water Rule, see Waters of the US.
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	A pipe or series of pipes that run longitudinal with the ground surface and capture excess stormwater to allow the green infrastructure practice to drain.
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. 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.
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.
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: and the Clean Water Rule.
Watershed	Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.
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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18.2 Planning

Courtyard of permeable pavers at University of Louisville Campus

Green infrastructure is a requirement in Louisville Metro pursuant to the Wastewater/Stormwater Discharge Regulations administered by Louisville MSD and requires proper planning. Planning guidance to effectively integrate green infrastructure in site design is provided in this section, including the following topics:

- Understanding stormwater regulations
- Green infrastructure strategies and concepts for various forms of development
- How to select green infrastructure based on your site characteristics
- Infiltration testing specifications
- Pretreatment requirements
- Signage to promote green infrastructure on your site

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18.2.1 Introduction

Green infrastructure projects at and surrounding the University of Louisville Campus were planned and designed to capture over 123,000,000 gallons of stormwater runoff.

The green infrastructure program was developed pursuant to MSD's Municipal Separate Storm Sewer System (MS4) stormwater permit, as well as the Federal Consent Decree to abate sewer overflows.

This section provides an overview of planning guidance and requirements for plan and design submittal for green infrastructure practices. More information on plan review checklists and design calculation sheets are available at www.louisvillemsd.org.

Planning strategies must meet the minimum requirements identified in this section to comply with MSD's green infrastructure requirements. However, as part of the planning process, property owners should consider additional benefits such as:

- Over-sizing green infrastructure for flood reduction benefits
- Participation in MSD's Green Infrastructure Financial Incentive Program (www.msdgreen.org for program information and availability)
- Ancillary benefits of certain green infrastructure practices

18.2.2 Overview of Regulations

Louisville Metro City Hall

Federal and local regulatory programs can impact water quality and quantity. This section provides an overview of the basic regulatory programs. The regulatory programs outlined in Chapter 18.2.2 should not be considered static, as requirements of regulatory programs frequently change over time. Therefore, the designer should always consult pertinent statutes and ordinances when developing a green infrastructure project. Where regulations are in conflict, the more restrictive requirements shall be applied. This chapter provides an overview of the Municipal Separate Storm Sewer (MS4) Stormwater Quality Program, including construction and post-construction requirements, water quantity permits, local permits, and KYTC permits.

Municipal Separate Storm Sewer System (MS4) Permit for Stormwater Quality

Louisville Metro is regulated by the MS4 Stormwater Quality Program, as required by the Clean Water Act, through the Kentucky Pollutant Discharge Elimination System (KPDES), which is administered by Kentucky Division of Water (KDOW). The MS4 stormwater quality permit program mandates that MS4 communities enforce stormwater management ordinances, regulations, and/or policies. MSD, the City of Anchorage, the City of St. Matthews, the City of Jeffersontown, the City of Shively and Louisville Metro are MS4 co-permittees and collaborate to meet permit requirements. As a result of this co-permittee relationship, Louisville MSD leads, implements and enforces designated permit activities, including erosion prevention and sediment control from construction sites and post-construction stormwater management through green infrastructure. Erosion prevention and sediment control is regulated through the Louisville Metro Erosion Prevention and Sediment Control Ordinance. Post-construction stormwater management is regulated through MSD's Wastewater/Stormwater Discharge Regulations.

MSD Wastewater/Stormwater Discharge Regulations (WDRs)

Effective August 1, 2013, MSD amended the WDRs to include post-construction minimum control measures and green infrastructure. The post-construction requirements apply to all development with a disturbed area equal to or greater than one (1) acre, including projects less than one acre that are part of a larger common plan of development or a common scheme of development equal to or greater than one acre (disturbed area does not include utility installation), located in the City of Louisville, Jefferson County, and the incorporated cities of Jefferson County. The purpose of the regulations is to prohibit non-stormwater discharges to the MS4, prevent improper disposal of chemicals and other materials into the MS4 that degrade water quality and to provide the necessary enforcement mechanisms. Pursuant to the WDRs, MSD has the authority to:

- Review and approve post-construction plans
- Perform pre-construction site meetings, inspections and negotiated compliance efforts in the enforcement of these regulations
- Provide education and training program for contractors
- Develop, implement, and administer a post-construction Best Management Practice (BMP) Long-Term Maintenance Program
- Administer and manage a fee in lieu program

Resources

Plan review requirements, checklists, calculation sheets, stormwater quality long-term maintenance agreements, and other resources are available on MSD's website, www.louisvillemsd.org.

Alternative Practices for Post-Construction BMPs and GMPs

To encourage the development and testing of alternative post-construction BMPs and GMPs, MSD adopted policies to enable alternative practices. Alternative management practices that are not included in the MSD Design Manual, Standard Specifications, and Standard Drawings, may be allowed upon review and approval by MSD. The alternative management practice must be supported by evidence that it will perform at least equivalently to a currently approved control contained in the MSD Design Manual, Standard Specifications, or Standard Drawings and conforms to current American Society for Testing and Materials (ASTM) Standards. However, if the control or practice fails, or is inadequate to contain the target pollutants (i.e. TSS) onsite or meet long-term post-construction stormwater management objectives, the permittee will be required to remove and replace it with a control approved by MSD and in accordance with the MSD Design Manual Standard Specifications and Standard Drawings.

Fee in Lieu Program

MSD has the authority per the Wastewater/Stormwater Discharge Regulations to establish an fee in lieu program to mitigate stormwater runoff off-site. This program would allow developments where green infrastructure is not feasible on-site to mitigate for water quality off-site or pay a fee that would fund stormwater quality mitigation projects.

Erosion Prevention and Sediment Control Ordinance

The City of Louisville/Jefferson County EPSC, § 159, defines land disturbing requirements at active construction sites disturbing greater than 2,000 square feet, or are part of a larger common plan of development disturbing greater than 2,000 square feet. 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. The permittee should consult the Louisville/Jefferson County EPSC Ordinance for specific permitting requirements prior to any land disturbing activity.

In addition, developments in Louisville Metro disturbing one acre or more, or are part of a larger common plan of development of one acre or more are subject to state permitting requirements under the KPDES Stormwater General Permit for Construction, KYR10.

Inspections, Permits, and Licenses

Louisville Metro Building Division oversees the implementation, inspection, and enforcement of the Kentucky Building Code KRS Section 105.1. A permit may be required when a property 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 Louisville Metro Building Division building official and obtain the required permit.

Kentucky Transportation Cabinet Encroachment Permits

Any firm, individual, or governmental agency that wants access to a road on the state highway system or wants to conduct any type of work activity on the right-of-way, must obtain a permit. In addition, work affecting state highways requires additional permits through the Kentucky Transportation Cabinet.

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 management ordinance. MSD is the administrator of Louisville Metro's Floodplain Management Ordinance. This ordinance must 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, or on the MSD website. Floodplain permits are required from both the state and local community. MSD is the local administer and the Kentucky Division Of Water (KDOW) issues a state permit. A permit, issued by MSD, is required for any disturbance in the floodplain including construction, filling, dredging, or any development in the Local Regulatory Floodplain. If a permit is not issued pursuant to local or state ordinances, development in the floodplain is prohibited and the property owner will be issued a Stop Work Order as well as fines. No development is permitted in the conveyance zone. This ordinance also has requirements for buffers along blue line streams.

An Application for Permit to Construct Across or Along a Stream from the (KDOW), Floodplain Management Section, is also required. KDOW should be contacted for more information regarding this permit.

Water Quality

The Clean Water Act is the federal legislation that governs water quality and there are several components of it that should 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.

Examples of potential permits that may be required for stormwater drainage or green infrastructure projects are provided in Table 18.2.2-A.

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. As updated TMDLs are developed and approved by KDOW, MSD is required to respond with additional regulatory requirements for site development for the respective pollutants of concern. For additional information regarding TMDLs, refer to KDOW's Water Quality website.

Potential Permits Required for Green Infrastructure Projects*

Table 18.2.2-A.

Permit	*Typical 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
MSD Application for Permit to Develop/ Repair in a Floodplain or in a Regulatory Conveyance Zone	Application; consult MSD website for step by step requirements	MSD	For construction in the Regulatory Floodplain or Regulatory Conveyance Zone
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
MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects
Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and USACE	When encroaching on the floodwall right-of-way
Stormwater Construction General Permit, KYR10	NOI	KDOW	Disturbance greater than one acre
Injection Well/ Underground Injection Control	Application	USEPA	Per injection well classification criteria at www.epa.gov.
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	Site Plan	Louisville Metro – Code Enforcement or City of Louisville Public Works	Any building
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
Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept. of Public Works	For any project which requires obstruction of a roadway

*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 a comprehensive list of potential permitting requirements.

18.2.3 Strategies and Concepts

Green Streets

Conceptual Green Streetscape

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 to high densities, including residential and commercial areas as well as parkways.

Special Considerations:

- Design consistency with local and state ordinances/regulations (see Table 18.2.2-B)
- Any construction in a roadway will require Louisville Metro right-of-way (ROW) and/or Kentucky Transportation Cabinet ROW encroachment approvals
- 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)
- ADA compliance
- Bicycle facility/route accommodations

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.

🡐 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.

Existing: Traditional Curb and Gutter Parkway with Island ➔

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

🡐 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.

🡐 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.

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

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

🡐 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 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 ➔

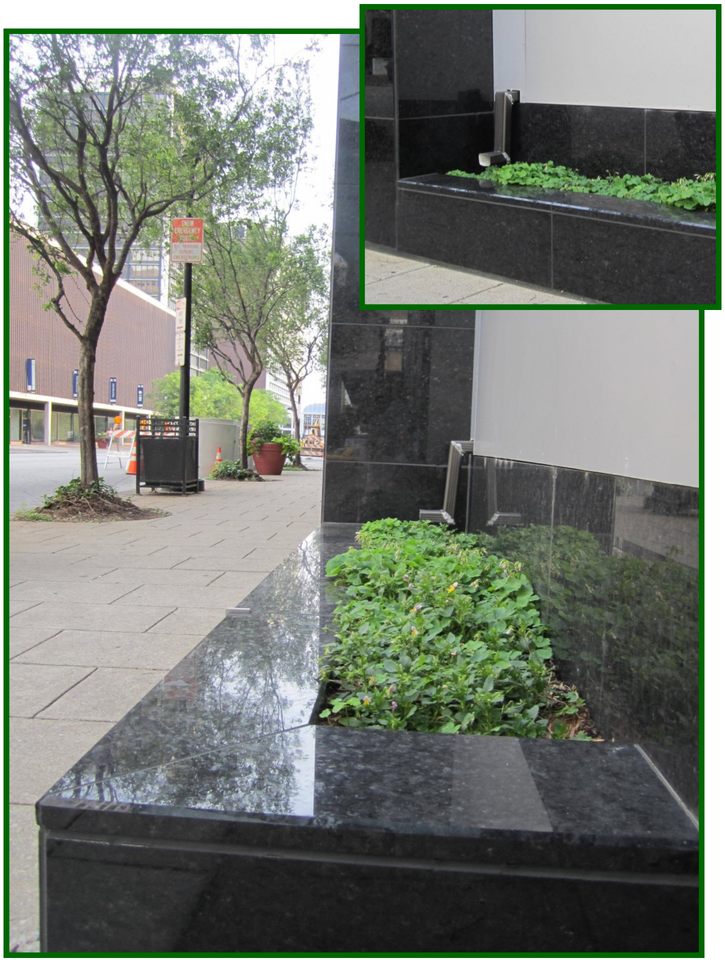
Surrounding a tree box with impervious concrete is a common practice.

← Green Option: Pervious Concrete Surrounding Tree Boxes

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

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.



Conceptual Green Intersection

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
- ADA compliance
- Permeable pavers, pervious concrete and porous asphalt maintenance and structural issues should be considered if used in a driving or heavy load areas (such as a drive lane in contrast to parking stalls)
- Permeable pavers, pervious concrete and porous asphalt placed in areas with trees will require additional maintenance to keep clean and functional
- Bicycle facility/route accommodations

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.

← 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.

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.

🡐 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 Green Intersection 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)

Stormwater Curb Extension Concept

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
- Bus stop coordination

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.

🡐 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.

Grass Grid Pavers at Big Rock in Cherokee Park

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.

Green Option #1: Curb Removal →

One of the simplest methods for more sustainable parking lot islands is removing raised beds and curbs (or creating curb cuts) at islands. At grade, or slightly sunken islands receive stormwater runoff and accommodate native plants and trees that can eliminate the need for supplemental irrigation.

← 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.

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.

← 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.

🡐 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.

Green Option #7: Internal Bioswale ➔

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

🡐 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.

18.2.3 Strategies and Concepts

Downspout Disconnection -

Downspout Disconnection

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 residential property owners to disconnect downspouts, conveying stormwater to lawns, or to a GMP. Contact MSD Customer Relations at (502) 587-0603 or visit www.msdgreen.org 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.

🡐 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.

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.

🡐 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.

Extensive Green Roof Bed and Patio

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.

🡐 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.

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

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

🡐 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.

Cisterns at the Green Building

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
- Seasonal use
- Decrease in potable water usage for landscape irrigation

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.

🡐 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 garden center.

Existing: Car Wash with Traditional Design ➔

Typical car washing facility.

🡐 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.

18.2.3 Strategies and Concepts

Urban Forestry

Description:

Urban forestry is defined by the care and management of trees in urban settings. Urban forestry can vary from planting tree 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:

- Land Development Code standards
- KYTC standards
- 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

Concept Uses of Urban Forestry

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

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.

🡐 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.

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.

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.

➔ 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.

Concept Uses of Urban Forestry

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

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

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

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

The picture to the left 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.

18.2.3 Strategies and Concepts

No Mow Buffer Zones

Bioretention cell at Willow Pond at Lexington Road and Grinstead Drive

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, enhancing water quality through shading to lower water temperature in channels, valuable corridor protection for streams and wetlands by decreasing bank erosion and minimizing risk of flooding by stabilizing soil, furnishing wildlife habitat 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
- Dense vegetation of buffer
- 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
- More information on no mow and low mow options can be found on the Louisville Metro Air Pollution Control District's (APCD) website at www.louisvilleky.gov/government/air-pollution-control-district/

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.

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.

🡐 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.

18.2.3 Strategies and Concepts

Stream Buffers

Stream buffer along Floyds Fork

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.

🡐 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.

🡐 Green Option #4: No Mow Stream Buffer

This stream buffer demonstrates a riparian buffer that is not mowed.

Stream Buffer Illustrations

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

Green Option #1: Native Grasses ➔

This picture demonstrates the use of native grasses as a hedge along a sidewalk and buffer for stormwater runoff..

🡐 Green Option #2: Native Flowers

This picture demonstrates the use of native flowers in bloom as a functional stream buffer and visually appealing landscape feature.

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

The picture to the right shows how grass grid pavers drain to a stream buffer before reaching the stream. Large boulders act as parking bollards to keep cars away from the buffer area.

🡐 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.

Description:

Retrofitting a wet detention basin can involve 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.

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.

← 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.

← 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.

18.2.3 Strategies and Concepts

Parks and Multi-Use Areas


Arthur K. Draut Park, St. Matthews

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.

← 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.

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.

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

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

SCHEMATIC BIO–SWALE WITH FLUME PLAN

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.

Local Park and Multi-use Areas

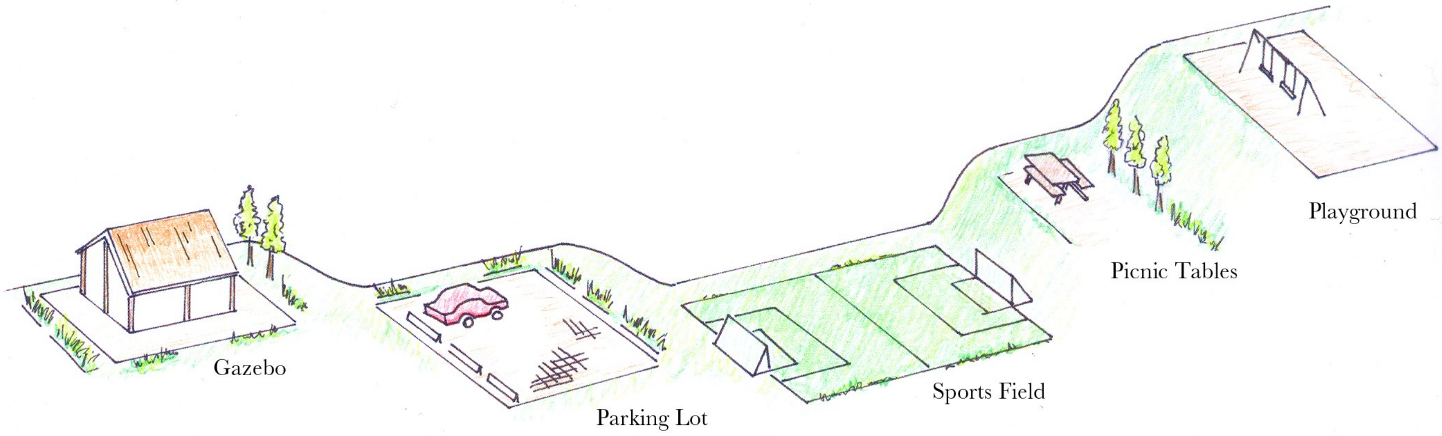
These pictures demonstrate some of the options for multi-use areas with stormwater benefits.

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.

← 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.



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.

18.2.3 Strategies and Concepts

Residential Neighborhoods

Bioswale with check dams and native plants under construction in a neighborhood development.

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
- Ownership/maintenance of property

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.

🡐 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.

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

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

🡐 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.

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.

← 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.

← Green Option #4: Treebox Bioswale

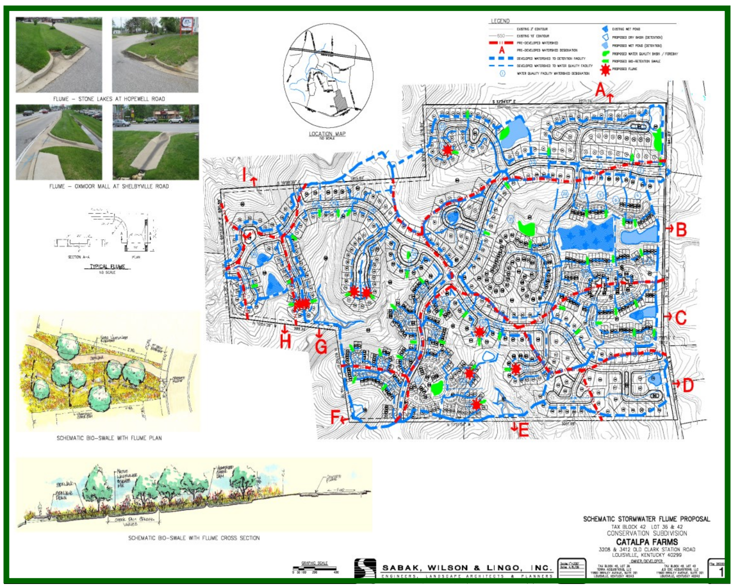
This design can be used along streets in neighborhoods. Not only does it have aesthetic benefits, it also provides storm water benefits as well.

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.

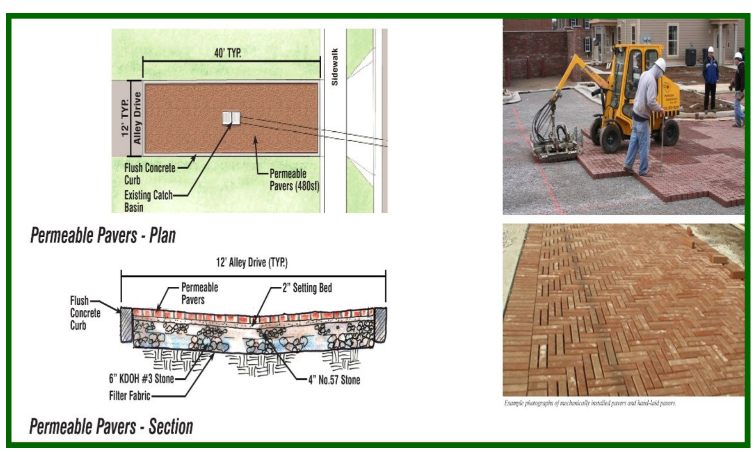


🡐 Green Option #2: Design Demonstrates the Use of Traditional Gray Infrastructure with GMPs

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.



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.

← 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.

18.2.4 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 guidance for managing the water quality requirements on a project site. The primary goals of a Green Management Practice (GMP) is to provide both water quantity reduction and water quality improvements before runoff leaves a site. Although the process for selecting GMPs is the same, the GMP selections will vary from site to site. There are many factors that contribute to the effectiveness of a specific GMP. It is important for a 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. This section 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, outlined in Section 18.2.2.

The GMPs in the MSD Design Manual should be considered as a list of tools and implemented based on the site conditions and stormwater management needs to comply with the Clean Water Act and post-construction stormwater water quality and quantity requirements. Furthermore, appropriate site planning will allow for 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.

This Section provides a summary of the general considerations for design and steps that can also be referenced in the GMP Summary Process flow chart, Exhibit 18.2.4-A. This Section provides more specific guidelines for the design of each GMP. At the end of the section there are various GMP examples 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})—0.6 inches
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 Operation and Maintenance (O&M) Documentation

Impacts of Stormwater Management

The purpose of stormwater management is to mitigate the impact on the hydrologic cycle resulting from alterations to land surfaces. As land is developed, the hydrologic cycle is impacted through a reduction in the natural storage and infiltration capabilities of natural pervious areas, including grasslands and forests. 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, which can increase stormwater runoff.

With urbanization, naturally occurring pervious areas can be reduced and replaced with impervious surfaces. 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 runoff 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

A summary of the potential pollutants including pollutant sources and pollutant impacts is provided in the following paragraphs.

