4/25/2018
Updated 4/5/2019

The purpose of these provisional standards is to provide design guidance for new practices included in the update of Ohio's Construction General Permit on 4/23/18. These provisional standards are provided until a fully updated and edited version of the Rainwater and Land Development manual (http://epa.ohio.gov/dsw/storm/technical_guidance.aspx) can be published.

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The following provisional standards are included in this document: PAGE

RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

UNDERGROUND STORMWATER MANAGEMENT SYSTEMS

DATE: 4/5/19

Description

Underground stormwater management systems (USWMS) are large subsurface reservoirs located under pavement or other open space that manage stormwater runoff through infiltration, detention or a combination of the two. Underground reservoirs may simply be backfilled with stone, but also may utilize specially designed structures (e.g., concrete vaults, large-diameter pipes, plastic “crates”, or plastic arches) to maximize storage in the space available.

A USWMS is often used to manage larger runoff events to comply with local peak discharge requirements. A USWMS that includes an acceptable pretreatment practice may be used as a water quality practice and, where site and soil conditions are favorable for infiltration, may be used to reduce runoff volume or meet groundwater recharge requirements.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	Underground infiltration systems can receive a runoff reduction volume (RRv) credit to reduce the water quality volume (WQv) requirement. Up to 100% of the WQv volume.	RRv must fully infiltrate within 48 hr If the site is capable of partially infiltrating the WQv, the infiltrated runoff reduction volume (RRv) may be subtracted from the WQv using the runoff reduction method (RRM)
Groundwater Recharge Volume (GWv)	Up to 100% of the RRv.	GWv must fully infiltrate within 48 hr

Condition Where Practice Applies

USWMS are a viable option where space to locate a large surface practice is limited. They can be located under paved areas, as well as under athletic fields or other grassy open space.

Planning Considerations

The decision to select an underground stormwater management system will depend on several factors including:

- Acceptance by the local stormwater authority
- Stormwater management system construction costs, and operating and maintenance costs
- Value or opportunity cost of real estate needed to locate a surface stormwater practice
- Availability and elevation of discharge outlet(s)
- Infiltration capacity of the underlying soil
- Presence of shallow bedrock, a shallow groundwater table or unstable slopes
- Potential for groundwater contamination

If a USWMS makes sense from an economic and site management perspective, the next decision is whether to employ an infiltrating system (open-bottom), one that treats the WQv with extended detention (closed-bottom or lined), or a combination of both. A fully or partially infiltrating system should be used if feasible because of the additional benefits (e.g., runoff volume reduction, peak discharge reduction, groundwater recharge) provided. Infiltrating systems work well on most new development sites with hydrologic soil group (HSG) A, B or C soils. Though infiltrating systems should be considered for previously developed sites, these sites present challenges (e.g., existing utilities, impacted soils) that may be exacerbated by the addition of infiltrated water.

Similarly, soils classified as HSG-D typically have hydrologic limitations (e.g., very low hydraulic conductivity, seasonal high-water table, shallow impermeable layer) that may make it challenging to meet minimum design criteria. Soils classified as sands, loamy sands, sandy loams, loams or silt loams at the depth of excavation typically have the infiltration capacity necessary to support an infiltrating system, whereas clays, silty clays, clay loams, silty clay loams and sandy clay loams at the excavated depth may not provide the infiltration capacity necessary to meet drawdown requirements.

A USWMS and accompanying pretreatment practices shall not to serve as erosion or sediment control practices during construction. Stormwater should be directed to separate sediment traps, basins or controls as required until major construction activities have ceased and the drainage area is permanently stabilized. The USWMS and accompanying pretreatment practices should be inspected and, if necessary, cleaned prior to being placed into service.

NOTE: The following minimum design criteria are provided to assure compliance with post-construction stormwater NPDES requirements and sustain the water quality function over the long-term. <u>The design engineer is responsible for the structural integrity of an underground stormwater system and any infrastructure it supports</u>. If proprietary pretreatment or storage infrastructure is utilized, designers shall follow, in addition to the criteria below, design recommendations provided by the manufacturer. The manufacturer recommendations should not lessen the design criteria below.