Nutrients Naturally occurring nutrients, such as phosphorous and nitrogen, are commonly found in manmade fertilizers which 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 algae growth, which can result in lower dissolved oxygen (DO) levels, as well as taste and odor problems. Lower DO levels are caused by the decomposition of organic materials in waterways and algae 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, sanitary sewer overflows (SSOs) and combined sewer overflow (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 a water column, or turbidity. Turbidity is the discoloration of water. Sediment typically comes from soil/streambank erosion, construction activities, or roadways. The impacts from excessive sediment include: stream warming, transportation of pollutants during rain events, destruction of stream habitats, declines in mussels and darters, and decreased flow capacity of pipes and channels, which can lead to localized flooding. Water that is too turbid does not allow sunlight to penetrate the water and grow phytoplankton, which are the foundation for the aquatic food chain.
Deicers	Deicers are used to melt snow and ice from roadways and walkways. Deicers can harm aquatic life by increasing salt levels and conductivity within stormwater runoff.
Floatables	Floatables include trash and organic materials such as leaves, grass, and other yard waste that float on the surface of the water. 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 local waterways can be decreased by treating and reducing stormwater runoff. Table 18.2.4-A contains a summary of the relative pollutant treatment and stormwater management benefits that can be provided by well-maintained GMPs. Table 18.2.4-A was derived from the stormwater benefits that are identified on each of the GMP fact sheets (Section 18.3). The intent of this table is to provide a brief summary of the potential benefits of the recommended GMPs including: Pollutant reduction, hydrologic characteristics, and a reduction in potential runoff volumes.

Green Management Practices Summary

Table 18.2.4-A

■ Significant Benefit ◩ Partial Benefit □ Low or Unknown Benefit		Pollution Reduction							
		Sediment	Phosphorous	Nitrogen	Metals	Pathogens	Floatables	Oil and Grease	Dissolved Pollutants
18.3.2	Rain Gardens	■	◩	◩	◩	◩	◩	◩	◩
18.3.3	Constructed Wetlands	■	◩	◩	◩	◩	◩	◩	◩
18.3.4	Green Wet Basins	■	◩	◩	◩	◩	◩	◩	◩
18.3.5	Green Dry Basins	■	◩	◩	◩	□	◩	◩	□
18.3.6	Extensive Green Roofs	□	□	□	□	□	□	□	□
18.3.7	Intensive Green Roofs	□	□	□	□	□	□	□	□
18.3.8	Permeable Pavers	◩	□	◩	◩	□	□	□	□
18.3.9	Pervious Concrete	◩	□	◩	◩	□	□	□	□
18.3.10	Porous Asphalt	◩	□	◩	◩	□	□	□	□
18.3.11	Tree Boxes	■	◩	◩	◩	□	◩	◩	◩
18.3.12	Rainwater Harvesting	□	□	□	□	□	□	□	□
18.3.13	Vegetative Buffers	◩	◩	◩	◩	□	◩	□	□
18.3.14	Underground Storage	◩	□	□	□	□	◩	□	□
18.3.15	Catch Basin Inserts	◩	□	□	◩	□	◩	◩	□
18.3.16	Proprietary Water Quality Units	*varies by technology*							
18.3.17	Infiltration Trenches	■	■	■	■	◩	◩	◩	◩

Table 18.2.4-A (Cont.)

■ Significant Benefit ◩ Partial Benefit □ Low or Unknown Benefit		Hydrologic Characteristics				Runoff Volume Reduction	Financial Consideration	
		Surface Flow Reduction	Infiltration	Stormwater Conveyance	Peak Flow Control	Runoff Capture	Maintenance	Cost
18.3.2	Rain Gardens	◩	◩	□	◩	■	Low	Low
18.3.3	Constructed Wetlands	◩	□	□	◩	□	Medium	Medium
18.3.4	Green Wet Basins	◩	□	□	◩	□	Low	Medium
18.3.5	Green Dry Basins	◩	□	□	◩	◩	Low-Medium	Low-Medium
18.3.6	Extensive Green Roofs	■	□	□	■	■	Low	High
18.3.7	Intensive Green Roofs	■	□	□	■	■	Medium	High
18.3.8	Permeable Pavers	■	■	□	□	■	High	High
18.3.9	Pervious Concrete	■	■	□	□	■	Medium	Medium
18.3.10	Porous Asphalt	■	■	□	□	■	Medium	Medium
18.3.11	Tree Boxes	◩	◩	◩	□	◩	Low	Medium
18.3.12	Rainwater Harvesting	□	□	□	□	□	Medium-High	Medium-High
18.3.13	Vegetative Buffers	◩	◩	◩	□	◩	Low	Low-Medium
18.3.14	Underground Storage	□	■	□	■	■	Medium	Medium-High
18.3.15	Catch Basin Inserts	□	□	□	□	◩	Medium-High	Low-Medium
18.3.16	Proprietary Water Quality Units	□	□	◩	□	□	Medium	Medium-High
18.3.17	Infiltration Trenches	■	■	■	◩	■	Medium-High	Medium

Green Management Practice Selection Process

Developing a green infrastructure project involves considering GMPs throughout the life of the project, from the concept stage through the final design and subsequent operation and maintenance. The flow chart in Figure 18.2.4-A outlines the GMP selection process. Each of these steps are discussed in more detail in this section.

Steps 1 through 5 of the flow chart below outline the steps to design a GMP based on water volume. If however the entire volume cannot be captured, a practice that focuses on the water quality can be implemented. Steps 6 and 7 outline this process.

Green Management Practice Selection Process

Step 1: Site Planning Recommendations

A. Conserve Natural Areas

1. Preservation of Undisturbed Areas
2. Preservation of Riparian Buffers
3. Reduction of Clearing and Grading
4. Location of Development in Less Sensitive Areas
5. Open Space Design

B. Reduction of Impervious Cover

1. Roadway Reduction
2. Sidewalk Reduction
3. Driveway Reduction
4. Building Footprint Reduction
5. Parking Reduction
6. Planters

↓

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

Required RE_{WQV}* = 0.60" (80th Percentile Storm)

**RE_{WQV} requirements may be greater than 0.60" for projects applying for MSD Financial Incentives*

↓

Step 3: Calculate Required Water Quality Volume (WQv)

$$\text{Required WQv (cubic feet)} = (1/12)(RE_{WQV})(Rv)(A) - (WQ_{vR})$$

where $Rv^{**} = 0.05 + 0.009(I)$

I = Impervious cover in percent

A = Disturbed drainage area in square feet

and

$$WQ_{vR} = (1/12)(RE_{WQV})(Rv)(IA_R)$$

Where IA_R = reduced impervious area

***If I equals 0, then Rv equals 0, and a GMP is not needed*

↓

(Continued on next page)

Figure 18.2.4-A Green Management Practice Selection Process

See Section 18.2.2: Overview of Regulations for exclusions.

Step 4: Select GMPs with Runoff Reduction Ability

1. Rain Gardens
2. Extensive Green Roofs
3. Intensive Green Roofs
4. Permeable Pavers
5. Pervious Concrete
6. Porous Asphalt
7. Tree Boxes
8. Rainwater Harvesting
9. Vegetated Buffers
10. Underground Storage
11. Catch Basin Inserts***
12. Infiltration Trenches

****Pretreatment Only*

Step 5: Determine Managed Water Quality Volume (MWQv)

There are 2 methods to determine MWQv:

Method 1: MWQv = (WQv)(GMP Management Capacity****)

**** *See Table 18.2.4-C GMP Water Quality Volume Management Capacities Based on Amount of Runoff Reduced.*

Method 2: MWQv=WQv-INFv*****

INFv (Infiltration Volume)=volume of water absorbed into the ground in a one-hour period = I A t

where: I = field infiltration rate (see section 18.2.5)

A = cross-sectional area (perpendicular to flow)

t = 1 hour

*****Note: for this option a report and the calculations from a Professional (Engineer or Geologist) is required and must be submitted with the practice designs.*

Is all of the WQv managed or treated? — Yes: go to Step 8. No: go to Step 6.

Step 6: Calculate Remaining Water Quality Volume (RWQv)

(If using GMP with less runoff reduction capacity)

RWQv (cubic feet) = 2(WQv - MWQv)

Step 7: Select Alternative GMPs to Treat the RWQv

1. Constructed Wetlands
2. Green Wet Basins
3. Green Dry Basins
4. Proprietary Water Quality Units******

******See Section 18.3.16 for more information.

Step 8: Operation & Maintenance (O&M) Documentation

1. Operation and Maintenance Plan
2. Long Term Operation and Maintenance Agreement

(Continued from previous page)

Figure 18.2.4-A Green Management Practice Selection Process

Following is a step-by-step explanation for the GMP selection process.

Step 1: Site Planning

During the first step of selecting GMPs for a project, consideration should be given to preserving the natural features of a project site, (conservation design). As discussed in Chapter 18.1.1 green infrastructure can range from natural features on a property that treat runoff, to manmade structures that treat stormwater before it enters 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. The first step of the selection process is to observe and evaluate the site characteristics, including the following:

Development Features Development features include both the natural and manmade features of the site, including utilities, park areas, waterfront areas, landscaping, conservation areas, roads, and sidewalks. Development features should be considered during the site assessment and planning phase.

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

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

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

Aesthetic and Habitat Related Issues Aesthetic and habitat related issues can include a site's proximity to impaired waters or sensitive areas, and if there are threatened and/or endangered species identified on the site.

Topography A site's topography will impact the location and types of GMPs that can be used. 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 if they cause 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 from the GMP to the downstream location must be considered because of the increased runoff volume and its potential migration to areas that may not have received runoff previously. Furthermore, in karst topographies, there is a risk that stormwater runoff may enter the water table with little to no pollutant treatment. This is why appropriate GMP selection is critical in these areas. Infiltration GMPs should not be used in karst topographies.

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

Wind Exposure Exposure to wind may 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 leaves, but reduce stormwater runoff by rainfall interception and evapotranspiration. In spite of these challenges, appropriately selected vegetation in GMPs can improve performance.

Existing Development and Steep Slopes — One goal of stormwater management is to allow for the natural recharge of 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.

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 are shown on the GMP fact sheet guidelines, with a typical design preference of 5:1 to 10:1 ratio of drainage area to GMP area. Ratios greater than 10:1 will be reviewed on a case-by-case basis. When incorporating proprietary water quality units into a site design, refer to the City of Indianapolis Stormwater Quality Unit (SQU) Selection Guide for product selection and to Table 18.2.4-C of this GMP manual for design criteria.

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

Additional site planning considerations include the following.

Costs — GMP costs may be incurred in the planning, design, construction, and operations and maintenance stages of a project.

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 as to 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 standards. The designer should consult all applicable ordinances and regulatory requirements, as that may impact the design process, selection criteria, operation and maintenance and the cost of the GMPs. Some of the planning and regulatory aspects to consider when planning GMPs for a 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 these requirements 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 Sections 18.2.2, 2.5 and Chapter 10 of 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 operation and maintenance is in Section 18.5.

Designated Land Use — The designated land use is a factor to consider since some GMPs are better suited for specific land uses than others. A summary of the most applicable land uses can be found on the first page of each GMP fact sheet (Section 18.3).

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 revised reductions in runoff volume. 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 18.2.4-B and 18.2.4-C.

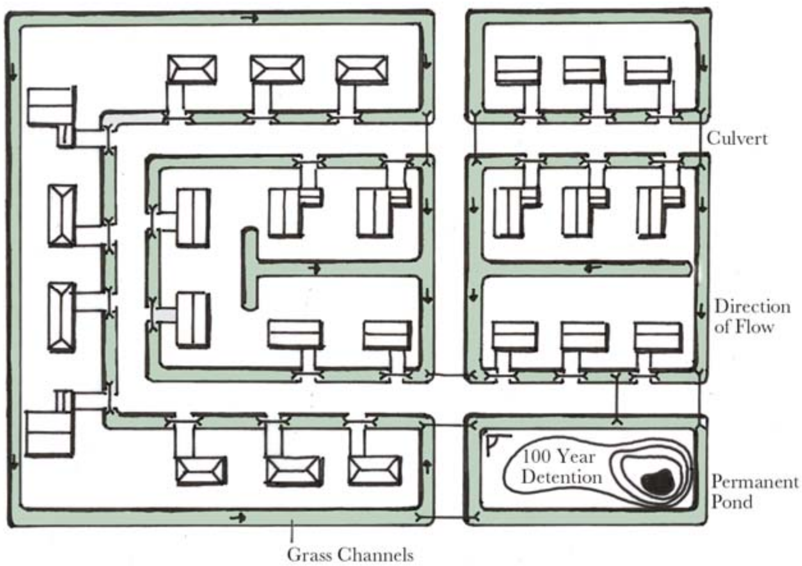


Figure 18.2.4-B. Multiple GMPs are used in a residential setting. The use of linear rain gardens or bioswales and a green detention basin are used in combination to manage the stormwater runoff.

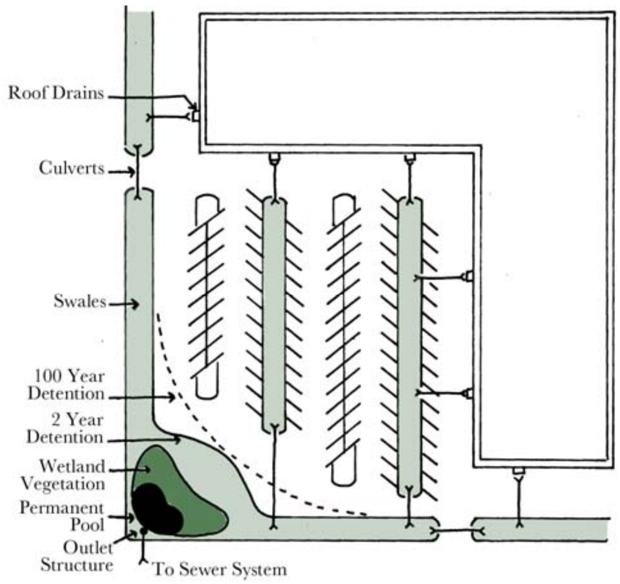


Figure 18.2.4-C. Multiple GMPs used in a commercial development, including directing roof drains to linear rain gardens or bioswales to a wetland system.

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 evaluating the site characteristics and identifying the opportunities and limitations of the site, the designer can select the most cost effective GMP to reduce stormwater runoff for a site..

Opportunities on a site may include:

- Existing utility easements for GMP areas.
- 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
- Soil types
- High water table
- Land use
- Existing utilities
- Local acceptance of particular GMPs

Consideration should be given to preserving the natural features of a site. Conservation design is a means of development to preserve the natural features of a site that can protect water resources, natural habitats, and sensitive areas. These practices provide significant benefit for reducing imperviousness and as a result, the amount of stormwater leaving the site. Table 18.2.4-B contains recommended conservation design practices.

Figure 18.2.4-D. Conceptual neighborhood green site plan

Conservation Design Practices

Table 18.2.4-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, existing vegetation and habitats.
Reduction of Clearing and Grading	Reducing planned grading and clearing to the minimum area 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.
Minimization of Development Impacts to the Site	Preserve the natural drainage patterns and topography of the land by incorporating natural features into a 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.
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 that contain high levels of organic material allow for the infiltration and storage of large quantities of rainfall, when compared 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 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 instead of a waste product • Managing stormwater at its source

Figure 18.2.4-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 18.2.4-F. This residential street in a development using conservation and open space design uses narrower streets than traditional practices.

Step 2: Determine the Required Water Quality Volume Rain Event

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

0.60 inches (80th Percentile Storm)-Event Capture (1 inch or greater for green infrastructure financial incentive stipend projects in areas of the combined sewer system).

Step 3: Calculate Required Water Quality Volume (WQv)

The third step of the process to select GMPs for a project site requires calculating the 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) = $(RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

- RE_{WQV} is the required water quality volume rain event, determined in Step 2
- R_V is the volumetric runoff coefficient, $R_V = 0.05 + 0.009(I)$, where I is the impervious area of the site as a percent
- A is the site area in square feet
- $WQ_{VR} = (^1/_{12})\ (RE_{WQV})(Rv)\ (IA_R)$, where IA_R = reduced impervious area

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 a combination 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's disturbed impervious area 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 these instances other site GMPs must be oversized to capture additional WQ_V to make up the difference for the total site water quality volume. The maximum oversizing of one GMP to account for bypassing site area shall be 10%.

The GMP Water Quality Volume Management (Capacities for each GMP are listed in Table 18.2.4-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 Managed Water Quality Volume (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 a 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 18.2.4-C, on the following page. The MWQ_V for a GMP is the WQv provided by multiplying the WQv of a GMP by the management capacity of the GMP (See Table 18.2.4-C for management capacity values). 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 Required WQv, then the designer can move to Step 8.

An alternative method to determine the MWQv is to take the difference between the WQv and the Infiltration Volume (INFv), or the volume of water absorbed into the ground over a one hour period. Infiltration rates must be in situ soil infiltration rates as determined in section 18.2.5. This method may be preferred when in situ soils provide sufficient infiltration capacity. A Professional Engineer or Geologist must verify the calculations of the infiltration volume and submit to MSD.

Due to the terrain of certain pieces of property, not all site developed stormwater runoff will be able to be directed into a GMP. If no more than 10% of the site has site generated stormwater runoff not managed by GMPs, then the calculated MWQv remains the same for the site. If more than 10% of the site has stormwater runoff that is not directed into a green management practice, the site needs to be redesigned so that 10% or less of the site developed stormwater runoff is not directed at a GMP.

GMP Water Quality Management Capacities

Table 18.2.4-C.

GMP	GMP Management Capacity as a % of the WQv
Rain Gardens	For rain gardens or planter boxes: • 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 For linear rain gardens or bioswales: • 100%, if entire WQv is stored within practice, including forebay, check dams and soils, and no underdrain is provided or underdrain is above the water level of the WQv stored in the stone or soil media • 50%, if entire WQv is stored within practice, including forebay, check dams and soils, and underdrain is provided
Constructed Wetlands	• 100%, if stores 76%-100% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 75%, if stores 51%-75% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 50%, if stores 25%-50% of RWQ_v over and above the normal water level for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone.
Green Wet Basin	• 100%, if stores 76%-100% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 75%, if stores 51%-75% of RWQ_v over and above the normal water levels for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone. • 50%, if stores 25%-50% of RWQ_v over and above the normal water level for at least 24 hrs, drains back to normal pool elevation within 36 hrs, and has a littoral zone.
Green Dry Basin	• 100%, if stores 76%-100% of RWQ_v for at least 24 hrs and drains within 36 hrs. • 75%, if stores 51%-75% of RWQ_v for at least 24 hrs and drains within 36 hrs. • 50%, if stores 25%-50% of RWQ_v for at least 24 hrs and drains within 36 hrs.
Extensive Green Roof	80%
Intensive Green Roof	95%
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

GMP Water Quality Management Capacities (Cont.)

Table 18.2.4-C.

GMP	GMP Management Capacity as a % of the WQv
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
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	• 100%, if the rainfall is stored and beneficially used later (i.e. rain water collected can be used to water plants, etc.) • 50%, if the rainfall is only temporarily detained in the cistern less than 36 hours
Vegetated Buffer	• 100%, if travel time is 10 minutes or greater for the WQ_v rain event • 30%, if time is between 1 and 10 minutes for the WQ_v rain event • 15%, if time is less than 1 minute for the WQ_v rain event
Infiltration Trenches	• 100% , if no underdrain or *underdrain is above the water level of the WQv stored in the media in the infiltration trench • 60%, if *underdrain is below the water level of the WQv stored in the media in the infiltration trench and it drains in 24 to 48 hours • 30%, if *underdrain is below the water level of the WQv stored in the media in the infiltration trench and it drains in less than 24 hours
Underground Storage	• 100%, if the collected rainfall runoff is infiltrated • 60%, if the collected rainfall runoff is only temporarily detained for 24-48 hours
Catch Basin Inserts	• 0%, pretreatment only, runoff reduction is not provided
Proprietary Water Quality Units**	100%, if the flow rate of the proprietary water quality unit is equal to or more than the peak flow rate calculated using the rational method with an intensity equal to 0.5 in/hr

** See Section 18.3.17 for Class V Injection Well definition and requirements.*
***See Section 18.3.16 Proprietary Water Quality Units for more information.*

Step 6 & 7: Calculate Remaining Water Quality Volume and Select Alternatives

If the MWQ_V is not greater than or equal to the Required WQv, then the designer should revisit the site planning recommendations to reduce the impervious area, consider alternatives, and/or include 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.

Step 8: Operation and Maintenance Documentation

During step 8 of the selection process for GMPs, consideration should be given to operation and maintenance of GMPs, including documentation requirements (see 18.5 for details on operation and maintenance needs). Maintenance is a critical aspect of a proper functioning GMP. Pursuant to the Wastewater/Stormwater Discharge Regulations, sites with GMPs the required to enter into long-term O&M agreements with MSD regarding the inspection and maintenance requirements for the GMPs. Additional reporting requirements may be necessary for properties receiving credits and/or stipends as part of the Green Infrastructure Financial Incentives Program. 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 O&M agreement and MSD policy, Section 18.5.

Routine inspections are an important element of GMP O&M. The inspection results should be documented and reviewed at least annually, to assess the effectiveness of the GMP.

Plan Submittal & Post-Construction

MSD requires that all projects with green infrastructure submit as-built drawings to MSD. The as-built drawings must contain information regarding depth and area of storage aggregate, GMP soil mixture, underdrain system, etc.

After the GMPs are designed the following aspects should be considered: GMP construction, long-term O&M agreements, inspection requirements and enforcement.

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 instillation. Knowledgeable personnel should provide construction oversight of the GMPs.

Long-Term Operation and Maintenance Agreements

The terms and conditions regarding the long-term operation and maintenance of each GMP are 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 regulations and policies.

GREEN MANAGEMENT PRACTICE (GMP) SELECTION PROCESS EXAMPLES

Following examples to demonstrate the process for selecting GMPs.

They are:

- Example 1– Size a Rain Garden
- Example 2 - Size a Planter Box
- Example 3 - Expanded Office Building
- Example 4 - Size an Infiltration Trench

Example 1 – Size a Rain Garden

An area in the combined sewer system is being developed (see illustration below). In this example, the developer wants to use a rain garden to manage the stormwater runoff from 34,600 square feet that is 85% impervious. To satisfy the maximum 10:1 contributing drainage area to GMP area ratio as stated in Step 1 of the selection process in section 18.2.4, the proposed rain garden is 3,460 square feet in area, has 18 inches of soil media that has a porosity of 0.4, a ponding depth of 10 inches, and an underdrain that is below the water level of the WQv stored in the soil media and drains in less than 24 hours. Will this rain garden manage 100% of the required water quality volume? The following example outlines a step-by-step process for how to use the selection process to determine the GMP's managed water quality volume.

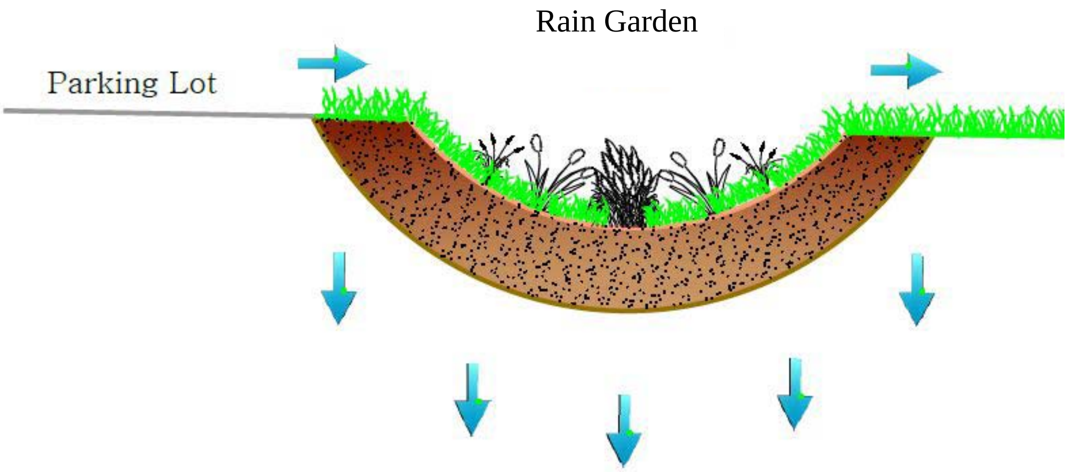


Figure 18.2.4-G Rain Garden & parking lot.

Example 1 – Size a Rain Garden *(Continued)*

Step 1: Site Planning Recommendation

The developer wants to minimize impervious cover.

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

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, the imperviousness is 85%. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(85)]34{,}600 = 1{,}410$ 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 = [(3,460)(1.5)(0.4) + (3,460)(0.83)] = 4,948 cubic feet

Step 5: Determine Managed Water Quality Volume (MWQv)

Since the rain garden has an underdrain that is below the water level of the WQv stored in the soil media and drains in less than 24 hours, the management capacity is only 30%. Therefore, the MWQv is:

4,948(0.3) = 1,484 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv is 1,484 cubic feet, while the required WQv is 1,410 cubic feet, so this GMP does manage all of the WQv.

(Skip to Step 8 of the GMP Selection Process.)

Step 8: O&M Documentation

Complete O&M documentation.

Example 2 – Size a Planter Box

A new development is proposed in the MS4 area (see illustration below). The developer wants to use a planter box with no underdrain to manage the stormwater runoff from 3,000 square feet of rooftop that is 100% impervious. The proposed planter box has 12 inches of soil media that has a porosity of 0.4 and a ponding depth of 3 inches. What is the area of the planter box 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's managed water quality volume.

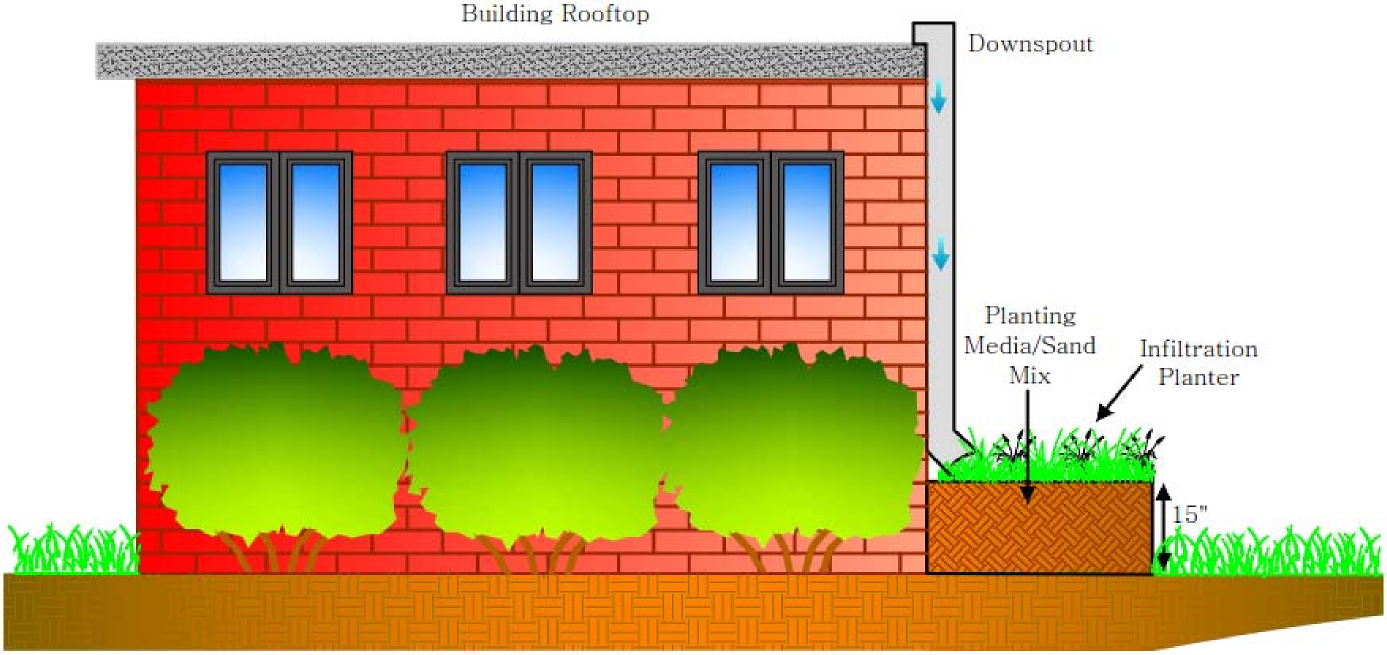


Figure 18.2.4-H Proposed infiltration planter site

Example 2 – Size a Planter Box (*Continued*)

Step 1: Site Planning Recommendation

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

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

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, the imperviousness is 100%. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(100)]3{,}000 = 143$ cubic feet

Step 4: Select GMPs with Runoff Reduction Ability

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

A required = 143/[1.0(0.4) + (0.25)] = 220 square feet

While a 220 square foot planter manages all of the WQv, the planter must be at least a tenth of the size of its contributing drainage area to satisfy the 10:1 contributing drainage area to GMP area ratio as stated in Step 1 of the selection process in section 18.2.4. Therefore, the planter box must be at least 300 square feet.

Step 5: Determine Managed Water Quality Volume (MWQv)

From the GMP Management Capacity Table (Table18.2.4-C), a planter box with no underdrain (Exhibit 18.2.4-H) has a management capacity equal to 100% of the WQv provided.

Managed WQv = (300)[1.0(0.4) + 0.25)](100%) = 195 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv (195 cubic feet) is greater than the required WQv (143 cubic feet). *(Skip to Step 8 of the GMP Selection Process.)*

Step 8: O&M Documentation

Complete O&M documentation.

Example 3 – Expanded Office Building

A developer is expanding an office building and adding parking outside the combined sewer system. While a number of GMP options were available, the developer decided to use a treatment train consisting of two rain gardens, a bioswale, and pervious concrete. Will these multiple GMPs manage 100% of the required water quality volume? An illustration of the proposed site and project specifics are as follows:

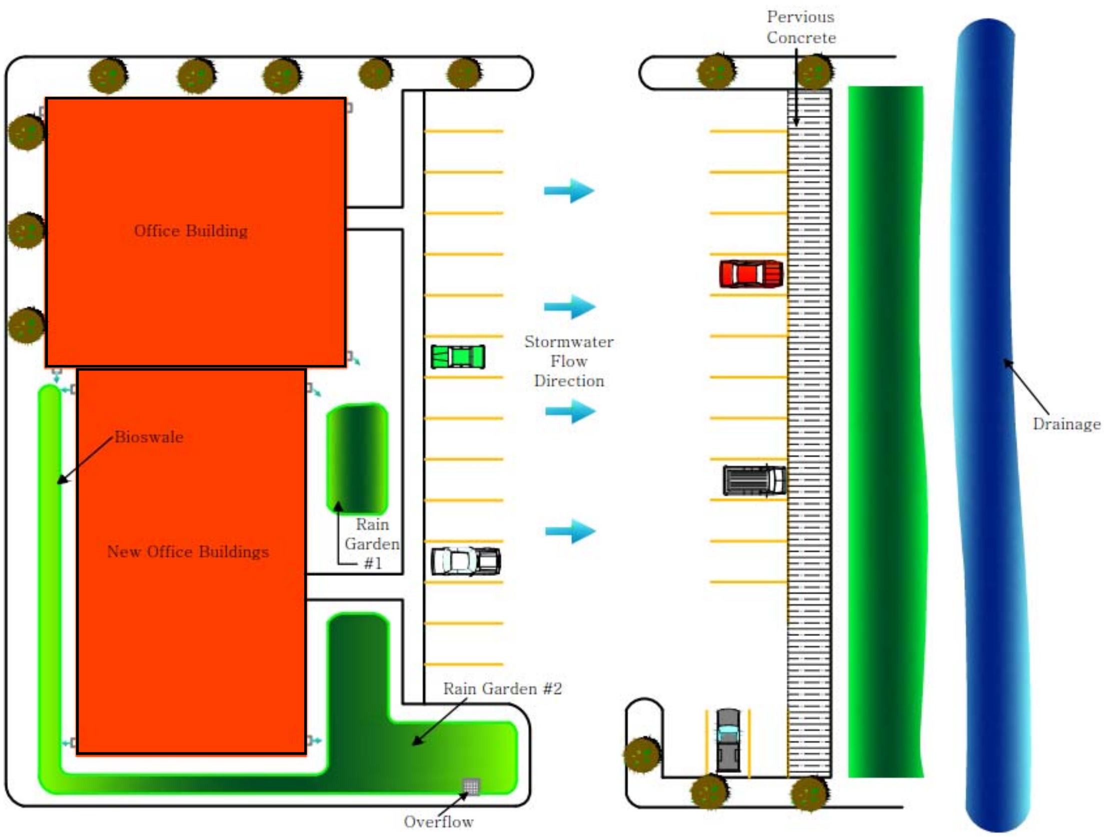


Figure 18.2.4-I Proposed office building Expansion

<u>Drainage Paths</u>

Bioswale: Stormwater runoff from a fourth of the existing landscaping, a fourth of the existing building, a fourth of the new landscaping, and a fourth of the new building flows into the bioswale. All remaining stormwater runoff from the bioswale discharges into Rain Garden #2.

Rain Garden #1: Stormwater runoff from a fourth of the existing landscape, a fourth of the existing building, a fourth of the new landscaping, and a fourth of new building flows into Rain Garden #1. All remaining stormwater runoff from Rain Garden #1 discharges into Rain Garden #2.

Rain Garden #2: Stormwater runoff from a fourth of the existing landscape, a fourth of the existing building, a fourth of the new landscaping, and a fourth of new building flows into Rain Garden #1. All remaining stormwater from the Bioswale, Rain Garden #1, and Rain Garden #2 discharges into the pervious concrete.

Pervious Concrete: Stormwater runoff from a fourth of the existing landscape, a fourth of the old building, a fourth of the new landscaping, and all of the existing and new parking lot flows into the Pervious Concrete along with remaining stormwater from Rain Garden #2.

Refer to the next page for GMP characteristics.

Example 3 – Expanded Office Building *(Continued)*

GMP Characteristics

The following GMP areas were sized to satisfy the maximum 10:1 contributing drainage area to GMP area ratio as stated in Step 1 of the selection process in section 18.2.4.

- Bioswale:
  - The contributing drainage area of the proposed Bioswale is 3,500 square feet; 2,500 square feet of which has been disturbed and is 80 percent impervious.
  - The proposed Bioswale is 350 square feet in area, has 6 inches of soil media with a porosity of 0.4, a ponding depth of 3 inches, and an underdrain that is below the water level of the WQv stored in the soil media and drains in less than 24 hours.
- Rain Garden #1:
  - The contributing drainage area of the proposed Rain Garden #1 is 2,500 square feet; 1,500 square feet of which has been disturbed and is 66.7 percent impervious.
  - The proposed Rain Garden #1 is 250 square feet in area, has 6 inches of soil media with a porosity of 0.4, a ponding depth of 4 inches, and an underdrain that is below the water level of the WQv stored in the soil media and drains in less than 24 hours.
- Rain Garden #2:
  - The contributing drainage area of the proposed Rain Garden #2 is 2,500 square feet; 1,500 square feet of which has been disturbed and is 66.7 percent impervious.
  - The proposed Rain Garden #2 is 250 square feet in area, has 6 inches of soil media with a porosity of 0.4, a ponding depth of 4 inches, and an underdrain that is below the water level of the WQv stored in the soil media and drains in less than 24 hours.
- Pervious Concrete:
  - The contributing drainage area of the proposed Pervious Concrete is 26,500 square feet; 16,500 square feet of which has been disturbed and is 97 percent impervious.
  - The proposed Pervious Concrete is 2,650 square feet in area, and consists of a gravel layer with a depth of 15 inches and a porosity of 0.4 and a concrete layer of 6 inches with a porosity of 0.18.
  - The Pervious Concrete contains an underdrain below the water level of the WQv stored in the gravel.

The following pages outline a step-by-step process for how to use the selection process to determine each GMP's managed water quality volume.

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)

The RE_{WQV} is 0.60 inches.

Step 3 (Bioswale): 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, the imperviousness of the Bioswale's disturbed drainage area is 80%. The WQv requirements only apply to the newly disturbed portion of the site so A = 2,500 square feet. Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(80)]2{,}500 = 96$ cubic feet

Step 4 (Bioswale): 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 = [(350)(0.5)(0.4) + (350)(0.25)] = 158 cubic feet

Step 5 (Bioswale): Determine Managed Water Quality Volume (MWQv)

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

158(0.3) = 47 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 47 cubic feet, while the required WQv is 96 cubic feet, so this GMP does not manage all of the WQv. There is a deficit of 49 cubic feet.
(Repeat steps 3 through 5 for the remaining GMPs used on-site, next page.)

Example 3 – Expanded Office Building *(Continued)*

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, the imperviousness of Rain Garden #1's disturbed drainage area is 66.7%. The WQv requirements only apply to the newly disturbed portion of the site so A = 1,500 square feet.

Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(66.7)]1{,}500 = 49$ 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 = [(250)(0.5)(0.4) + (250)(0.33)] = 133 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:

133(0.3) = 40 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 40 cubic feet, while the required WQv is 49 cubic feet, so this GMP does not 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 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, the imperviousness of Rain Garden #2's disturbed drainage area is 66.7%. The WQv requirements only apply to the newly disturbed portion of the site so A = 1,500 square feet.

Adding the values to the equation yields the following:

$WQv = (^1/_{12})(0.60)[0.05 + 0.009(66.7)]1{,}500 = 49$ cubic feet

Remember, the remaining WQV from the bioswale (49 cubic feet) and rain garden #1 (9 cubic feet) discharges into rain garden #2. As a result, the total required WQv of rain garden #2 is 49 + 9 + 49 = 107 cubic feet.

Step 4 (Rain Garden #2): 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 = [(250)(0.5)(0.4) + (250)(0.33)] = 133 cubic feet

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

Since Rain Garden #2 has an underdrain and drains in less than 24 hours, the management capacity is only 30%. Therefore, the MWQv is:

133(0.3) = 40 cubic feet

Is all of the WQv managed or treated?

No

The MWQv is 40 cubic feet, while the required WQv is 107 cubic feet, so this GMP does not manage all of the WQv. There is a deficit of 67 cubic feet.

(Repeat steps 3 through 5 for the remaining GMP 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, the imperviousness of the Pervious Concrete's disturbed drainage area is 97%. The WQv requirements only apply to the newly disturbed portion of the site so A = 16,500 square feet. Adding the values to the equation yields the following:

WQv = ($^1/_{12}$)(0.60)[0.05 + 0.009(97%)]16,500 = 761 cubic feet

Remember, the remaining WQV from rain garden #2 is 0.3 cubic feet and discharges into the pervious concrete. As a result, the total required WQv of the pervious concrete is 67 + 761 = 828 cubic feet.

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

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

Adding the values to the equation yields the following:

WQv provided = 2,650[(0.4)(1.25)] + 2,650[(0.18)(0.5)] = 1,564 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:

1,564(0.6) = 938 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv is 938 cubic feet, while the required WQv is 828 cubic feet, so this GMP does manage all of the WQv.

(Skip to Step 8 of the GMP Selection Process.)

Step 8: O&M Documentation

Complete O&M documentation.

Example 4 – Infiltration Trench Parking Lot Design

A store and parking lot (see illustration below) is being retrofitted with an infiltration trench. In this example, the developer wants to use an infiltration trench to manage the stormwater runoff from the total disturbed area of 0.25 acres (10,890 square feet) that is 76% impervious. To satisfy the maximum 10:1 contributing drainage area to GMP area ratio as stated in Step 1 of the selection process in section 18.2.4, the proposed infiltration trench is 1,089 square feet, has 4 feet of #3 stone with a porosity of 0.4, a ponding depth of 6 inches, and an underdrain below the water level of the WQv stored in the stone and drains in less than 24 hours. Will this infiltration trench manage 100% of the required water quality volume?

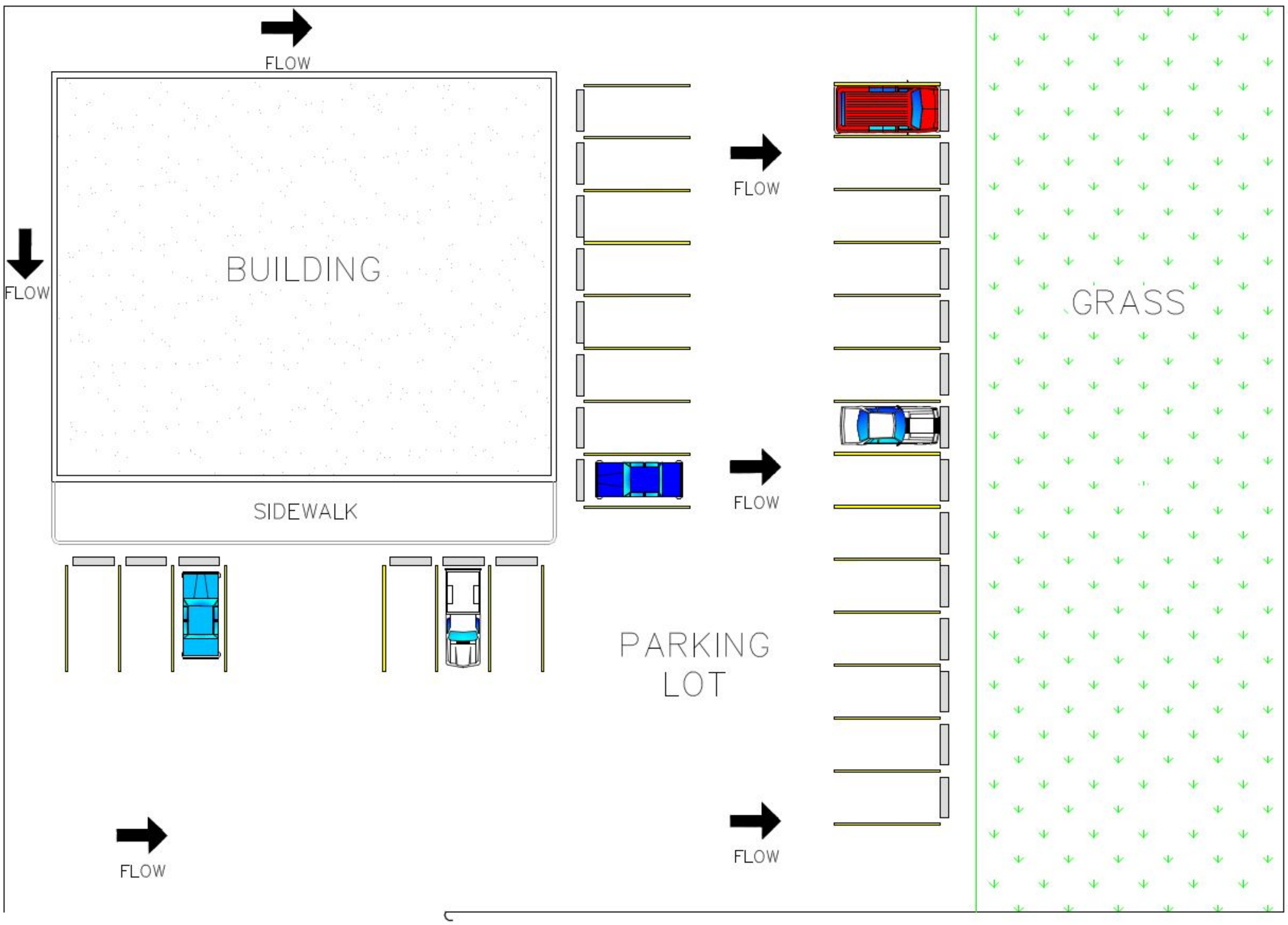


Figure 18.2.4-K Existing conditions.