USWMS Pretreatment Criteria

Pretreatment practices are required with USWMS to assure compliance with post-construction stormwater NPDES requirements. Pretreatment practices serve the two-fold purpose of increasing the overall effectiveness of an USWMS as well as making maintenance operations practical by isolating sediment.

A pretreatment practice must be installed prior to any inlet into the USWMS (Figure 1). Multiple inlets to the storage system may require multiple pretreatment practices.

Enhancements or additional pretreatment practices should be considered to treat specific pollutants from potential stormwater “hot spots”.

Each pretreatment practice must be designed to capture and treat the Water Quality Flow (WQf) calculated for its drainage area. Flow exceeding the WQf and bypassing the pretreatment should be directed to the extended detention storage. All flow through the pretreatment practice must do so without re-suspending or exporting accumulated sediment.

USWMS that utilize extended detention to manage the WQv must be coupled with a pretreatment practice certified at a 50 percent total suspended solids (TSS) removal rate. USWMS that utilize infiltration to manage the WQv must be coupled with a pretreatment practice certified at a 80 percent TSS removal rate. Pretreatment practices that may be coupled with a USWMS include the following:

- a manufactured treatment device (MTD) appropriately certified for the required TSS removal rate by the State of New Jersey Department of Environmental Protection (NJDEP) MTD certification program or the State of Washington, Technology Assessment Protocol - Ecology (TAPE) certification program and meeting Practice Standard #.# : Pretreatment, Flow-Through Treatment Devices; or
- a subsurface geotextile filter system meeting Practice Standard #.#: Pretreatment, Subsurface Geotextile Filter System.

Design Criteria – All Practices

Outlet – The drawdown control device must be fitted with measures to prevent clogging. Consider grates or trash racks where necessary. All outlets shall be easily accessible from the surface, requiring no underground entry for routine inspection and maintenance activities. A bypass or overflow outlet in excess of the WQv or design peak discharge requirement should be installed.

Storage Volume - Detention storage volume created by pipes, arches, chambers, vaults or other related infrastructure must be specified by the manufacturer and noted in the design calculations. The designer should provide stage-storage (depth-volume) information in sufficient detail (recommend maximum 3” or 0.25 ft depth increments) to facilitate modeling and review. Stage-storage relationships are available from most manufacturers and within some design software.

If the void space within stone backfill is to be used as detention storage, a maximum porosity of 0.4 shall be used. The backfill must be uniformly graded, clean-washed gravel or crushed stone. A maximum porosity of 0.3 may be used for sand backfill. Aggregates that may leach should not be used as backfill where void space detention is to occur.

Drain Time – The WQv within the underground system must fully drain within 48-hr whether through infiltration, extended detention, or a combination of both. The outlet structure shall not discharge more than the first half of the WQv in less than one third of the drain time.

Configuration – USWMS should be configured such that flow is uniformly distributed throughout the storage. Structural storage system headers or manifolds may be designed to convey flow across the system where necessary.

Resuspension – USWMS utilizing structural storage systems should utilize measures such as wet sumps or internal baffles to limit resuspension of sediment and dissipate energy at the entrance points where necessary.

Excavation Lining –The sides of the excavation must be lined with a Class I, non-woven geotextile filter fabric to restrict the amount of sediment entering the facility. The bottom of the excavation should be not be covered to promote infiltration. The soil surface should be scarified or de-compacted prior to placing the USWMS. An open-mesh geogrid with a minimum aperture of 1 inch may be utilized where necessary to provide soil stability or prevent migration of aggregate into the infiltration bed.

Access – USWMS must have sufficient surface access, typically at multiple locations, to perform inspection and maintenance of the system. Access shall be provided, at a minimum, over the inlet and outlet of the system. The number of access manholes will depend on the size and configuration of the system as well as the maintenance methods required.

Design Criteria – Extended Detention USWMS

Extended detention USWMS may be designed to allow for infiltration by exposing the soil subgrade surface and providing an internal water storage volume. Where groundwater contamination, hydraulic short-circuiting or other concerns exist, the system should be lined with an impermeable barrier.