Example 4 – Infiltration Trench Example *(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)

The 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, the imperviousness is 76%. The WQv requirements only apply to the newly disturbed portion of the site so A = 10,890 square feet. Adding the values to the equation yields the following:

WQv = $(^1/_{12})$(0.60)[0.05 + 0.009(76)]10,890 = 400 cubic feet

Step 4: Calculate the Provided Water Quality Volume (WQv Provided), or storage capacity of Infiltration Trench

WQv Provided= (A)[(Porosity of Media)(Depth of Media) + (height of water above in situ soils)]

Adding the values to the equation yields the following:

WQv Provided= (1,089)[(0.4)(4) + (0.5)] = 2,287 cubic feet

Example 4 – Infiltration Trench Example *(Continued)*

Step 5: Determine Managed Water Quality Volume (MWQv)

Since the infiltration trench has an underdrain below the water level of the WQv stored in the media and drains in less than 24 hours, the management capacity is 30%. Therefore, the MWQv is:

2,287(0.3) = 686 cubic feet

Is all of the WQv managed or treated?

Yes

The MWQv is 686 cubic feet, which is in excess of the required WQv of 400 cubic feet. This GMP manages all of the WQv.

(Skip to Step 8 of the GMP Selection Process.)

Step 8: O&M Documentation

Complete O&M documentation.

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

18.2.5 Infiltration Testing Specifications

Key Considerations:

- Different approaches for:
  - Feasibility
  - Conceptual design
  - Financial Incentives Projects
- May involve field work with safety concerns
  - Excavation safety
  - Shoring of deep test pits

Single-ring infiltrometer infiltration test. (*Photo: URS*)

The purpose of green management practices is to store, treat and infiltrate stormwater into the soil, mimicking natural systems. Subsurface conditions are key in assessing the feasibility of infiltration in the design of green management practices (GMPs). Infiltration capacity testing and design of GMPs that rely on infiltration to treat the stormwater quality volume shall follow the specifications summarized in this chapter. While National Resources Conservation Service (NRCS) soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits. The following infiltration testing options are addressed in this fact sheet:

☑ Single-Ring Infiltrometer
☑ Test Pit
☑ Other Infiltration Testing and Verification Methods

Infiltration Testing Requirements

The following outlines infiltration testing requirements for all GMPs in Jefferson County in order to take credit for infiltration volume as part of the stormwater quality volume (see Chapter 18.2.4 Selection Process). The minimum average infiltration rate for all practices shall be 0.5 inches/hour. Where the minimum infiltration rate is not achieved, design cannot account for infiltration and an underdrain is required. Perched or elbowed underdrains, a minimum of 4 inches in diameter, are recommended to increase exfiltration through increased contact time with native soils. Infiltration tests shall not be conducted in the rain or within 24 hours of significant rainfall events (greater than 0.5 inches), or when the temperature is below freezing.

Infiltration testing performed, including testing procedures followed, shall be documented and submitted as part of the plan approval process to MSD.

Portions of this Section present testing methods at the bottom of an excavation. It is the testing personnel's responsibility to be aware of and take proper health and safety precautions for activities in an excavation. See the U.S. Occupational Health and Safety Administration (OSHA) for guidelines and requirements (www.osha.gov).

Tiered Testing Approach

MSD's tiered approach to infiltration testing recognizes the importance of accurate in situ conditions while screening out sites unsuitable for infiltration practices and thereby reducing soil investigation and testing costs. The following tiers include:

1) Feasibility Analysis
2) Conceptual Design Testing

Minimum testing requirements for each tier are summarized in Table 18.2.5-A.

Qualified Professionals

Infiltration testing shall be conducted by a qualified professional and plans including infiltration testing results must be certified by a professional engineer or professional geologist.

Minimum Infiltration Rates

Minimum infiltration rates for design are specified in GMP fact sheets provided in Section 18.3 of this chapter.

High Water Table

Where a high water table occurs (vertically) within three feet of the plane of infiltration (bottom of GMP), infiltration shall not be considered as part of the water quality volume. Data may be acquired by the NRCS methods or other field methods.

Table 18.2.5-A. Tiered Infiltration Testing Requirements

Green Management Practice Type	Tier 1: Feasibility Analysis	Tier 2: Conceptual Design Testing		Financial Incentive Program Projects (per Section 18.9)
		For initial yields greater than 0.5"/hr	For initial yields less than 0.5"/hr	
Linear practices (i.e. bioswales, interconnected tree boxes, infiltration trenches, etc.)	1 single-ring infiltrometer test per site	All of the following are required: • 1 single-ring infiltrometer test • 1 test pit per 400 linear feet • Minimum 1 infiltration test per test pit of GMP practice	Underdrain required	All of the following are required: • 1 single-ring infiltrometer test* • 1 test pit per 400 linear feet • Minimum 2 infiltration tests per test pit of GMP practice
Non-linear practices (rain gardens, basins, etc.)	1 single-ring infiltrometer test per site	All of the following are required: • 1 single-ring infiltrometer test • 1 test pit per 2500 square feet of practice area • Minimum 1 infiltration test per test pit per GMP **More tests are acceptable as long as additional tests are spaced evenly. An effective infiltration rate should be determined by averaging infiltration tests.	Underdrain required	All of the following are required: • 1 single-ring infiltrometer test* • 1 test pit per 2500 square feet of practice area • Minimum 2 infiltration tests per test pit per GMP **More tests are acceptable as long as additional tests are spaced evenly. An effective infiltration rate should be determined by averaging infiltration tests.

**Includes Conceptual Design testing.*

Shallow Soils/Depth to Bedrock

Thin soil zones and shallow bedrock limit the capacity of GMPs to exfiltrate into native soils. Where shallow soils and depth to bedrock occurs (vertically) within three feet of the plane of infiltration, infiltration shall not be considered as part of the water quality volume. Data may be acquired by NRCS or field methods.

Karst Topography

Sinkholes and karst topography limit options for GMPs, and additional infiltration may cause sinkholes to develop. Where sinkholes or karst features are present onsite, infiltration shall not be considered as part of the water quality volume.

Construction Equipment and Minimizing Compaction

For green management practices designed to infiltrate stormwater runoff, it is essential that soils are not compromised by compaction from construction equipment. Care should be taken to minimize soil compaction throughout the GMP and especially at the plane of infiltration so that infiltration rates of native soils are not impacted. Acceptable excavation methods at infiltration practices include hand labor with shovels or the use of an excavator such as a backhoe or trackhoe (located outside the perimeter or footprint of the practice). Heavy equipment should never be used over existing or the footprint of planned infiltration practices. Prior to site disturbance, the perimeter of the practice should be partitioned off with temporary fencing/tape to keep heavy equipment from crossing the perimeter throughout time of active construction. In cases where the GMP is sufficiently large that equipment must enter it, methods proposed to limit and restore compacted soil must be approved in advance.

Long-term Infiltration Rates

Infiltration rates may decrease over time due to settlement of filter media, compaction, or accumulation of sediment in the practice. To sustain infiltration rates long-term, it is important that a maintenance plan is in place. Regular maintenance should be conducted to optimize operating infiltration rates.

Background and Desktop Analysis

A desktop analysis of soils data, topography, the location of streams, waterbodies, existing/previous land uses, and structures is encouraged to identify potential GMP locations and types. Existing or previous soil investigation or lab data may also be used to support preliminary siting of GMPs and infiltration testing. While NRCS soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits.

Tier 1: Feasibility Analysis

A minimum of one single-ring infiltrometer test must initially be performed on site.

Single-Ring Infiltrometer Infiltration Test

This test method utilizes perforated 200 mm to 250 mm (8-inch to 10-inch) plastic or metal canisters with bottom, set in coarse drainage sand, to minimize disturbance to in-place soils and to prevent siltation of the test hole during testing.

1) Holes in the test canister should be 3 mm (1/8 inch) diameter and spaced on 25 mm (1 inch) centers.
2) Excavate a test hole to the depth of the infiltration plane, or the bottom of the GMP and approximately 25 mm (1 inch) larger diameter and approximately 25 mm (1 inch) deeper than the dimensions of a test canister. If the depth of testing is greater than 18”, it may be necessary to excavate a shallow test pit to conduct testing.
3) Check that the sides of the test hole are not smooth, but scarified.
4) Place coarse drainage sand in the bottom of the hole and place the canister firmly into the hole. The bottom of the hole should be uncompacted.
5) Backfill the space around the canister with soil and tamp the soil into place.
6) Fill canister with water and allow to drain completely or to soak the surrounding soils for a minimum of one hour, whichever occurs first.
7) Re-fill the canister and measure the rate at which the water level drops.
8) Record the infiltration rate as the decrease in depth of water per hour (inches/hour).

Where the feasibility analysis does not meet minimum infiltration criteria, the designer may prefer to the use of an underdrain rather than continue with further testing.

Where the feasibility analysis meets minimum infiltration criteria, the test pits are necessary for conducting infiltration testing per table 18.2.5-A to further verify site information characteristics.

Tier 2: Conceptual Design Testing

Test Pit Infiltration Test

This test method consists of a trench or pit that allows visual observation of the soil horizons and overall soil conditions at a particular location on the site. Multiple test pit observations can be made for a relatively low cost and in a short time period. The use of soil borings shall not be substituted for test pits. Test pits allows in-situ visual observation of soil conditions, where soil borings do not. Soil borings are encouraged to supplement data collection, but cannot be substituted for infiltrometer or test pits.

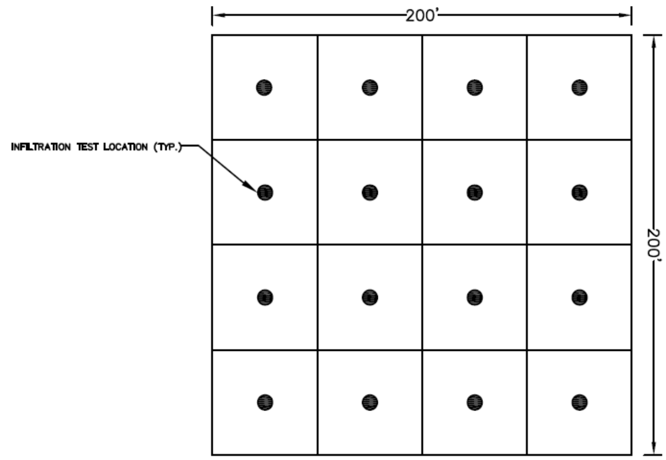
1) Dig a backhoe-excavated trench/pit, 2-1/2 to 3 feet wide, to the proposed depth of the infiltration plane of the practice, or until bedrock or fully saturated conditions are encountered.
2) Safe test pit entry should always be observed. A test pit should never be accessed if it is not safe to do so. OSHA regulations should always be observed.
3) Document soil profile (soil horizons, soil texture and color and depth below ground surface, depth to water table, depth to bedrock, etc).
4) Based on observed field conditions, the qualified professional should consider modifying the proposed infiltration plane of the practice and adjust infiltration testing locations as necessary.
5) Perform Single-Ring Infiltrometer test (above) at depth of infiltration plane of the proposed practice.
6) Soil samples may be collected at various horizons for additional analysis at the designer's discretion.
7) After testing is complete, re-fill test pit with original native soils and stake the location of the test pit.

Other Infiltration Testing and Verification Methods

Other infiltration testing standards that are acceptable include ASTM D3385—09 Standard Test Method for Infiltration Rate of Soils in Filed Using Double Ring Infiltrometer.

Verification methods such as soil borings may be used to verify site conditions where final locations of GMPs are adjusted and do not fall within the original testing location. Test results must verify that the soil conditions are the same as those from the original test results.

Designers should also consider construction access and



staging during the design process. Activities that could compact soils where GMPs are sited should be avoided. Where site constraints make this unavoidable, the designer shall compensate accordingly in the design of the GMP.

Typical Infiltration Basin Infiltration Test Pattern

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18.2.6 Pretreatment

Infiltration trench at University of Louisville School of Business

Pretreament practices are recommended for green infrastructure to facilitate long-term maintenance and extend the life of the practice. Protection of green infrastructure from erosive velocities and clogging from fines and sediment is critical to sustain designed soil infiltration rates.

Pretreatment practices are required for infiltration practices such as infiltration trenches to slow down and spread out flow, as well as improve ease of maintenance for cleaning out fines and sediment. When fines and sediment enter infiltration trenches, the stone and underlying material clogs, reducing infiltration capacity. Once this material becomes clogged, the practice must be excavated and re-installed.

The following pretreatment measures may be used:

- Forebay
- Vegetated strip
- Proprietary water quality unit
- Catch basin inserts

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18.2.7 Educational Signage

Demonstration rain garden at the intersection of Swan Street and Ellison Avenue

Green infrastructure offers unique multi-purpose and beneficial opportunities for stormwater capture and treatment, sewer overflow mitigation, heat island mitigation, carbon footprint reduction, and community beautification.

MSD has promoted the use and awareness of green infrastructure through educational signage at demonstration projects. Awareness of the benefits of green infrastructure not only has value to the public, but is also important for property owners and landscape maintenance contractors.

MSD offers a series of educational sign templates that are available for public use to promote your investment in green infrastructure and benefits to the community. The following sign templates are available:

- Rain garden
- Tree boxes
- Permeable pavers
- Green parking lots

GREEN INFRASTRUCTURE IMPROVES THE QUALITY OF OUR WATERWAYS

The goal of green infrastructure is to capture and infiltrate rainwater onsite, as a cost-effective solution for reducing sewer overflows.

HOW TREE BOXES MAKE A DIFFERENCE

Tree boxes are installed along urban streets, providing an area for rainwater to collect and absorb into the ground. They reduce the amount of rainwater taking up space in the sewer system, filter pollutants and increase the tree canopy. On average, one tree captures 1,350 gallons of stormwater runoff during a typical rainfall year.

COMBINED SEWER SYSTEM

The combined-sewer system—usually located in older sections of our city—has one pipe that conveys a combination of wastewater and stormwater to a water quality treatment center for cleansing and release back into one of our local waterways. During dry weather these pipes convey only wastewater. In heavy rains, the system can become overloaded with rainwater. Then a mixture of rainwater and wastewater can overflow into our waterways. Green infrastructure helps solve this problem by soaking up the rainwater before it reaches the system.

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WHY TREE BOXES ARE IMPORTANT

FOR MORE INFORMATION VISIT: MSDGREEN.ORG

GREEN INFRASTRUCTURE IMPROVES THE QUALITY OF OUR WATERWAYS

The goal of green infrastructure is to capture and infiltrate rainwater onsite, as a cost-effective solution for reducing sewer overflows.

HOW PERMEABLE PAVERS MAKE A DIFFERENCE

Permeable pavers help reduce stormwater runoff by allowing rainwater to filter through the paved surface into the soil below. This allows natural filtration of harmful pollutants, which could end up in our waterways.

COMBINED SEWER SYSTEM

The combined-sewer system—usually located in older sections of our city—has one pipe that conveys a combination of wastewater and stormwater to a water quality treatment center for cleansing and release back into one of our local waterways. During dry weather these pipes convey only wastewater. In heavy rains, the system can become overloaded with rainwater. Then a mixture of rainwater and wastewater can overflow into our waterways. Green infrastructure helps solve this problem by soaking up the rainwater before it reaches the system.

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WHY PERMEABLE PAVERS ARE IMPORTANT

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GREEN INFRASTRUCTURE IMPROVES THE QUALITY OF OUR WATERWAYS

The goal of green infrastructure is to capture and infiltrate rainwater onsite, as a cost-effective solution for reducing sewer overflows.

HOW GREEN PARKING LOTS MAKE A DIFFERENCE

Green parking lots can use several different green infrastructure solutions. Permeable pavers allow rainwater to seep through pavement, into the soil below. A rain garden is a wide, shallow bowl-shaped area filled with native plants and amended soil. They allow for the absorption of stormwater runoff.

COMBINED SEWER SYSTEM

The combined-sewer system—usually located in older sections of our city—has one pipe that conveys a combination of wastewater and stormwater to a water quality treatment center for cleansing and release back into one of our local waterways. During dry weather these pipes convey only wastewater. In heavy rains, the system can become overloaded with rainwater. Then a mixture of rainwater and wastewater can overflow into our waterways. Green infrastructure helps solve this problem by soaking up the rainwater before it reaches the system.

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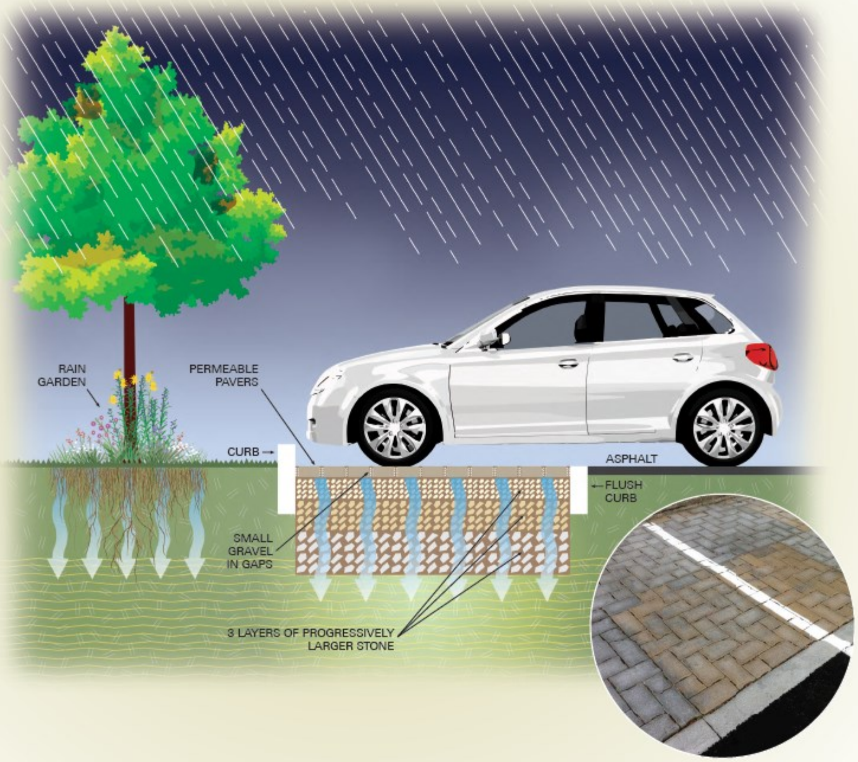
WHY GREEN PARKING LOTS ARE IMPORTANT



FOR MORE INFORMATION VISIT: MSDGREEN.ORG

GREEN INFRASTRUCTURE IMPROVES THE QUALITY OF OUR WATERWAYS

The goal of green infrastructure is to capture and infiltrate rainwater onsite, as a cost-effective solution for reducing sewer overflows.

HOW RAIN GARDENS MAKE A DIFFERENCE

Rain gardens are shallow landscaped areas shaped like bowls that capture rainwater runoff. By diverting stormwater into rain gardens, we improve the health of our local waterways and create beautiful gardens for the community.

COMBINED SEWER SYSTEM

The combined-sewer system—usually located in older sections of our city—has one pipe that conveys a combination of wastewater and stormwater to a water quality treatment center for cleansing and release back into one of our local waterways. During dry weather these pipes convey only wastewater. In heavy rains, the system can become overloaded with rainwater. Then a mixture of rainwater and wastewater can overflow into our waterways. Green infrastructure helps solve this problem by soaking up the rainwater before it reaches the system.

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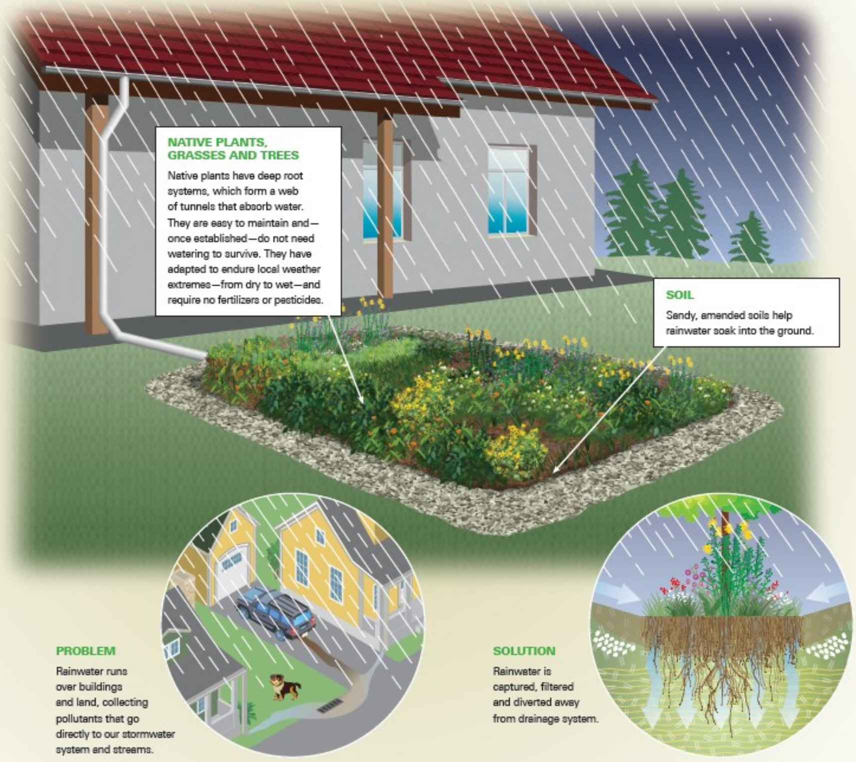
HOW RAIN GARDENS MAKE A DIFFERENCE



FOR MORE INFORMATION VISIT: MSDGREEN.ORG

18.3.1 Introduction

Native flowers and grasses line a sidewalk.

This section provides design standards and requirements for green infrastructure. Information on each green management practice are provided in the fact sheets, as well as:

- Benefits and limitations
- Application and site feasibility
- Design criteria
- Application and Site Feasibility Criteria
- Step by Step Design Procedures

MSD has developed companion documents to support the design and plan submittal process. Plan review checklists and design calculation sheets are available at www.louisvillemsd.org.

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Metropolitan Sewer District

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Green Management Practice (GMP) Fact Sheet

18.3.2 Rain Gardens

Residential landscaped rain garden with native and cultivar plants

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
- Downspout conveyance

Key Considerations:

- Use of native vegetation
- Overflow structure
- Infiltration

Cost: Low
Maintenance: Low

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	Partial Benefit
Stormwater Conveyance	Low or Unknown Benefit
Peak Flow Control	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

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

Rain gardens, also referred to as bioretention/biofiltration cells or bioswales/linear rain gardens 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. They can also take form in a raised landscape bed, or stormwater planter box. 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

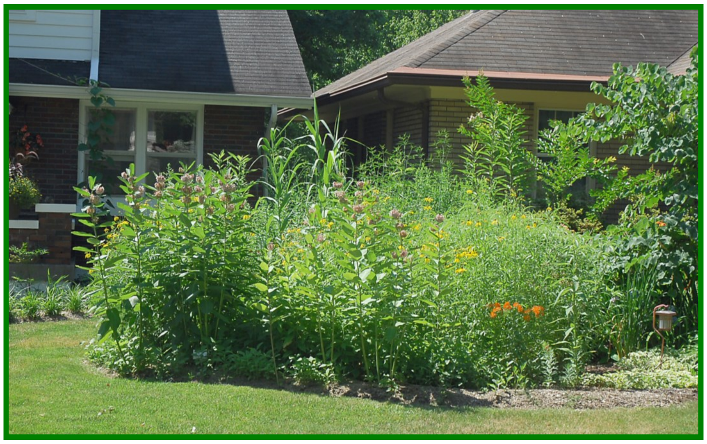
- Good retrofit capability
- Reduces volume of stormwater runoff
- Provides infiltration and groundwater recharge, filtering pollutants and reducing runoff volume
- Suitable for runoff from highly impervious areas
- Increases biodiversity by providing urban habitats for wildlife

Disadvantages/Limitations

- Location constraints (utilities, shallow groundwater, bedrock, sinkholes, down gradient from buildings/ basements, overflow pathway, etc.)
- Maintenance commitment (basic gardening/landscape maintenance)
- Available space for capture of target volume
- Not for slopes >4%.

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.louisvillemsd.org.



A residential rain garden

Concept flow-through planter box rain garden

Physical Requirements

Key physical considerations are:

- Soil type and infiltration—Rain gardens should drain within 48 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. Sandy, permeable soils promote infiltration but are also susceptible to erosion, and should be protected in applications receiving or directing stormwater conveyance.
- 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.
- Slopes—Slopes affect flow rates, bioswale/linear rain garden capacities, infiltration rates, and erosion
- Building foundations—Sufficient space is required from building foundations. Where a gravel infiltration trench is used in a rain garden, 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.

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. For a summary of design parameters, see Table 18.3.2-A.

Design criteria to consider includes:

- Type
- Location
- Flow capacity, velocity and freeboard
- Erosion prevention
- Slopes
- Inlet and pretreatment
- Sizing and ponding area
- Soil composition
- Plant selection
- Outlet design
- Mosquito control

Type

Based on site characteristics and desired aesthetics, select the type of rain garden, i.e. traditional rain garden, planter box or linear rain garden/bioswale.

Rain garden at Louisville & Jefferson County MSD main office with naturalized native plantings.

A linear rain garden, or bioswale, conveys stormwater runoff from the building's downspouts

Flow-through rain garden planter

Stepping stones allow accessibility across this linear rain garden/ bioswale

Planters: Where a raised bed or box is desired, a planter box type of rain garden may be suitable for the site. 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. Typical sections of open and closed box designs are shown in Exhibits 18.3.2-G and 18.3.2-H. If the in-situ soil infiltration rate is less than 0.5 inches per hour, then an underdrain is required. Underdrains should be designed to be a minimum of 4 inches in diameter. 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. A planter should not accept drainage from more than 0.25 acres of impervious area; a smaller drainage area is encouraged for better performance.

Linear Rain Gardens or Bioswales: Where conveyance or mild slopes exist on site, linear rain gardens or bioswale type of rain gardens may be suitable. Bioswales are generally shallow, wide, and gently sloped, and contain deep rooted native vegetation that helps slow and filter stormwater.

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 multiple 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 erosion or sediment flow are not suitable locations for rain gardens because the structures and soil may become clogged. In addition, rain gardens should be placed at least 10 feet from building foundations and underground utilities, with the exception of closed or flow-through planter boxes. See Exhibit 18.3.2-C for a rain garden typical cross-section.

Flow Capacity, Velocity and Freeboard

Since linear rain gardens, or bioswales, and planters can be conveyance features, they are designed to slow and detain small storm events while also safely bypassing large storms to protect the rain garden from erosion. Construction phasing is necessary to prevent erosion prior to establishment of rain garden plant material. The rain garden must be protected and kept offline until the contributing watershed is stabilized. Erosion upstream will deposit sediment in the rain garden, clogging amended soils and requiring reconstruction of the rain garden.

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

Erosion Prevention

Linear rain gardens, or bioswales, conveying stormwater 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.

Slopes

Site topography should be considered in bioswale design, including slope and cross-sectional area to maintain non-erosive velocities. Typically, slopes should be less than 2%. In areas with slopes between 2% and 4%, check dams or weirs should be placed perpendicular to the flow to increase detention and extend time for infiltration. Rain gardens or bioswales are not suitable for slopes greater than 4%. Placement of check dams or weirs should include scour protection to limit erosion. See Exhibits 18.3.2-L, M, N, O, & P for check dam placement and bioswale design layouts.

Linear rain garden/bioswale with rustic log check dams

Linear rain garden/bioswale with naturalized native plants

Inlet and Pretreatment:

Pretreatment eases 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 is needed to facilitate maintenance and removal of accumulated sediment and to prevent 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 18.3.2-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 12 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 must be equal to or greater than the Water Quality Volume (WQv).

See Table 18.3.2-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. During grading, care should be taken that soil is not compacted.

For traditional rain gardens on flat surfaces or open box rain garden planters, it is important to evaluate in situ soil conditions and determine the need for an underdrain and engineered soils (slopes less than 2%):

- Engineered Soils Option 1: If the primary purpose is to promote infiltration and improve water quality, it is important that soils are not compacted. Soils may be amended with an engineered soil mix. This option works best with well draining native soils.
- 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.

For linear rain gardens, or bioswales, that convey stormwater runoff, it is important to consider the stability of the soil under erosive stormwater velocities. Evaluate in situ soil conditions and consider the following options when designing the soil composition for a linear rain garden or a bioswale (slopes between 2% and 4%):

- 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 Exhibit 18.3.2-I.
- 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 Exhibit 18.3.2-J.
- 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 Exhibit 18.3.2 K.

Rain garden with native and cultivar plants

Check dams should be used to pond water within linear rain gardens to slow flows, prevent erosion and promote infiltration. Typical check dam construction materials are earth, stone, river rock, and rot resistant timbers. During construction, the system should be kept off-line until the watershed is fully stabilized, and slopes should be stabilized with erosion control mats or native plant mats to protect from erosion and downstream clogging of the system.

Engineered Soils: 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. If the infiltration rate is less than 0.5 inches per hour an underdrain is required. Underdrains should be designed to be a minimum of 4 inches in diameter. 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 Engineered Soils with an 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 in this situation 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. Where filter fabric is necessitated, choose non-woven filter fabric. Underdrains should be designed to be a minimum of 4 inches in diameter. Cross-sections of soil composition options and underdrain schematics are shown in Exhibit 18.3.2-B and 18.3.2-I.

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.

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. Multch options include shredded bark mulch, which is preferred to maximize moisture and nitrogen retention, and stone mulch, which is preferred in areas where steeper slopes and higher velocities are present. 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.

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.

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. See Exhibit 18.3.2-L.

Mosquito Control

By design, rain gardens should not be in danger of becoming a breeding ground for mosquitoes. It takes 10 to 14 days after a mosquito hatches, for it 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.

Rain Garden Application and Site Feasibility Criteria

Table 18.3.2-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 4% 1%-2% preferred Where greater than 4%, use terracing techniques to achieve slopes as needed
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 • Bypass or design overflow of 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
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 48 hours • Installation of check dams to provide adequate residence time
Pretreatment	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 depends on soil composition.
Storage Capacity	Rain garden total volume should be equivalent to the Required Water Quality Volume. Required WQv (cubic feet) = $(^1/_{12})(RE_{WQ_v})(Rv)(A) - (WQ_{VR})$, where • RE_{WQ_v} = required water quality volume rain event (refer to chapter 18.2.4) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the rain garden (ft^2), with a maximum drainage area to rain garden area ratio of 10:1. Ratios greater than 10:1 will be reviewed on a case-by-case basis. • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area The design volume provided by a linear rain garden or 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

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. Consider types of rain gardens, including a linear rain garden or bioswale that will convey water, or a rain garden planter. 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, peak flow rate 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 18.3.2-A can be used in this form:

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

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

A = (WQv)/[d(P)+h] (see table 18.3.2-A).

Linear rain gardens, or bioswales, should achieve the residence time provided in table 18.3.2-A. Bioswales must be designed to safely bypass or convey flow rates produced by larger storm events with adequate freeboard and minimum erosion. Larger storms (2-, 10-, and 100-year) should be modeled to size bypass, 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 18.3.2-A. Create a rough layout of the rain garden dimensions including existing trees, utility lines, and other obstructions.

Step 4: Determine the pretreatment volume

Pretreat with forebay, weir or check dam, and scour protection. Size the forebay per Table 18.3.2-A. The forebay storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Step 5: Determine rain garden parameters

Size bottom width, depth, length and slope necessary to achieve the residence time and/or store the WQv per Table 18.3.2-A.

Step 6: Determine check dam needs

For linear rain gardens or bioswales that exceed slope requirements in table 18.3.2, 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

For linear rain gardens and bioswales, based on the average 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

For linear rain gardens and bioswales, based on the average 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 bypass or convey safely. This includes meeting freeboard requirements per Table 18.3.1-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 native vegetation and landscaping plan

Choose deep rooted native plants or non-invasive 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.

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

18.3.3 Constructed Wetlands

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

Constructed wetland

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
Peak Flow Control	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit

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 help treat the stormwater. Wetland systems can store 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 aquatic and wildlife species
- 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 surface area of at least 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 Exhibit 18.3.3-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—Utilize a 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
- Slope—Elevation differences are typically 2-5 feet between inlet and outlet

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 18.3.3-A.

Design criteria to consider includes:

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

Pocket wetland

Configuration, Layout and Slope

Common constructed wetlands components include the following:

- Access
- 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
- Hydraulic connectivity

These components are shown in Exhibits 18.3.3-B and 18.3.3-C. 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 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 and/or naturally colonizing amphibians and insects. 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.

Constructed wetland with native plantings

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 and/or naturally colonizing amphibians and insects in the micropool can also help manage mosquito larvae production within the wetlands.

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

Constructed wetland with soft rush

WQv storm event. In addition, the wetland or pond should drain to the normal pool level within 36 hours following the rain event.

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, dry zones, and a temporary cover seed (see Exhibit 18.3.3-D). Select plants appropriate for each zone.

Choices available for planting the wetlands include seed, rhizomes, bare root stock, potted plants, plugs 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 have an increased survival rate. 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.

Construction phasing is necessary to prevent erosion prior to establishment of plant material. During construction, the system should be kept offline until the contributing watershed is fully stabilized, and slopes should be stabilized with erosion control mats or native plant mats to protect from erosion.

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 equipment access should be considered while in the configuration/layout phase of design.

Constructed wetland cell in Buchel

Constructed Wetlands Application and Site Feasibility Criteria

Table 18.3.3-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 (cubic feet) = $(^1/_{12})(RE_{WQV})(Rv)(A) - (WQ_{VR})$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.2.4) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the wetland (ft^2) • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area

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 18.3.3-A can be used in this form: WQv (ft^3) = $(RE_{WQV})(Rv)(A/12)$- (WQ_{VR}). 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 18.3.1-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 18.3.3-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 18.3.3-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 18.3.3-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 and densities for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources and alternative sources for plant and seed mixtures

Louisville and Jefferson County
Metropolitan Sewer District

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Green Management Practice (GMP) Fact Sheet

18.3.4 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

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
Peak Flow Control	Partial Benefit

Runoff Volume Reduction

Runoff Capture	Low or Unknown 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 and they retain the stormwater runoff for at least 24 hours. 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

- Projects may require complying 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 and detention of the stormwater runoff. 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. See the last page for Step by Step Green Wet Basins Design Procedures.

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
- Outlet Structure—outlet structure designed to provide retention for the 2, 10, and 100-yr storms.

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 following criteria should be included in the design of green wet basins. For a summary of design parameters and site feasibility criteria, see Table 18.3.1-A on page 5.

Design criteria to consider for green wet basins include:

- Conveyance
- Soils
- Landscaping/plant selection
- Slopes
- Outlet Structures
- Forebay
- Safety

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 Exhibit 18.3.4-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/Side Slopes

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

Basin in Buchel has a naturalized buffer 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.

Wet basin with small buffer

Forebay

Excessive sediment accumulation in a green wet basin 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 and/or natural colonizing amphibians/ insects. 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.

Outlet Structure

The outlet structure should include orifices or weirs (or a combination there of) to provide at least 24 hours of detention of the 2, 10, and 100 year storms. Considerations should be given to protecting the orifices from getting clogged with debris.

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.

Green Wet Basins Application and Site Feasibility Criteria

Table 18.3.4-A.

Design Parameter	Criteria
Drainage Area	At least 25 acres of upstream drainage area to maintain water levels during dry weather; capable of passing the 100 year storm and a minimum of 3 feet deep
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 and cover approximately 25% of total pond surface
Conveyance	Minimum length to width ratio of 2:1 with 3:1 or more preferred and emergency spillway
Soil Permeability	Soil permeability should be ≤ 0.14 inches/hour
Pretreatment—Forebay	10% of the water quality volume
Design Flows and Conveyance Capacity	Detain for at least 24 hours and pass the 2-, 10- and 100-year storms with at least one foot of freeboard. Detention basins shall drain back to normal pool within 36-hours after the storm event per MSD Design Manual.

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 for at least 24 hours 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 18.3.4-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, 10, and 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

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18.3.5 Green Dry Basins

Green dry basin concept rendering

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

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	◩
Nitrogen	◩
Metals	◩
Pathogens	□
Floatables	◩
Oil and Grease	◩
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	◩
Infiltration	□
Stormwater Conveyance	□
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 basins 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
- 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 following criteria should be included in the design of green dry basins. For a summary of design parameters, see Table 18.3.5-A on page 7.

Design criteria to consider for green dry basins include:

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

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 prevent the re-suspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 4-6 feet. 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. Reference Table 18.2.4-C for drawdown requirements.

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.

Green dry basin concept rendering

Green Dry Basins Application and Site Feasibility Criteria

Table 18.3.5-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	10% of the required water quality volume
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 18.3.5-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 at 10% of the required water quality volume.

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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Green Management Practice (GMP) Fact Sheet

18.3.6 Extensive Green Roof

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

Extensive green roof planted with vegetables (foreground) and sedum (background)

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
Peak Flow Control	Significant Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit

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. Fully saturated, extensive green roofs weigh approximately 15-25 pounds per square foot. 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, given that structural considerations are met.

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 Exhibit 18.3.6-A for a typical exstensive green roof cross-section. For a summary of design parameters, see Table 18.3.6-A on page 6.

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. If the roof is intended for access by building occupants or patrons, beds

Newly planted sedum on extensive green roof

Established sedum plants on extensive green roof 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.

Roof garden patio includes a green house and extensive green roof planted with vegetables and herbs

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 Exhibit 18.3.6-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.

Installation of plants on an extensive green roof

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.

Extensive green roof showing drainage slots and non-vegetated buffer along roof perimeter

Stormwater treatment train flows from green roof to cisterns to a bioswale

Excess drainage from extensive green roof flows from drainage layer slots over non-vegetated buffer to roof downspouts, which discharge into a rain garden

Extensive green roof with non-vegetated access path and buffers around vents

Extensive Green Roof Application and Site Feasibility Criteria

Table 18.3.6-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 (cubic feet) = $(^1/_{12})(RE_{WQV})(Rv)(A)$- (WQ_{VR}), where • RE_{WQV} = required WQv rain event (refer to Chapter 18.2.4) • 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) • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
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.

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 18.3.6-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 18.3.6-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

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 18.3.6-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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Green Management Practice (GMP) Fact Sheet

18.3.7 Intensive Green Roof

Intensive (deep) and extensive (shallow) green roof beds

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
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. Intensive green roofs weigh approximately 25-80 pounds per square foot. 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 Exhibit 18.3.7-A for a typical cross-section of an intensive green roof planting. For a summary of design parameters, see Table 18.3.7-A.

Intensive green roof beds, planted with evergreen shrubs

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

Application and Site Feasibility Criteria

Table 18.3.7-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 (cubic feet) = $(^1/_{12})(RE_{WQV})(Rv)(A) - (WQ_{VR})$, where • RE_{WQV} = required WQv rain event (refer to Chapter 18.2.4) • $Rv = 0.05 + 0.009(I)$ where ♦ I = impervious cover of the contributing drainage area in percent • A = contributing drainage area to the green roof (ft^2) • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
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.

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 18.3.7-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 18.3.7-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

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 18.3.7-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.

Louisville and Jefferson County Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.3.8 Permeable Pavers

Typical Implementation Areas:

- Parking lot stalls and overflow parking
- Crosswalks, sidewalks, multi-use paths

Key Considerations:

- Soil type and stability
- Grade
- Traffic volume
- Type of desired drainage
- Storage retention/infiltration
- Ratio of drainage area to area of pavers

Cost: High
Maintenance: High

Installation of permeable interlocking concrete pavers

Stormwater Management Benefits

Pollutant Reduction

Sediment	Partial
Phosphorus	Low or Unknown
Nitrogen	Low or Unknown
Metals	Partial
Pathogens	Low or Unknown
Floatables	Low or Unknown
Oil and Grease	Low or Unknown
Dissolved Pollutants	Low or Unknown

Hydrologic Characteristics

Surface Flow Reduction	Significant
Infiltration	Significant
Stormwater Conveyance	Low or Unknown
Peak Flow Control	Low or Unknown

Runoff Volume Reduction

Runoff Capture	Significant

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

Permeable pavers are pavement surfaces that promote infiltration of stormwater through gaps in the system. Pavers can be used in block or grid-systems, 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. Permeable Pavers improve water quality through:

- ☑ Effective removal of light sediment and pollutants
- ☑ Possible reduction of stormwater runoff through infiltration to surrounding soils
- ☑ Surface flow reduction of peak flows

Advantages/Benefits

- Reduces volume of stormwater runoff
- Reduces impermeable areas
- Reduces need for drain pipe
- Longer life than traditional pavement
- Reusable product
- Reduces need for detention space
- Attractive/aesthetic pavement options

Disadvantages/Limitations

- Higher cost of pavers versus traditional concrete or asphalt pavement
- Geotechnical exploration required
- Maintenance requirements
- Specialized knowledge required for proper installation
- Not recommended for use in roadway
- Not recommended under tree canopy

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 (Geologist or Engineer) with geotechnical experience shall evaluate the soil to determine the proper design for the site being considered for permeable pavers. The Engineer shall determine the capacity, permeability and the soil type of the selected site. It is recommended that samples be taken from the site prior to construction to be used as a reference to ensure proper material is being used. This will help contractors be consistent in providing the specified aggregate during construction. To minimize the frequency and amount of needed maintenance, it is recommended that strict silt control measures be used. By keeping the site clean during construction and keeping vegetation along the application will reduce clogging on the practice once the construction is complete. See section 10.5.20 for the aggregate specifications. 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 18.3.8-A below summarizes typical CBR ranges based on soil classification.

Table 18.3.8-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

Physical Site Considerations

Minimum site requirements:

- The ratio of Drainage Area:Paver Footprint Area should not exceed 10:1. Ratios greater than 10:1 will be reviewed on a case-by-case basis.
- 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

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 Exhibits 18.3.8-A through 18.3.8-C for permeable pavers typical sections. For a summary of design parameters, see Table 18.3.8-B. Consider the following criteria when using permeable pavers for a green management practice:

- Intended Use
- Storage Capacity
- Slopes (Subsoil and Pavement)
- Soil Stabilization
- Edge Restraint
- Base Design
- Choker Course
- Permeable Paver Selection
- Frost Heave Consideration
- Outlet Design
- Maintenance

Intended Use

Intended use is a key consideration when selecting the type of permeable paver. This fact sheet addresses brick, concrete, concrete/grass grid, gravel and articulated concrete block paver types. Intended use will drive the selection of paver type, for example grass pavers would be suitable for overflow parking, but not for heavily traveled surface roads. Site specific considerations should be evaluated per this fact sheet and discussed with the product manufacturer.

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.

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 18.2.4).

The WQv provided by the designed permeable paver system can be calculated using the equation in Table 18.3.8-B. The WQv provided should meet or exceed the required WQv.

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 subsoil have a 0% slope and the surface have a 0.5% slope if it is at all possible. For subsurface slopes greater than 2%, benching is required.

Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with permeable pavers 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, geogrid 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 geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid 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 in the pavement system over time. Any geogrid used in conjunction with the permeable pavers shall include the following geogrid specifications, at a minimum:

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

Edge Restraint

An edge restraint is a barrier around the perimeter of the permeable pavers. It must be made of concrete and be adjacent to asphalt and other paved surfaces. This feature can be placed flush with the top of the pavers so that it can be driven over if overflow is desired, but must adhere to Louisville Metro/ADA requirements. 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. Edge restraints are required for brick, concrete, and articulated concrete block/ paver types.

Mechanical installation of permeable interlocking concrete pavers

Installation of permeable interlocking concrete pavers

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 geogrid 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 geogrid is recommended to be placed between the two layers of stone in the base layer. The second layer of stone consists of double washed (with quarry certification letter confirming the stone was double washed) No. 57 stone and should be placed directly upon the geogrid 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). See section 18.4.2, Aggregate Specifications, for additional guidelines on the aggregate used for this practice. 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. Choker Course should be used for brick, concrete, and articulated concrete block pavers. Choker course may be omitted provided manufacturer specifications given that pavers can produce a level surface without a choker course.