Drawdown - For extended detention USWMS, the WQv has a minimum 24-hour drawdown time, with no more than ½ of the WQv draining from the facility in the first 8 hours. A graph or table indicating the drawdown of the WQv should be included in the supporting documentation.

Design Criteria – Infiltrating USWMS

Level Infiltration Bed – The subgrade soil surface shall be level; a stepped or terraced design with berms can be used to locate multiple level infiltration cells on gently sloping areas.

Minimum Infiltration Bed Area – The minimum area of the subsurface infiltration bed (A_{inf}) must exceed 0.05 times the contributing impervious drainage area (A_{imp}): $A_{inf} > 0.05*A_{imp}$

Design Infiltration Rates –Soil infiltration rate is a key input parameter for estimating WQv drain time and assuring the intended post-construction stormwater performance of infiltrating systems. Procedures to determine appropriate design infiltration rates are outlined in Section X.XX Determining Design Infiltration Rates for Infiltrating Stormwater Practices [Section Title]

For infiltrating underground stormwater management systems, the WQv must be infiltrated into the subgrade soil within 48 hours. The design infiltration rate of the subgrade soil will be based on field measurements at the appropriate depth and be verified during construction (see Appendix #: Infiltration Testing for Stormwater Practice Design). The infiltration rate shall be based on the final, after-compaction subgrade properties, if compaction is required.

Internal Water Storage (IWS) Depth - For infiltrating systems, the underdrain must be placed above the aggregate-adjusted depth of the WQv. A 6" minimum d_{IWS} for HSG A, B & C soil is recommended, whereas a 3" minimum d_{IWS} is recommended for HSG D.

Aggregate – All aggregate must be clean, double-washed aggregate free from fines (ASTM STD). All aggregate used in storage layers must be uniform, open-graded aggregate of size #1, #2, #4, or #57 (as recommended by manufacturer if applicable). A porosity of 0.40 should be used in calculations.

Hydraulic Disconnection from Utilities – The location and condition of all existing and proposed utilities should be established before an underground system is selected. All conflicting utilities must be relocated outside the underground system, and all utilities and utility trenches must be hydraulically disconnected from the stormwater management system.

Vertical Separation from High Water Table or Bedrock – The excavated bottom of the infiltration reservoir should be at least two feet higher than the seasonal high-water table (SHWT) or underlying bedrock. The separation can be reduced to one foot when the applicant can prove the water table will subside to its pre-storm elevation in five days or less.

Geotextile – The sides of the excavation must be lined with a Class I, non-woven geotextile filter fabric to restrict the amount of sediment entering the facility. Geotextile filters should not be used on the bottom of the infiltrating systems to prevent loss of infiltration capacity through clogging or masking of the filter fabric. An open-mesh geogrid with a minimum aperture of 1 inch may be utilized where necessary to provide soil stability or prevent migration of aggregate into the infiltration bed.

Design Considerations – All Practices

USWMS with structural storage systems may have confined entry limitations per Occupational Safety and Health Administration (OSHA) regulations.

Sample Design Calculations

Infiltration:

$T_d = WQv / (f)(A_{inf})$
Where,
T_d = drawdown time (hr)
WQv = water quality volume (ft^3)
f = infiltration rate of subgrade soil (in/hr)
A_{inf} = area of infiltration bed (ft^2)

Runoff Reduction Volume (RRv):

$RRv = WQv = A_{inf} * d_{WQv}$
Where,
RRv = runoff reduction volume (ft^3)
$d_{WQv} = WQv/A_{inf}$ = depth of the water quality volume (ft) [Not adjusted for porosity]
Subject to the following criteria:
Entire RRv must infiltrate within 48 hours
If the WQv does not fully drain within 48 hr, the RRv is adjusted to include only the depth of water infiltrated in 48 hr (d_{48}):
$RRv = A_{inf} * d_{48}$
The RRv cannot exceed the WQv.

Construction

For infiltrating systems, care should be taken to minimize compaction and smearing of the bottom and sides of the excavated reservoir. Any smearing or compaction will reduce the infiltration capacity of the practice. Before placement of any aggregate, the excavated bottom of the excavation for infiltrating systems should be scarified to a depth of 3 inches to reduce the effects of smearing.