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 roads 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, paths, and utility access

A snow plow removing snow from pavers

Installation of permeable articulated concrete block mats

- Emergency access lanes

Gravel (Course Graded-Well Draining)

- Made of natural materials
- Suitable for trails, parking and storage
- Emergency access lanes

Articulated Concrete Block

- Made of natural materials
- Suitable for roads, walking 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.

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. Underdrains should be designed to be a minimum of 4 inches in diameter. Perched or elbowed underdrains (Exhibit 18.3.8-B) are encouraged to allow for temporary storage and groundwater infiltration. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

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.

Construction of a green parking lot

Permeable Pavers Application and Site Feasibility Criteria

Table 18.3.8-B.

Design Parameter	Criteria
Size (Area & Depth)	The ratio of drainage area to area of pavers should be small (10:1). Based upon the design storage capacity and the following equation: WQv (ft^3) provided=(A) [(p1)(d1)] *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 (% void) • d1 =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 be inspected by an Engineer with geotechnical experience • Geogrid 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(cubic feet) = ($^1/_{12}$)(RE_{WQV}) (R_V) (A)- (WQ_{VR}), where
	
	• WQv required = Required WQv (ft3)
	• RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.2.4)
	• 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)
	• WQ_{VR} = ($^1/_{12}$)(RE_{WQV})(R_V)(IA_R)
	  ♦ Where IA_R = reduced impervious area

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 ft^3, the storage capacity equation from Table 18.3.8-B can be used in this form:

$$WQv\ (ft^3) = REWQV\ (RV)\ (A/12) - (WQ_{VR}),$$

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.

$$WQv\ (ft^3)\ provided = (A)\ [(p1)(d1)]$$

*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: Layout the Site

Mark the area of the site where permeable pavers will be placed, to minimize soil disturbance and compaction.

Step 4: 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 5: Excavate the Subsoil

Excavate the site to the depth shown in the design. Extra care should be taken not to compact the subsoil.

Step 6: Soil Stabilization

Geogrid 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. Geotextile fabric may be used in conjunction with the geogrid if recommended by the engineer for soils separation between the aggregate and subsoil but shall not be used as a soil stabilization device.

Step 7: Edge Restraint (for Articulated Concrete Blocks only)

The edge restraint should be placed around the perimeter of the permeable pavers; this serves as a lateral load confining barrier. 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. 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 8: 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 9: Choker Course

The choker course is placed on top of the base layer and serves as a leveling surface to place pavers on. It 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 10: 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 11: 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 (minimum 4 inches in diameter) that run longitudinal with the pavers to remove stormwater runoff. Perforated pipes may either be at the base of the aggregate or at some intermediary level to allow for temporary storage.

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

Green Management Practice (GMP) Fact Sheet

18.3.9 Pervious Concrete

Typical Implementation Areas:
- Parking lot parking stalls
- Sidewalks
- Multi-use paths

Key Considerations:
- Soil type and stability
- Traffic volume
- Type of desired drainage

Cost: Medium
Maintenance: Medium

Installation of Pervious Concrete

Stormwater Management Benefits

Pollutant Reduction	
Sediment	◩
Phosphorus	□
Nitrogen	□
Metals	◩
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Hydrologic Characteristics	
Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	□
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. It is recommended to contact the Kentucky Ready Mix Concrete Association to identify resources to oversee proper installation (www.nrmca.org). The drainage of the stormwater through the pavement reduces the volume of stormwater entering the storm sewer system. Pervious Concrete improves water quality through:

- ☑ Removal of light sediment and pollutants
- ☑ Reduction of stormwater runoff through infiltration to surrounding soils
- ☑ Surface flow reduction of peak flows

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 recommended for use in roadway
- Not recommended under tree canopy
- 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 Feasibility

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 0.5 in/hr are suitable for subsoil material.

Physical Site Considerations

Minimum feasibility requirements:

- The ratio of Drainage Area:Paver Footprint Area should not exceed 10:1. Ratios greater than 10:1 will be reviewed on a case-by-case basis.
- Areas should have permeable soils (minimum 0.5 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 18.3.9-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 18.2.4).

Installation of pervious concrete

The WQv provided by the designed pervious concrete system can be calculated using the equation in Table 18.3.9-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. For subsurface slopes greater than 2%, benching is required.

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 geogrid 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 geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid 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 geogrid used in conjunction with the permeable pavers shall include the following specifications, at a minimum:

Geogrid Specifications:

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid 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; with quarry certification letter confirming the stone was double washed) 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

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 Exhibits 18.3.9-A through 18.3.9-D on page 5 for typical sections of pervious concrete pavement.

Aggregate

No. 8 and/or No. 9 double washed stone (with quarry certification letter confirming the stone was double washed) 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 Exhibit 18.3.9-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. Underdrains should be designed to be a minimum of 4 inches in diameter. See Exhibit 18.3.9-D for a typical section of pervious concrete with an underdrain system. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

Pervious concrete surface (Photo: Kentucky Concrete Pavement Association)

Pervious concrete at Louisville Fire Station

Green striping is a public education tool at this “green” parking lot

Pervious Concrete Application and Site Feasibility Criteria

Table 18.3.9-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) • p1 = porosity of base layer (% void) • d1 = 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. A separation of less than 15 feet will be reviewed on a case-by-case basis based on the geotechnical evaluation of the soil provided by a Professional Engineer.
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 a Civil Engineer with geotechnical experience Geogrid 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)- (WQ_{VR}), where • WQv required = Required WQv (ft^3) • RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.2.4) • 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) • WQ_{VR} = ($^1/_{12}$)(RE_{WQV})(R_V)(IA_R) ♦ Where IA_R = reduced impervious area

Pervious Concrete Construction Procedure

Table 18.3.9-B.

Step No.	Description
Step 1: Lay out 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	Geogrid will be placed on the subsoil as a soil stabilization device. Only approved geogrid that meets the minimum specifications may be used. Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid 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 (with quarry certification letter confirming the stone was double washed). 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 ft³, the storage capacity equation from Table 18.3.9-A can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12) - (WQ_{VR})$$

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.

$$WQv\ (ft^3)\ provided = (A)\ [(p1)(d1)]$$

*Note: this formula only applies if the concrete surface and sub soil have a 0% slope.

Construction of a pervious concrete sidewalk

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

Geogrid 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. Geotextile fabric may be used in conjunction with the geogrid 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 (minimum 4 inches in diameter) 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

18.3.10 Porous Asphalt

Iroquois Amphitheater

Typical Implementation Areas:

- Parking lot stalls
- Sidewalks
- Bicycle paths and multi-use paths

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	□
Peak Flow Control	□
Runoff Volume Reduction	
Runoff Capture	■

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

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. Porous Asphalt improve water quality through:

☑ Removal of light sediment and pollutants
☑ Possible reduction of stormwater runoff through infiltration to surrounding soils
☑ Surface flow reduction of peak flows

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 recommended for use in roadway
- Not recommended under tree canopy

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

Kentucky Horse Park, Lexington KY

Kentucky Horse Park, Lexington KY

Design Criteria:

The design of porous asphalt includes several elements to ensure proper drainage and infiltration of the stormwater. See Exhibits 18.3.10-A through 18.3.10-D for asphalt pavement typical section designs. For a summary of design parameters and physical site requirements, see Table 18.3.10-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 18.2.4). The WQv provided by the designed porous asphalt system can be calculated using the equation provided in Table 18.3.10-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. For subsurface slopes greater than 2%, benching is required.

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 geogrid 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 geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the stone

Construction of Porous Asphalt

reservoir. The geogrid 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 geogrid used in conjunction with the porous asphalt shall include the following specifications, at a minimum:

Geogrid Specifications:

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid 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 18.3.10-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 18.3.10-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

Drainage Pipes

Stone Reservoir with Drainage Pipes

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 use of trenches or an underdrain system must be implemented.

<u>Trenches</u>

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.

<u>Underdrain Systems</u>

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. Underdrains should be designed to be a minimum of 4 inches in diameter. Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour.

University of New Hampshire

Porous Asphalt Application and Site Feasibility Criteria

Table 18.3.10-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) • p1 = porosity of base layer (% void) • d1 = depth of base layer (ft) Note: The ratio of Drainage Area:Paver Footprint Area should not exceed 10:1. Ratios greater than 10:1 will be reviewed on a case-by-case basis.
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 • Geogrid 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)- (WQ_{VR}), where
	• WQv required = Required WQv (ft^3)
	• RE_{WQV} = Required WQv Rain Event (Refer to Chapter 18.2.4)
	• 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)
	• WQ_{VR} = ($^1/_{12}$)(RE_{WQV})(R_V)(IA_R)
	    ♦ Where IA_R = reduced impervious area

Steps to Construct Porous Asphalt

Table 18.3.10-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	Geogrid will be placed on the subsoil as a soil stabilization device. Only approved geogrid that meets the minimum specifications may be used. Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid 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 18.3.10-B can be used in this form:

$$WQv\ (ft^3) = RE_{WQV}\ (R_V)\ (A/12) - (WQ_{VR})$$

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

Geogrid shall be placed on the subsoil surface prior to placing any aggregate for soil stabilization and geotextile fabric may be used in conjunction with the geogrid 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 (minimum 4 inches in diameter) that run longitudinal with the pavement to carry stormwater away from the pavement

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP)

18.3.11 Tree Boxes

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
- Metro Planning Approval

Cost: Medium
Maintenance: Low

Tree boxes along Story Avenue

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
Peak Flow Control	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Partial Benefit

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
- May not comply with KYTC requirements for state roads

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. Tree boxes will need Metro/KYTC approval during the design phase, depending on where the tree boxes are installed and which entity holds jurisdiction.

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.
- Location—Construction in a Louisville Metro right-of -way (ROW) or Kentucky Transportation Cabinet ROW will require conformance to applicable standards
- Footprint—A grate covering the tree box footprint is preferred to a fence around the perimeter of the box.
- Curb Cuts—Curb cuts must be rounded or covered with a plate.

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 18.3.11-A on page 5.

Design criteria to consider includes:

- Selection of tree box type and size
- Soil composition
- Plant selection
- Maintenance

Tree box series

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 Standard Drawing GI-01-00). If infiltration is not desired, temporary detention of the stormwater runoff can be accomplished using a flow-through sealed box design (see Standard Drawing GI-01-00). 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 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 18.3.11-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.

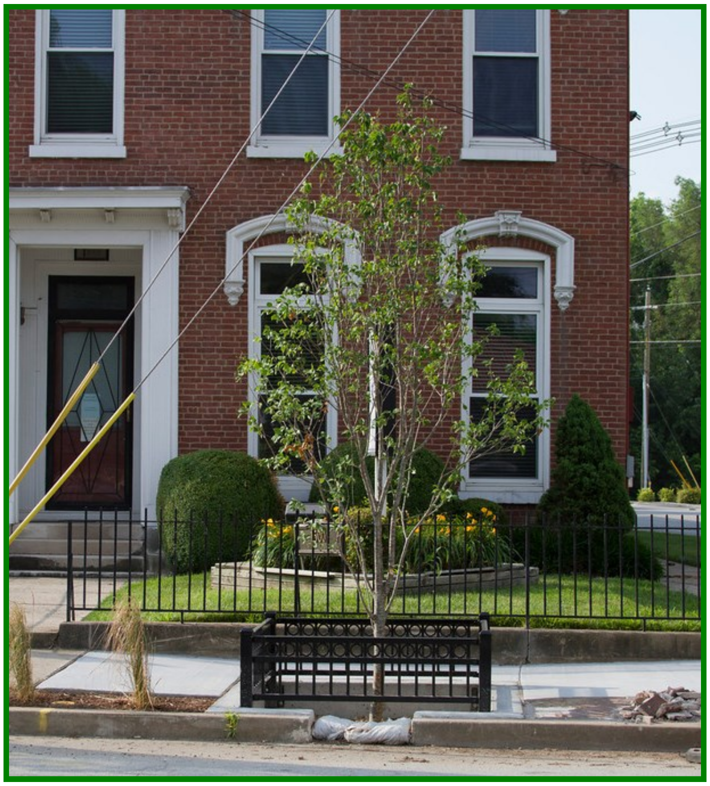
The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

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 (minimum 4 inches in diameter) 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.



Stone bags cover the tree box inlet to protect it from sediment deposition from the construction site until the site is fully stabilized

Tree box

Tree Box Application and Site Feasibility Criteria Chart

Table 18.3.11-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 (cubic feet) = $(^1/_{12})[(RE_{WQV})(Rv)(A)]- (WQ_{VR})$, where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.2.4) • 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) • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
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)

For tree and plant species, see MSD Design Manual Chapter 13

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 18.3.11-A can be used in this form:

$WQv\ (ft^3) = (RE_{WQV})(Rv)(A/12) - (WQ_{VR})$.

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 18.3.11-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

Green Management Practice (GMP)

18.3.12 Rainwater Harvesting

Cisterns drain to a bioswale at the Green Building in Louisville

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
- Supply of water versus demand for usage

Cost:	Medium
Maintenance:	Medium—High

Stormwater Management Benefits

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

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. It should be noted that rainwater harvesting is more beneficial when the demand is great enough to balance water supply.

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 18.3.12-A.

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

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.

Cisterns harvest rainwater and water the rain gardens below at the Green Building

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.

Rainwater Harvesting Application and Site Feasibility Criteria

Table 18.3.12-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 (cubic feet) = $(^1/_{12})[(RE_{WQV})(Rv)(A)]$- (WQ_{VR}) where • RE_{WQV} = Required WQv Rain Event (refer to Chapter 18.2.4) • 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) • $WQ_{VR} = (^1/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
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.

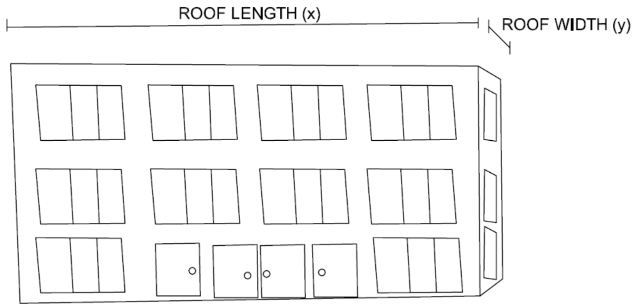
Rainwater Harvesting Step by Step Design Procedures

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)



Building schematic for drainage area

A cistern should be sized to capture the required WQv, which is as follows:

$WQv\ (ft^3) = (^1/_{12})[(RE_{WQV})(Rv)(A)] - (WQ_{VR})$, 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
$WQ_{VR} = (^1/_{12})[(RE_{WQV})(Rv)(IA_R)]$
Where IA_R = reduced impervious area
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.

Louisville and Jefferson County Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Green Management Practice (GMP) Fact Sheet

18.3.13 Vegetated Buffers

Vegetated buffer strip along a bike path

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 (2%-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. The slope shall be a minimum of 2% and a maximum of 6%. The vegetation shall 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. Uniform grading within the buffer is required to maintain the sheet flow throughout the buffer. In addition, the buffer slope shall be a maximum of 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 to provide the buffer width and length is required
- Slope—The slope of the vegetated buffer shall be a minimum of 2% and a maximum of 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 Exhibit 18.3.13-A. For a summary of design parameters, see Table 18.3.13-A.

Design criteria to consider include:

- Buffer slope and length
- Buffer width
- Soil composition
- Drainage area
- Flow length of drainage area
- Inlet
- Naturalized planting plan
- Maintenance

Buffer Slope and Length

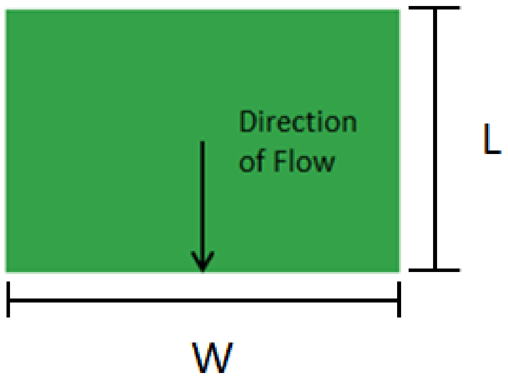
The vegetated buffer slope in the direction of flow shall be a minimum of 2% and a maximum of 6%, which prevents

Typical vegetated buffer

ponding of the runoff, but does not promote the formation of concentrated flow. The length of the buffer (parallel to flow) shall be a minimum of 25 feet and shall be determined using the formula given in Table 18.3.13-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 shall be greater than or equal to the width of the contributing drainage area.



Vegetated buffer length and width

Soil Composition

A vegetated buffer shall be used on soils that have minimal clays and an infiltration rate greater than two inches/hour. The objective is to use soils that are 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.

Flow Length of Drainage Area

The flow length of the drainage area shall be less than 300 feet. This will maintain sheet flow of stormwater into the vegetated buffer and reduce the risk of shallow concentrated flow forming.

Inlet

Stormwater runoff must enter the vegetated buffer in sheet flow across its entire width for it to be effective. The inlet design shall also accommodate the passing or diversion of flows greater than the runoff from the required WQv rain event.

Naturalized Planting Plan

A naturalized planting plan is required for vegetated buffers. The plan shall include bedding preparation, identification of the various planting zones and recommended plants for each planting zone.

Native species or native, non-invasive cultivars are required for use in vegetated buffers. Plants shall consist of native or native cultivars of deep rooted herbaceous plants (grasses, forbs, wildflowers), shrubs and trees. Native plants are indigenous to Kentucky and are low-maintenance plants that require minimal watering, weeding, pest control, fertilization and pruning, and are ideal for naturalized vegetated buffers. For this reason, exotic, non-native species are not suitable for vegetated buffers due to watering and other maintenance requirements. Include an inventory of all plants present in the vegetated buffer in the planting plan.

Restored stream reach of Middle Fork Beargrass Creek includes vegetated buffers and a walking trail

Remove invasive plant species if they are present in the vegetated buffer and replace with approved native plants. A list of native and native cultivar species (nativity categories N and C) are provided in Chapter 13 of the MSD Design Manual.

Plants should be selected based site conditions (i.e. sun/shade and wetland indicator status) suitable for each zone (see Chapter 13 of the MSD Design Manual).

The planting plan and established plant density shall be consistent with the Manning's "n" value specified in design for buffer length and travel time. See Chapter 13 of the MSD Design Manual for plant spacing requirements.

Restored stream reach of South Fork Beargrass Creek at Masemure Court includes vegetated buffers

Vegetated Buffers Application and Site Feasibility Criteria

Table 18.3.13-A.

Design Parameter	Criteria
Buffer Slope and Length	• Slope in the direction of flow shall be between 2 and 6% • Buffer length (parallel to the flow) shall be a minimum of 25 feet and be calculated using the following equation: $L=[(T)^{1.25}(P)^{0.625}(S)^{0.5}]/0.334n$, where L = length of the buffer parallel to the flow path (ft) T = travel time through the filter strip (minutes), reference Table 18.2.4-C P = required WQv rain event (refer to Chapter 18.2.4) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient, typical values (per USDA Urban Hydrology for Small Watersheds, TR-55): Grass, dense grasses, n=0.24 Range (natural), n=0.13 Woods, light underbrush, n=0.40 Woods, dense underbrush, n=0.80
Buffer Width	• The width of the vegetated buffer (perpendicular to the flow) shall be greater than or equal to the width of the contributing drainage area • 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) Q = peak discharge to the buffer from the required WQv rain event (cfs) W = minimum width of the filter strip (perpendicular to the flow (ft)
Soil Composition	The infiltration rate within the vegetated buffer needs to be at least two inches/hr for existing, undisturbed land. For disturbed or redeveloped applications, lower existing infiltration rates may be acceptable.
Drainage Area	The area draining to the vegetated buffer needs to be less than three acres. The flow length of the drainage area shall be less than 300 feet.
Inlet	Stormwater runoff must enter the vegetated buffer in sheet flow across its entire width.

Vegetated Buffers Application and Site Feasibility Criteria

Table 18.3.13-A (continued).

Design Parameter	Criteria
Travel Time	Select a buffer length of at least 25 ft, use the following equation to calculate travel time, T (in minutes): $T=[0.42*(n*L)^{0.8}]/(P^{0.5}*S^{0.4})$ L = length of the buffer parallel to the flow path (ft) T = travel time through the filter strip (minutes), reference Table 18.2.4-C P = required WQv rain event (refer to Chapter 18.2.4) S = slope of the filter strip along the flow path (%) n = Manning's "n" roughness coefficient, typical values (per USDA Urban Hydrology for Small Watersheds, TR-55): Grass, dense grasses, n=0.24 Range (natural), n=0.13 Woods, light underbrush, n=0.40 Woods, dense underbrush, n=0.80

Parking lot runoff drains to a vegetated buffer at the Parklands of Floyds Fork

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 18.3.13-A, especially the infiltration rate of the underlying soils.

Step 2: Determine buffer width

The width of the vegetated buffer (perpendicular to flow) shall be equal to the width of the contributing drainage area.

Step 3: Determine the peak flow rate and depth of flow

Use modeling to calculate the peak runoff and depth of flow from the required WQv rain event (Q). Confirm that the depth of flow is less than 1 inch. 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) shall be modeled to size overflow or bypass structures to safely convey the flow.

Step 4: 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.

Step 5: Determine the Travel Time Through the Filter Strip

Calculate the travel time, T (in minutes), using the following equation:

$$T=[0.42*(n*L)^{0.8}]/(P^{0.5}*S^{0.4})$$

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. Consideration shall be given for minimizing erosion at the beginning of the buffer. In addition, the vegetated buffer shall 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 naturalized planting plan

Choose native plants (consistent with designed Manning's "n" value) to incorporate into the vegetated buffer based on aesthetic preferences, plant heights and sun/shade tolerances. Include an inventory of all plants present in the vegetated buffer in the planting plan. Remove invasive plant species if they are present in the vegetated buffer and replace with approved native plants. The plan shall include the following information, consistent with Chapter 13 of the MSD Design Manual:

- Planting zones
- The species (nativity categories native (N) and native cultivar (C) only) to be planted within each planting zone, plant material types (seed, bare-root, potted), and plant sizes
- Plant count and spacing for each species
- Planting bed preparation and planting methods
- Establishment, maintenance and care requirements
- Acceptable sources for the plants

See Chapter 13 of the MSD Design Manual for planting plan requirements.