Construction sequence is key to initial and long-term function of any infiltration practice. Runoff shall not be directed into the infiltration facility until the drainage area is stabilized and all sediment removed.

Maintenance

USWMS are generally less visible and more difficult to access than surface-based BMPs. Therefore, regular maintenance and early detection of performance issues are imperative to prevent significant failures.

The SWPPP should outline how and when maintenance will be performed (how, who, when/how often). For the first year of operation, underground systems should be inspected monthly and after each major (> 1”) storm event. After the first year, quarterly inspections are recommended, preferably after a storm. Consult manufacturer’s guidance for maintenance access, procedures and frequency.

If sediment is not removed mechanically, then great care must be taken not to flush sediments downstream into the receiving waters.

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Detail Drawing/Specs

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

INFILTRATION BASIN

DATE: 4/20/18

Description

Infiltration basins are vegetated open impoundments located on native soils with high infiltration capacity designed to capture and infiltrate runoff into the underlying soil. Infiltration basins will infiltrate the water quality runoff event, but also can be used to meet flood control or peak discharge requirements.

Infiltration basins require sediment pretreatment practices that remove most suspended solids before entering the basin. This is typically accomplished by directing runoff through a grass filter strip, water quality swale or forebay before it is discharged to the basin.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	An infiltration basin can be used to receive a RRv credit to reduce the site's WQv requirement. Up to 100% of the WQv.	RRv must fully infiltrate within 24 hr
Groundwater Recharge Volume (GWv)	An infiltration basin can be used to help meet the Darby Watershed groundwater recharge requirement (GWv). The amount of water infiltrated within 24 hr, up to 100% of the RRv.	GWv must fully infiltrate within 24 hr [It is expected the soil profile to a depth of 24" will drain within 48 hr]

Condition Where Practice Applies

Drainage Area – Infiltration basins are well-suited for drainage areas up to 10 acres and are a preferred substitute for extended detention basins on highly permeable soils.

Soil Characteristics – Infiltration basins work well on most new development sites with hydrologic soil group (HSG) A soils, and potentially can work on HSG-B soils. Most HSG-B soils and all HSG-C and HSG-D soils are not suitable for infiltration basins because of hydraulic conductivity limitations. Soil hydraulic conductivity describes the ability of water to move through a soil. For infiltration basins to be considered, saturated hydraulic conductivity (K_{sat}) must be at least 0.5 inches per hour throughout the soil profile. Rates lower than the minimum will result in extended ponding and nuisance conditions. This typically limits infiltration basins to sandy loam or loamy sand soils, though certain loam or silt loam soils (sand content $\geq$ 50%; clay content <20%) may provide the required K_{sat}. Field tests would be needed to verify K_{sat} for loam or silt loam soils.

Sites located in gravelly soils or coarse sands (typically sites with K_{sat} > 4 in/hr) will not provide adequate runoff treatment or protection against groundwater contamination; for these sites, replacing the top 12 inches of soil with soil that meets the bioretention practice specification will provide protection against groundwater contamination. Infiltration basins should not be constructed in fill. On-site evaluation of soil parameters related to hydraulic conductivity and groundwater by a trained professional is recommended.

Previously Developed Sites - Though infiltration basins can be considered for previously developed sites, these sites present challenges (e.g., previous grading or filling of native soils, contaminated soils) that may limit their use.

Industrial or Other Areas of Potential Ground Water Contamination – This practice should not be used in heavy industrial developments, or areas with chemical storage, pesticide storage or fueling stations.

Planning Considerations

The decision to select an infiltration basin primarily depends on the following factors:

- Infiltration capacity of the underlying soil
- Presence of shallow bedrock, a shallow groundwater table or unstable slopes
- Ability to provide adequate pretreatment
- Potential for groundwater contamination

Sediment Clogging – A principle threat to infiltration basins and a common reason for their failure is clogging of the permeable soil surface. An effective pretreatment sediment trapping system is an essential part of all infiltration basin designs. Grass filter strips, grass swales and/or sediment settling forebays should be incorporated so that most sediment is removed from runoff prior to reaching the infiltration basin. Additionally, infiltration basins may not be installed until disturbance from construction has ended and soils are stabilized.

Groundwater Protection – The soils for which infiltration basins are a suitable option typically overlie high quality groundwater aquifers. Precautions must be taken to guard against the facility introducing contaminants into water supply aquifers. Excessively permeable soils (K_{sat} > 4 in/hr) will not effectively stop pollutants and should only be used for infiltration basins if a 12-in thick bioretention media cap is included to slow and treat infiltrating runoff.

Infiltration basins should be used with caution in well-head protection areas, i.e., areas of the state where the public water supply comes from ground water. At a minimum, infiltration structures should not be located within 100 feet of an active water supply well. A minimum vertical separation of 2 feet between the bottom of the infiltration basin and the seasonal high water elevation of the groundwater must be maintained, although larger separations are recommended where achievable. Normally, infiltration through soil is a highly effective and safe means of removing pollutants and protecting groundwater from contamination. Removal mechanisms involve sorption, precipitation, trapping, and bacterial degradation or transformation.

Design Criteria

Pretreatment Required – Pretreatment is required for all infiltration basins. Recommended pretreatment practices include gravel verges, filter strips, and grass swales. Concentrated flow inlet points should be pretreated through a sediment forebay.

Drain Time Requirement – The WQv must fully drain within 24 hours.

Level Infiltration Bed – The infiltration basin surface shall be level; a stepped or terraced design can be used to locate multiple level infiltration cells on gently sloping areas.

Minimum Infiltration Bed Area – The minimum area of the level infiltration bed (A_{inf}) must exceed 0.05 times the contributing impervious drainage area (A_{imp}): $A_{inf} > 0.05*A_{imp}$.

Design Infiltration Rates – For infiltration basins, the WQv must be infiltrated into soil within 24 hours. Accurately predicting the soil infiltration rate is a key input parameter for estimating WQv drain time and assuring the intended post-construction stormwater performance of infiltrating systems. Procedures to determine appropriate design infiltration rates are outlined in Section X.XX Determining Design Infiltration Rates for Infiltrating Stormwater Practices [Section Title]

The design infiltration rate of the subgrade soil will be based on field measurements at the appropriate depth and be verified during construction (see section on measurement and verification of subgrade infiltration rate). The infiltration rate shall be based on the final, after-compaction subgrade properties, if compaction is required.

Maximum Ponding Depth - The maximum ponding depth for the WQv design volume shall be 18 inches above the infiltration bed.

Vertical Separation from High Water Table or Bedrock – The infiltration basin surface should be at least two feet higher than the seasonal high water table (SHWT) or underlying bedrock. The separation can be reduced to one foot when the applicant can prove the water table will subside to its pre-storm elevation in five days or less.

Observation Wells - A minimum of one observation well shall be provided within the infiltration basin, and located toward the center of the basin, to allow tracking of water table depth in the soil underlying the basin. Observation wells should be 5 to 6 feet in depth and constructed of 1.5 to 2.0 inch diameter PVC pipe. To allow the water table to rise in the observation well, ten to twelve 0.25-inch holes should be drilled in the bottom 2-3 feet of pipe (2 holes drilled on opposite sides of the pipe on 4-inch centers) and the length of pipe with holes wrapped with geotextile filter fabric.

Side Slopes – Basin side slopes shall be a minimum of 3:1 or flatter (4:1 or flatter is recommended) to allow mowing and other maintenance.

Vegetative Cover - A dense, vigorous vegetative cover shall be established throughout the infiltration basin within one year of basin construction. A dense vegetative cover will prevent erosion and sloughing and will also help maintain relatively high infiltration rates.