Coneflowers line a vegetated buffer at the Parklands of Floyds Fork

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18.3.14 Underground Storage

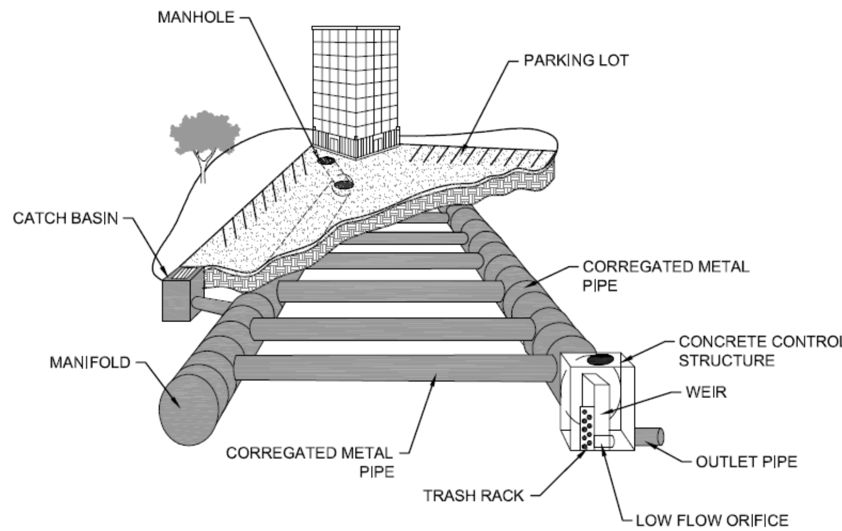
Typical Implementation Areas:

- 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



Typical underground stormwater storage system

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	Significant Benefit
Stormwater Conveyance	Low or Unknown Benefit
Peak Flow Control	Significant 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

- 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. For a summary of design parameters, see Table 18.3.14-A on page 4.

Design criteria to consider includes:

- EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)
- Inlet and pretreatment
- Outlet
- Overflow and bypass
- Infiltration
- Overburden support
- Drain time
- Maintenance

EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)

Infiltration drains are generally long, narrow stormwater quality features that capture stormwater. However, an infiltration drain 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):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system."

If the infiltration drain designed meets any of the criteria listed above, the EPA form 7520-16 should be filled out and all other additional EPA regulations should be followed. Other terms including well, injection well, improved sinkhole or drywell will trigger requirements by the EPA.

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.

Underground Storage Application and Site Feasibility Criteria

Table 18.3.14-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 the 100-year, 24-hour event at a minimum.
Conveyance	Pass the runoff from the 2-, 10- and 100-year, 24-hour events.
Volume	Underground storage volume should be at least equivalent to the Required WQv. WQv (cubic feet) = $(^{1}/_{12})[(RE_{WQV})(Rv)(A)] - (WQ_{VR})$ where • RE_{WQV} is the Required WQv Rain Event (refer to Chapter 18.2.4) • 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) • $WQ_{VR} = (^{1}/_{12})(RE_{WQV})(R_V)(IA_R)$ ♦ Where IA_R = reduced impervious area
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 18.3.14-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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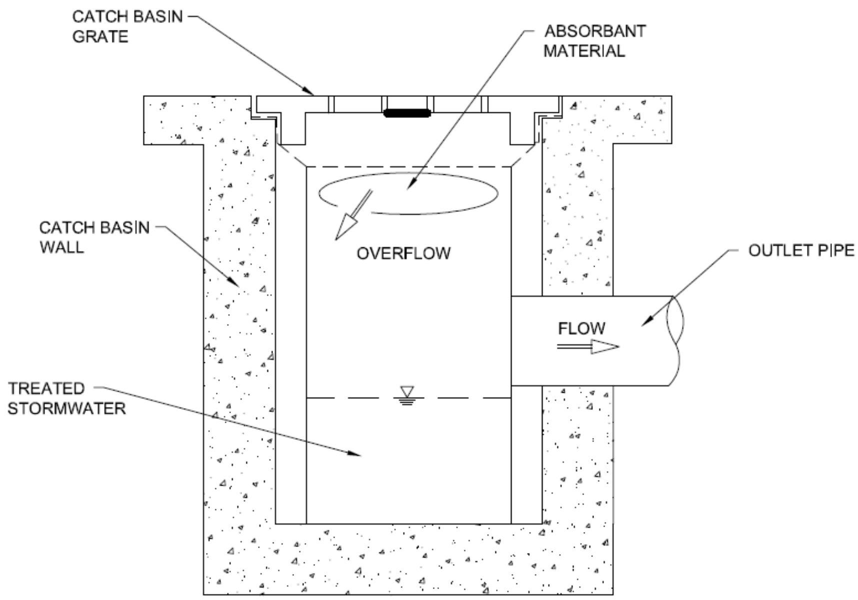
18.3.15 Catch Basin Inserts



Catch basin insert schematic

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

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
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 may only be used as pretreatment for other GMPs. Catch basin inserts improve water quality through:

☑ Filtering sediment, debris and oils
☑ Effective form of pretreatment

Advantages/Benefits:

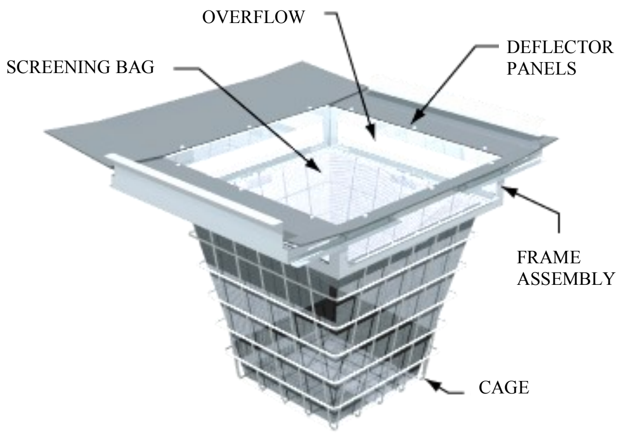
- Typically easy installation
- Appropriate for sites with space limitations and where infiltration is not an option
- Appropriate for retrofit applications
- No aboveground or underground storage is needed beyond the typical storm sewer system

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 inserts may only be used as pretreatment for other GMPs, and cannot receive credit toward a site's required water quality volume.



Catch basin insert with a metal screen to catch sediment and debris

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

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. 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.

Catch basin insert incorporates a specialized filtration fabric and a mesh lining to remove various types of pollutants

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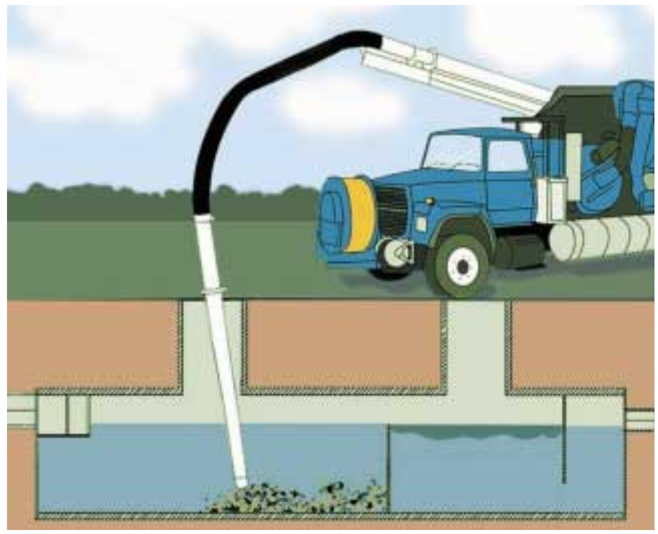
Green Management Practice (GMP)

18.3.16 Proprietary Water Quality Units



Water quality units are typically equipped with access risers for easier inspection and maintenance

Typical Implementation Areas:

- Pretreatment
- Urban hot spot sources
- Parking lots and roadways
- Hazardous substance facilities
- Curb and inlet runoff
- Retrofit areas

Key Considerations:

- Unit type

Cost:	Medium-High
Maintenance:	Medium

Stormwater Management Benefits

Pollutant Reduction

Sediment	80% TSS required
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
Peak Flow Control	Low or Unknown Benefit

Runoff Volume Reduction

Runoff Capture	Low or Unknown 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 space-efficient and use a swirling vortex or 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 total suspended solids
- ☑ Effective removal of oil/grease
- ☑ Pretreatment and use in series with other GMPs

Advantages/Benefits

- Ease of installation
- Optimal for sites less than 5 acres, with space limitations or where infiltration capacity is limited
- Appropriate for retrofit applications
- Good for impervious area runoff that may clog other types of GMPs
- Can be designed to be suitable for hazardous substance runoff

Disadvantages/Limitations

- Not effective for volume reduction or infiltration of stormwater
- Maintenance frequency varies depending on size of structure and quantity of flow and pollutants
- Not effective for removal of dissolved pollutants and fine particles
- Potential source of pollutants if maintenance is neglected
- Low community amenity value (habitat, flood control, landscaping)

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 constraints:

- Unit type—Proprietary water quality units vary based on the manufacturer; the main types of units are outlined below

Chambered Devices

Chambered devices (Exhibit 18.3.16-A) allow water to flow into a sump-like structure separated by vertical baffle plate walls, dividing the structure into chambers. Sediment and debris settle and oil and grease collect at the surface in the first two chambers, and flow exits the unit in a third chamber. A filter inside the water quality unit to absorb oil and grease may be necessary for applications receiving runoff from roadways or parking lots. Determination of need will be made on a case by case basis during the plan review process. As with hydrodynamic units, these structures are typically designed to bypass larger storms. Regular inspection and maintenance frequency should be considered as part of the design process.

Hydrodynamic Devices

Hydrodynamic units (Exhibit 18.3.16-B) route flow through the system using a swirling motion. Particles of sediment and debris separate and fall to the bottom, while floating materials are retained by a baffle wall. A filter inside the water quality unit to absorb oil and grease may be necessary for applications receiving runoff from roadways or parking lots. Determination of need will be made on a case by case basis during the plan review process. Hydrodynamic devices are generally effective in treating smaller storms and are typically designed to bypass flow from larger storm events to prevent re-suspension of captured sediment and debris. Regular inspection and maintenance frequency should be considered as part of the design process.

Sand Filters

Sand filters are devices that use sand or other filter media, to filter and remove pollutants from stormwater runoff. Sand filters consist of two chambers, including a pretreatment chamber and a sand/filter media chamber. Sand filters are required to have a pretreatment chamber to settle out coarse sediment and solids that could clog the sand/filter media. A filter inside the water quality unit to absorb oil and grease may be necessary for applications receiving runoff from roadways or parking lots. Determination of need will be made on a case by case basis during the plan review process. Common types of sand filters include: surface (Exhibit 18.3.16-C), underground (Exhibit 18.3.16-D), perimeter, organic, and pocket systems.

Design Criteria

Design for water quality units shall be based on MSD minimum design requirements as well as the manufacturer's recommendations. Design criteria include:

- Location
- Inflow regulation
- Pretreatment
- Sizing
- Installation
- Pollutant removal
- High flow bypass

Location

Water quality units can be installed upstream of GMPs in series for pretreatment. Pretreatment is required for GMPs where maintenance access is limited such as infiltration trenches, etc. Refer to manufacturer's recommendations for maximum drainage area.

Inflow Regulation

All proprietary water quality units shall be configured as offline systems, diverting the water quality volume into the unit for treatment and returning flow to the conveyance system or downstream GMP. Inflow regulation protects the unit from peak flows while treating the first flush and designed water quality volume.

Pretreatment

Proprietary water quality units containing a filter media require a pretreatment/settling chamber to remove coarse sediment, solids, and debris that could clog the filter media.

Sizing

Water quality units should be sized using the methodology indicated per Table 18.2.4-C.

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 proper installation. 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. At a minimum, units must achieve a Total Suspended Solids (TSS) removal efficiency of 80% based on OK-110 (D_{50}=110µm) particle size distribution for the peak flow rate, as specified in Table 18.2.4-C, and be approved by the City of Indianapolis. If the water quality unit is to be used as pretreatment for another GMP, a minimum of 50% TSS removal is required.

A filter inside the water quality unit to absorb oil and grease may be necessary for applications receiving runoff from roadways or parking lots. Determination of need will be made on a case by case basis during the plan review process. 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.

High Flow Bypass

All proprietary water quality units shall be configured as offline systems (see Inflow Regulation of this section), diverting the water quality volume into the unit for treatment and returning flow to the conveyance system or downstream GMP. Bypassing high flows protects the unit from peak flows while treating the first flush and designed water quality volume.

Proprietary Water Quality Unit Approval

MSD formally allows reciprocity with the City of Indianapolis for approving proprietary water quality units using the "City of Indianapolis Stormwater Quality Unit (SQU) Selection Guide". Units approved by the City of Indianapolis using the TSS specification above may be considered "approved" for use in Jefferson County for the required flow rate (Table 18.2.4-C).

If a unit is not on the list, the design engineer must submit third party verification of performance (such as New Jersey Department of Environmental Protection, New Jersey Corporation of Advanced Technology, Maine Department of Environmental Protection, etc.) to show that the proposed unit meets MSD's specifications, for MSD review and approval for use.

View through the maintenance access port of a proprietary water quality unit shows trash and debris that is separated from stormwater runoff; regular inspection after rain events and maintenance is necessary to clean out these materials

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Green Management Practice (GMP) Fact Sheet

18.3.17 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

Construction of an infiltration trench at the University of Louisville near the Speed Art Museum

Stormwater Management Benefits

Pollutant Reduction

Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	◩
Floatables	◩
Oil and Grease	◩
Dissolved Pollutants	◩

Hydrologic Characteristics

Surface Flow Reduction	■
Infiltration	■
Stormwater Conveyance	■
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. Overland flow or a perforated inlet pipe allows stormwater to infiltrate through an aggregate bed and into the underlying soil, filtering stormwater pollutants. Design requirements for infiltration trenches include: pretreatment, drainage area size, storage capacity, and the exfiltration of the water to subsurface soil. Infiltration trenches improve water quality through:

- ☑ Treatment of stormwater percolating through soil
- ☑ Removal of light sediment/pollutants (pretreatment required to prevent clogging)

Advantages/Benefits

- Suitable for sites with limited space
- Reduces volume of stormwater runoff and provides peak flow control
- Appropriate for small sites (< 5 acres) unless large infiltration area is available
- Provides infiltration and pollutant filtration
- Works well with other GMPs 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
- Access to infiltration interface is limited

Application and Site Feasibility

Infiltration trenches are appropriate for use in series with other GMPs. They are typically filled with aggregate and contain no outlet structure. **A pretreatment device is required 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. There are a variety of ways these structures can be designed, but must include pre -treatment. Infiltration trenches can receive overland flow from a forebay through gravel or grass. They can also receive point flow from a proprietary water quality unit that drains to the aggregate filter media.

Physical Requirements

Key physical constraints:

- Surface dimension vs. depth—if an infiltration trench is designed so that it 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—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 18.3.17-A.

Design criteria include:

- EPA Regulations for Class V Injection Wells
- Location
- Cover Types
- Sizing
- Soil Stabilization
- Storage Capacity
- Slopes
- Pretreatment
- Infiltration Testing
- Storage Media
- Overflow
- Observation well
- Erosion Prevention
- Mosquito Control

EPA Regulations for Class V Injection Wells and Underground Injection Control (UIC)

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 certain criteria (see the Class V wells page at www.epa.gov):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system." (epa.gov)

If the infiltration trench designed meets any of the criteria listed above, the EPA form 7520-16 should be filled out and all other additional EPA regulations should be followed. Wells, injection wells, improved sinkholes or dry wells will trigger EPA permitting requirements. MSD cannot approve injection wells without EPA approval.

Location

Infiltration trenches are retention structures when they are designed to effectively capture and infiltrate stormwater runoff. When finding the most appropriate location for the trench, it is best to find a location with a small drainage area (approximately less than five acres). For larger drainage areas, it is recommended that a comparable area be used for infiltration, more than one infiltration trench is installed, or another GMP be established in series (see Table 18.3.17-A). Infiltration testing is required per Section 18.2.5.

Space considerations must be made for pretreatment of flow into the trench, consistent with Section 18.2.6.

An improved sinkhole can be considered a Class V Injection Well by the EPA (Photo: Sabak, Wilson and Lingo)

Depth to groundwater table should be at least four feet lower than the lowest point of the infiltration structure to promote effective exfiltration into native soils. Areas with heavy sediment flow or a significant pollutant load are not suitable locations because the pretreatment device and sub-surface aggregate may become clogged or the groundwater contaminated.

Infiltration trenches should be located at least 10 feet from building foundations and underground utilities. See Exhibits 18.3.17-A through E for typical design layouts/ profiles.

Cover Types

- Grass
- Pea gravel
- Pervious pavers
- Permeable Concrete/Concrete
- Porous Asphalt/Asphalt
- Pervious pedestrian mats (playground surfacing)

Sizing

The surface storage parameter should be designed to retain/capture the volume produced by the rainfall events specified in Table 18.3.17-A. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. An overflow feature should be installed to move excess water during a large storm event or in case of clogging.

Sizing of infiltration trenches is based on the volume provided by the porosity of the media in the trench and in the ponding area above the trench media. The volume should at least be equal to the WQv. See Table 18.3.17-A for the WQv formulas.

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 subgrade and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns geogrid 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 geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid 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 geogrid used in conjunction with the infiltration trench shall include the following specifications, at a minimum:

Geogrid Specifications

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- 100% resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device, however it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

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 roadways, for example, should have an adequate overflow system and maintain adequate freeboard to avoid flooding or overtopping the pavement.

Slopes

Site topography should be considered in an infiltration trench design. Typically, natural slopes of areas providing stormwater drainage flow to the trench should be less than 15%. This prevents excessive scouring of the vegetated area due to high velocities from stormwater inflow. See Exhibits 18.3.17-C through E 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. Exhibit 18.3.17-E shows the cross section of a pretreatment device. The following list provides some examples for pretreatment methods:

- Forebay
- Vegetated Strip
- Proprietary Water Quality Unit—Required for surface infiltration areas, such as those with stormwater runoff that includes sediment and floatables (oil/ grease), i.e. parking lots and roadways (see Section 18.3.16).
- Catch Basin Inserts

Infiltration Testing and Native Soils

Infiltration testing is required to be performed per Section 18.2.6. Infiltration trenches typically contain no outlet structure. The native soils beneath 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 trench have in situ soils that are Hydrologic Soils Group A or field determined to be equivalent, then the infiltration capability of the soils can be factored into the sizing of the infiltration trench. Modeling and analysis for infiltration trench management of the required WQv can be prepared by the design professional and submitted to MSD for review and concurrence.

Where native soils do not provide favorable infiltration rates, or infiltration rates less than 0.5 inches per hour, chambered systems can be used to increase the storage volume and potential for infiltration. These chambers/ arrays are typically plastic and arc-shaped with an open bottom and bedded in stone.

The slope of subsurface native soils shall not exceed 5% and shall not be sloped towards building foundations. For subgrade soils sloped between 2% and 5%, subsurface berms or check dams are required. Stepping of subsurface soils through the use of check dams or terracing is recommended to reduce surface area.

Storage Media

Infiltration trenches should be installed using double-washed aggregate (with a certification letter from the quarry), pea gravel, sand, and filter fabric. All storage media should be clean and free of fines. For more information on aggregate requirements, see Section 18.4.2. River rock may be used in trenches with non-load-bearing applications. A 6 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 should also be installed on the sides only of the trench to prevent migration of the native soils into the storage media. A 6 inch to 12 inch layer of pea gravel is required for the top layer of the trench to facilitate capture of sediment before it enters the storage layer and to facilitate maintenance for removal of sediment that passes through pretreatment structures (see Exhibit 18.3.17-C).

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 installation of the high flow bypass or diversion structure will be largely based on each site design. For overflows tied into the combined sewer system, backflow prevention is required.

Construction of an infiltration trench at the University of Louisville near the Speed Art Museum

Construction of an infiltration trench at the University of Louisville near the Speed Art Museum

Observation Well

Observation and clean-out wells should be installed near the inlet and the center of the trench, or within the first two rows/arrays for detention chambers systems to monitor the water level of the trench and check for clogging. The observation well shall 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 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.

Erosion prevention and sediment control measures must be in place and maintained to protect and prevent clogging of the infiltration trench prior to full stabilization of the site (see Section 18.4).

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 structure, the chances of providing mosquito habitat are virtually eliminated. If the trench holds enough water for mosquitoes to successfully breed, there is a problem with the aggregate or overflow structure that should be addressed.

Construction of an infiltration trench at the University of Louisville near the Speed Art Museum

Infiltration Trench Application and Site Feasibility Criteria Chart

Table 18.3.17-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) Designs meeting certain specifications, such as a greater depth than width, may fall under EPA regulations for Class V Injection Wells. See www.epa.gov for regulations.
Longitudinal Slope	No greater than 15%
Side Slopes	Dependent on integration of soils and OSHA safety requirements.
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 (required)	Size pretreatment to hold 10% to 15% of the WQv, or 80% TSS where the use of proprietary water quality units is required (surface infiltration areas).
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 and no more than 10:1 drainage area to GMP footprint for surface infiltration areas. Ratios greater than 10:1 will be reviewed on a case-by-case basis. Greater drainage areas are acceptable where influent is piped and pretreated.
Drawdown Time	Dewatering of the trench should occur within 24-48 hours

Storage Capacity	Total volume should be equivalent to the required WQv.
	
	Required WQv (cubic feet) = ($^1/_{12}$)(RE_{WQV})(Rv)(A)- (WQ_{VR}) where
	• RE_{WQV} = required WQv rain event (refer to Section 18.2.4)
	• 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)
	• WQ_{VR} = ($^1/_{12}$)(RE_{WQV})(R_V)(IA_R)
	    ♦ Where IA_R = reduced impervious area

Infiltration Trench Step by Step Design Procedures

Step 1: Define goals/primary function of the trench

Define the goals/primary function of the trench. Consider whether the 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 trench will be an improved sinkhole or a subsurface fluid distribution system (www.epa.gov). If the trench meets this criteria, then all applicable EPA regulations must be followed for a Class V Injection Well. MSD cannot approve injection wells without EPA approval.

The design should be based on the restrictions/requirements, goals, and primary function(s) of the infiltration trench.

Step 2: Determine pretreatment method

Consider the type of pretreatment device and preferred maintenance per Section 18.2.6). Forebays or vegetated strips may be used for non-impervious drainage areas or rooftops. Proprietary water quality units (Section 18.3.17) are required for drainage areas receiving sediment and floatables (oil/grease), such as parking lots and roadways .

Preferred maintenance should also be a consideration for pretreatment method and available surface area. Compact, urban sites may benefit from using a proprietary water quality unit which can be cleaned out with a vacuum truck. Infiltration trenches with forebay, vegetated strip pretreatment, or grass or pea gravel surface treatments require a larger surface area.

Step 3: 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 18.3.17-A can be used in this form: WQv (ft^3) = (RE_{WQV})(Rv)(A/12)- (WQ_{VR}). The minimum surface area of the infiltration trench should be determined using the following formula:
A = (WQv)/[d(P)+h] (see Table 18.3.17-A).

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

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

Step 4: Determine if site is appropriate

Determine if the development site and conditions are appropriate for the use of an infiltration trench (see Table 18.3.17-A). Create a rough layout of the dimensions including existing trees, utility lines, and other obstructions.

Step 5: Determine the pretreatment volume

Pretreatment can reduce flow velocities or facilitate sediment removal and maintenance of the infiltration trench. A forebay, water quality unit or other pretreatment system is required (see Step 2). Size the pretreatment per Table 18.3.17-A. The pretreatment storage volume counts toward the total WQv required, and may be subtracted from the WQv for subsequent calculations.

Splash blocks should be used to dissipate the concentration of stormwater runoff at surface inlets/overflows to prevent scour.

Step 6: Determine infiltration trench parameters

Size bottom width, depth, and length necessary to achieve the WQv per Table 18.3.17-A.

Step 7: 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 8: 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.

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18.4 Construction

Construction of infiltration basin at the University of Louisville

Green infrastructure is a requirement in Louisville Metro pursuant to the Wastewater/Stormwater Discharge Regulations and requires proper construction techniques. Construction requirements and guidance for green infrastructure is provided in this section.

18.4.1 Introduction

Construction of permeable paver parking lane and tree boxes

This section addresses construction practices unique to construction of green infrastructure as a supplement to MSD's erosion prevention and sediment control requirements. More information on consideration for permits is included in Section 18.2.2 of this Chapter, Overview of Regulations. Proper construction practices are critical to the initial and long-term functionality of green infrastructure. Because most green infrastructure practices rely on infiltration to maximize treatment volumes, it is important to protect the location of green infrastructure on construction sites.

The following practices are notable for site construction that includes green infrastructure:

- Construction sequencing
- Compaction
- Good housekeeping and pollution prevention
- Drainage
- Aggregate specifications (see Section 18.4.2)
- Setbacks from streams

Construction Sequencing

Construction sequencing is prudent to construct and stabilize all other areas of the site prior to the installation of green infrastructure. Erosion and sedimentation carried from other areas of the construction site can clog and compromise the permeability of green infrastructure filter media and native soils.

Good Housekeeping and Pollution Prevention

Good housekeeping practices, or pollution prevention practices, protect green infrastructure as well as keeps harmful pollutants and construction waste out of our waterways. Spills and excess materials should be promptly cleaned up so that they do not wash into downstream.

Construction waste placed removed from working area and placed in waste can

Drainage

Green infrastructure captures and treats stormwater runoff. During construction, it is critical that the upstream drainage areas be fully stabilized prior to construction of green infrastructure.

Compaction

Compaction should be minimized in locations for green infrastructure construction. These areas should be identified and market by stakes or construction fencing to create a barrier so that heavy equipment does not compact native soils. Excavation should be performed by hand or performed from outside of the footprint of the practice when heavy equipment is necessary.

A contractor applies aggregate for placement of permeable pavers

Aggregate Specifications

See Section 18.4.2 for more information.

Setbacks from Streams

Some streams require undisturbed stream buffers to protect the stream during construction. More information on Kentucky stream buffer requirements during construction are provided in the stormwater construction general permit, KYR10.

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18.4.2 Aggregate Specifications

Stone used as a base layer for Green Infrastructure

Clean Aggregate Specification

There are fundamentally different aggregate specifications for green infrastructure and traditional gray infrastructure practices. Green infrastructure requires water flow, storage, and infiltration through media and aggregate, whereas traditional projects combine aggregate with binding agents, creating impermeable surfaces. For aggregate used in green infrastructure projects, it is especially important to minimize fines coating the surface of the aggregate stone by double washing. Aggregate that is not double washed and clean is not suitable for green infrastructure practices. Aggregates used in green infrastructure practices must be accompanied with a certification letter from the quarry indicating that the stone was double washed.

Compaction and Settlement

The aggregate components of green infrastructure should be compacted to minimize post-construction settlement while allowing exfiltration into in situ soils. Compact the aggregate utilized for storage volume or load-bearing structures to minimize settlement at the surface. Where applicable, review Louisville Metro standards for ADA compliance. Compaction of the aggregate needs to be determined by the designer based on the anticipated loads at the surface. Typically, vibratory plate compactors are used to obtain about 95% compaction of the aggregate.

At the aggregate/in-situ soil interface, the intermixing of these two materials should be minimized. Two typical approaches for minimizing this intermixing is the use of geotextile fabric (non-woven, sides only) and geogrids. Geogrids provide structural stability and keep the different layers of aggregate separated (i.e. the No. 3 aggregate layer should be kept separate from the No. 57 aggregate layer). This separation will help reduce settling due to the smaller particles filling in the void space provided by the larger aggregate. The aperture size of the geogrids is important in keeping the aggregate layers separated. See specifications for green management practices for use of geogrid and geofabric in combination with manufacturer specifications. Typically, geogrid is applied at each layer of aggregate size, and geofabric is placed on the sides only, not on the bottom of the practice.

Prohibited Materials

Green infrastructure relies on the void space and connection with in situ soils to store and exfiltrate stormwater. Dense Grade Aggregate (DGA) is aggregate that includes a wide variety of stone sizes. Stormwater cannot pass through DGA as readily as coarse grades and is not acceptable for use in green infrastructure. For this reason, the use of dense grade aggregate, construction waste, waste concrete, recycled materials, and similar materials is prohibited in the construction of green infrastructure.

Non-Structural Applications

For non-structural applications (i.e. rain gardens, bioswales, etc). river rock may be used instead of a crushed limestone as the coarse aggregate. Additional caution shall be used in the vicinity of roads, parking lots, sidewalks, etc. when using river rock. Double washed crushed No. 3 Stone, No. 57 Stone, and No. 8 Stone is also acceptable. River rock is considered an acceptable substitute because there is less fines and grit on the rock. However, river rock is not recommended for practices with a loading (i.e. roads, parking lots pavers and sidewalks); due to reconsolidating and shifting. River rock is typically available in the following sizes: 1/2" and down, 3/8"—5/8", 3/4"—2".

Structural Applications

For structural applications where green infrastructure is to be used to support applications carrying load (i.e. permeable pavers), conform to the gradations provided in the remainder of this section. These include:

- No. 3 Stone
- No. 57 Stone
- No. 8 Stone

Furnish crushed aggregate meeting the quality of section 805 of the Kentucky Transportation Construction Standards with the following exception: a shale content of 2% will be allowed, providing the combined shale, friable particles, and minus No. 200 content does not exceed 2%.

Required Documentation:

A specification sheet certified by the quarry is required for all structural applications or otherwise where coarse aggregate stone is used for green infrastructure. Certifications for coarse aggregate specifications shall be supplied to MSD inspectors and the property owner on site for each load of aggregate.

Close up of a practice settling

Geogrids to provide stability and separate aggregate

Geotextile fabric on the sides of a green practice

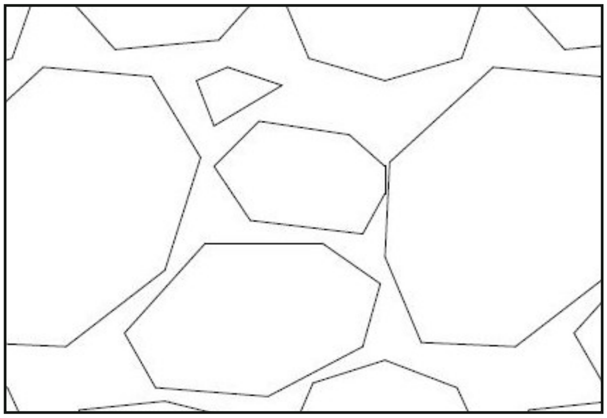
No. 3 Stone

No. 3 stone is placed at the very bottom of the structure and is used as a storage area. The stones must be double washed to keep as much fine material out of the storage area as possible.

Table 18.4.2-A: Gradation Sizes of No. 3 Aggregate

Sieve Size-Percent Passing*				
2 ½ inch	2 inch	1½ inch	1 inch	½ inch
100	90-100	35-70	0-15	0-2

* No greater than 2% passing No. 200.



Number 3 Stone used in legends

Number 3 Stone

Number 3 Stone

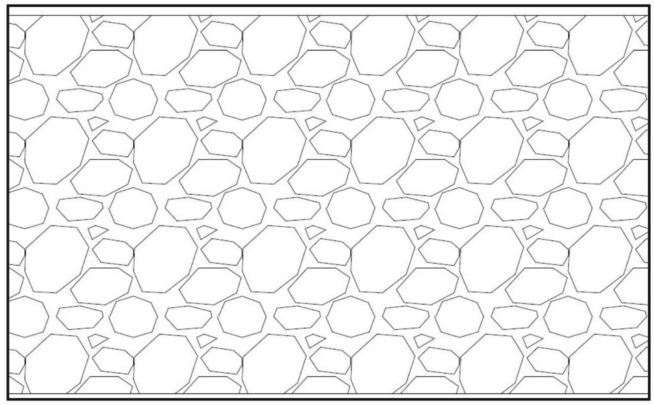
No. 57 Stone

No. 57 stone should be used as a base for a structure with loadings. An example of this would be sidewalks and roadways. In addition, it is generally placed on top of No. 3 stone. For practices that include pervious pavers, the No. 57 rock should be placed directly below the bricks. Most practices require double washed No. 57 stone. This 'washing' allows for fine material to be removed from the rocks, reducing the amount of clogging in the structure.

Table 18.4.2-B: Gradation sizes of No. 57 Stone

Sieve Size-Percent Passing*				
1 ½ inch	1 inch	½ inch	No. 4	No. 8
100	95-100	25-60	0-10	0-2

* No greater than 2% passing No. 200.



Number 57 Stone used in legends

Number 57 Stone

Number 57 Stone

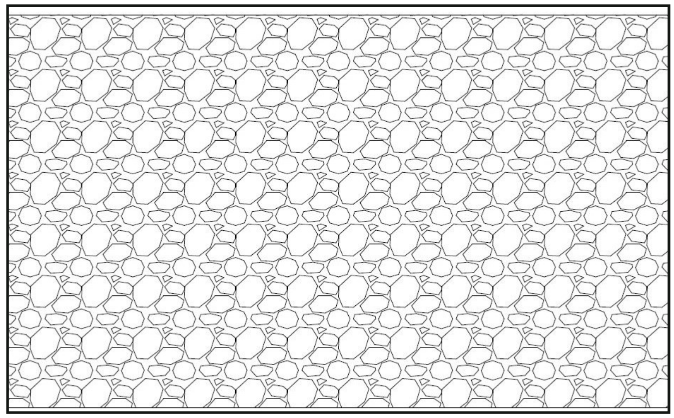
No. 8 Stone

No. 8 stone should be placed between the brick, concrete, or articulate concrete pavers. The stone should be washed, to keep fine material out of the storage areas and reduce clogging.

Table 18.4.2-C: Gradation Sizes of No. 8 Stone

Sieve Size-Percent Passing*				
½ inch	3/8 inch	No. 4	No. 8	No. 16
100	85-100	10-30	0-10	0-5

* No greater than 2% passing No. 200.



Number 8 Stone used in legends

Number 8 Stone

Number 8 Stone

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18.5 Operation & Maintenance Guidance

Clockwise from top left: number 8 Stone into permeable pavers, cutting back old growth on native plants, mulching a rain garden, sweeper removes dust and debris from pervious pavers.

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 large rain events.

In general, the inspection and maintenance of GMP systems includes:

- Removal of sediment buildup
- Removal of debris from any 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 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 (O&M) procedures for each GMP.

Rain Gardens

Maintenance should be periodically conducted to ensure that the rain garden area is functioning properly. Initially, the landscape will require more intensive maintenance to ensure proper species establishment and function. 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
- Weeding of non-native invasive 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. Care should be given when mulching not to allow mulch to pile up on the stems of plants (woody or herbaceous.)

After rainstorms, it is important to inspect the rain garden cell and make sure that drainage paths are clear and that the 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/bioretention pond is not functioning properly, repairs to the under-drain as well as inflow and outflow structures may be needed.

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 18.5-A on the next page.

Trash removal

"No Mow" maintenance signs installed at a rain garden in a Louisville Metro Park

Table 18.5-A. Bioswales & Rain Gardens Maintenance Schedule

Schedule	Activity
At least 4 times during 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 • A mulching depth of about 3-4 inches should be inspected and obtained, and additional mulch should be 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 or soil recycling center

A MSD worker cleans out the inlet structure for a rain garden

Constructed Wetland

Constructed wetlands should be visited every two to three weeks 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
- 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 the structural integrity of the outlet and containment edges.
- Erosion and burrow repair
- Monitoring and removal of debris and sediment buildup with special not to their effect on water storage capacity.
- Invasive nonnative species control
- 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 insure 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/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.

If near a populated area, monitor the wetland regularly for mosquito populations and develop and implement a control plan as needed.

For the Constructed Wetland Maintenance Schedule, See Table 18.5-B below:

No mow buffer surrounding wetland in Buechel

Table 18.5-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 18.5-C below.

Wet basin with small buffer; trash and debris needs to be removed from the practice to prevent clogging at the inflow and outflow.

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 replacement of dead or diseased plants, replanting of eroded areas, and invasive species control. The basin should also be trimmed annually to prevent the growth of woody species.

For the Green Dry Basin Maintenance Schedule, see Table 18.5-C.

Dead or damaged plants as well as weeds or other invasive species should be removed from the practice as necessary.

Table 18.5-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

Wet basin with native vegetation along the perimeter. Trash and debris should be removed from practice

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 18.5-D below.

Remove sediment, trash, weeds and debris

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 exotic plants becoming established.

For the Green Dry Basin Maintenance Schedule, see Table 18.5-D below.

Table 18.5-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
4-8 times during growing season	• Remove sediment, trash, weeds and debris • Implement landscaping maintenance plan for trimming to achieve desired aesthetic qualities • Mulch as needed • 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

Permeable Pavers

Block permeable pavers (brick, concrete, articulated concrete block) require that 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 damages and repaired as needed. Research has shown that the use of a street sweeper or air jet to maintain pavers is relatively ineffective, that a vacuum/water jet combination attachment is most effective for surface maintenance, and that the rate of surface clogging can be slowed by adding a chip stone to the gaps between blocks.

Permeable pavers should be inspected for trash, debris and dirt and cleaned several times per year, as needed

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 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.

Permeable pavers should be kept free of dirt and debris

Grass grid permeable pavers can be irrigated and fed as a normal lawn. It is important that they are not aerated. As a general rule of thumb, if a golf course nearby irrigates their lawn, you will need to irrigate grass pavers.

Gravel grid permeable pavers require little maintenance when installed correctly. Areas that experience traffic require the most attention as gravel will work it's way out of the rings. A broom can be used to get the gravel back into place or, if necessary, adding stones to the area. Generally the practice should only require attention once or twice a year.

In times of winter snow, pervious pavers can be plowed similarly to any other unpaved road, requiring the blade to be lifted about a half inch above the turf. Please note, the use of sand, ash, salt, or other deicing products should be avoided, as they will adversely affect all concrete and turf materials. However, organic deicers are recommended.

For the Permeable Pavers Maintenance Schedule, see Table 18.5-F.

Cleaning of permeable pavers

Table 18.5-F. Permeable Pavers Maintenance Schedule

Schedule	Activity
2-5 times per year as needed for low traffic areas with little or no tree coverage	• Vacuum/water jet combination attachment • Replace aggregate between pavers as necessary
6-10 times per year as needed for high traffic areas with trees or other dust or grit sources	• Vacuum/water jet combination attachment • Replace aggregate between pavers as necessary • Placement of a chip stone in the gaps between blocks can reduce the rate of surface clogging (optional)
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 pavement should be maintained monthly and between storms to ensure the success of the system. This involves regular vacuuming and jet washing of the pavement surface to remove debris and sediment. Upland and adjacent areas should be kept vegetated to reduce erosion and sediment flow onto the pavement area. The surface should be inspected annually for deterioration; areas with pavement failure should be resurfaced. Pervious pavement is intended for areas of low traffic; heavy traffic use and large vehicles should be prohibited.

In winter months, the use of sanding materials and deicing products should be limited. 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 18.5-G below.

Pervious Pavements should be kept free of dirt and debris to keep the practice draining effectively

When pervious pavements get clogged, it will be necessary to clean the pavement

Table 18.5-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 and vacuum pavement with a street sweeper and 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

Tree 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. The soil and mulch in the boxes should be tested periodically to avoid the build-up of pollutants that may harm the vegetation. Any mulch used should be replaced biannually.

Series of tree and planter boxes accept stormwater runoff from a roadway

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 Box Maintenance Schedule, see Table 18.5-H below.

Table 18.5-H. Tree Box 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 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. Rain barrels 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 18.5-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.

Table 18.5-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 paint cistern so sunlight can not penetrate system • 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

Initially, vegetated buffers should be inspected after rain events to ensure proper draining. The vegetated buffer should maintain desired slope, length and width. 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 Maintenance Schedule, see Table 18.5-K below.

Inspect vegetation for health and signs of stress

Table 18.5-K. Vegetated Buffer 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. In addition to general maintenance procedures, the catch basin inserts should be replaced annually.

For the Catch Basin Insert Maintenance Schedule, see Table 18.5-L below.

Catch basins should be kept free of sediment, trash and debris and cleaned as needed

Catch basin inserts should be cleaned regularly to ensure water can flow through the practice and replaced annually

Table 18.5-L. Catch Basin Inserts Maintenance Schedule

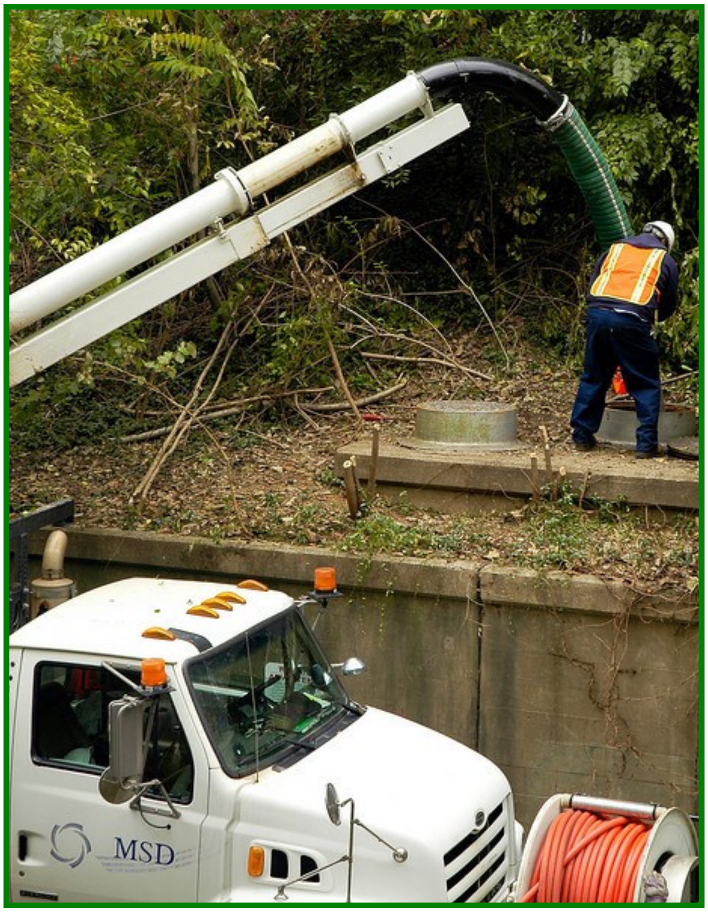
Schedule	Activity
Preventative Measures	• Inflow should flow through the filter system
Regularly	• Inspect catch basin inserts for clogging and remove sediment, trash or debris
Semi-annually in spring and fall	• Visit site to ensure there is not excessive erosion or sediment flow upstream of the catch 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. In general, 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 18.5-M below.



MSD employees use a vacuum truck to cleanout existing structures

Table 18.5-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 of unwanted material.

For the Infiltration Trenches Maintenance Schedule, see Table 18.5-O below.

MSD employees use a vacuum truck to cleanout the sump of an infiltration trench

Infiltration Trenches should be cleaned and kept free of dirt, trash, and debris

Table 18.5-O. Infiltration Trenches Maintenance Schedule

Schedule	Activity
2-3 times per year, as needed	• Monitor the trench observation well after large rain events and check for any ponding water • Mow or trim the perimeter of the practice 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 and 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.

18.6 References

The use of green infrastructure and native plants creates pollinator habitat in our urban environment.

MSD acknowledges resources and support from numerous communities and entities that assisted in developing this document. The following are key references that were used in developing the document.

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