Design Calculations

The area of the level infiltration bed typically will be determined from the following equation for minimum infiltration area:

$A_{inf} \geq 0.05*A_{imp}$

Where:

A_{inf} = minimum area of the basin's level infiltration area (ft^2)
A_{imp} = impervious area within the contributing drainage area (ft^2)

To show compliance with WQv requirement determine time (T_d) for WQv to fully infiltrate:

$T_d = WQv / (f)(A_{inf})$

Where,

T_d = drawdown time (hr)
WQv = water quality volume (ft^3)
f = infiltration rate of soil (in/hr)
A_{inf} = area of infiltration bed (ft^2)

Runoff Reduction Volume (RRv):

$RRv = WQv = A_{inf} * d_{WQv}$

Where:

RRv = runoff reduction volume (ft^3)
$d_{WQv} = WQv/A_{inf}$ = depth of the water quality volume (ft)

Subject to the following criteria:
Entire RRv must infiltrate within 24 hours
If the WQv does not fully drain within 24 hr, the RRv is adjusted to include only the depth of water infiltrated in 24 hr ($d_{24\text{-}hr}$):
$RRv = A_{inf} * d_{24\text{-}hr}$
The RRv cannot exceed the WQv.

Construction

For infiltrating systems, care should be taken to minimize compaction during excavation of the basin. Any compaction will reduce the infiltration capacity of the practice. Light equipment and/or tracked equipment with low ground pressure, and construction techniques (e.g., use of plywood to distribute ground pressure) that minimize compaction should be used.

Construction sequence - Timing is key to initial and long-term function of any infiltration practice. Due to their sensitivity to sediment, infiltration basins should not receive runoff from disturbed areas of the site. Runoff shall not be directed into the infiltration facility until the drainage area is stabilized and all sediment removed. A dense, vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the infiltration basin.

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. Rough excavation of the basin may be scheduled with the rough grading phase of the project to permit use of the material as fill in earthwork areas. Otherwise, infiltration measures should not be constructed or placed into service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed basin with a large volume of fine sediment. This could seriously impair the natural infiltration ability of the basin floor.

The specifications for construction of a basin should state the following: 1) the earliest point at which storm drainage may be directed to the basin, and 2) how this delay in basin use is to be accomplished. Due to the wide variety of conditions encountered among projects, each project should be evaluated separately to postpone basin use for as long as possible.

Excavation - Initially, the basin floor should be excavated to within one foot of its final elevation. Excavation to the finished grade should be delayed until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light, tracked-equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Maintenance

For the first year of operation, infiltration basins should be inspected monthly and after each major (> 1”) storm event. After the first year, quarterly inspections are recommended, preferably after a storm.

The drainage area will be carefully managed to reduce the sediment load to the infiltration basin.

Vegetation in and around the basin will be maintained at a height of six to twelve inches. Mowing is allowed only when the basin is dry (at least 72 hours after a runoff event). Mowing should occur no more than weekly and can be as infrequent as 4 to 6 mowings per year.

No portion of the infiltration basin should be fertilized after the initial fertilization required to establish the vegetation. Lime may be allowed if soil testing shows it is needed.

The top several inches of soil should be replaced (with bioretention media) when the dewatering time of the infiltration basin exceeds 24 hours. If after replacing surface media the infiltration basin still does not drain in 24 hours, more thorough investigation is required to identify and fix the operational problems.

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Detail Drawing/Specs

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

PRETREATMENT

DATE: 4/5/19

Description

Pretreatment practices capture coarse sediments, trash, and debris, and in some cases floatable materials and oil, prior to entry into a primary treatment practice. Pretreatment practices are part of a treatment train. On their own pretreatment practices do not meet Ohio's water quality performance standards; however, the use of properly designed pretreatment:

- limits clogging of the primary treatment practice by trash and large debris,
- protects the primary treatment practice from excessive siltation,
- extends the service life of the primary treatment practice,
- reduces overall maintenance requirements and costs, and
- increases overall pollutant removal.

Pretreatment options for concentrated flow include (1) pretreatment swales, (2) forebays, (3) flow-through treatment devices, and (4) deep sump catch basins/traps. Grass filter strips (5) are recommended pretreatment for sheetflow conditions only.

Condition Where Practice Applies

Pretreatment is recommended for all projects, especially areas with the potential to generate a high volume of trash or sediment, or where the primary treatment practice has limited maintenance access.

The principle threat to infiltration practices and a common reason for their failure is sediment clogging of the permeable soil layer. An effective pretreatment sediment trapping system is an essential part of all infiltration practices.

Many practices such as such as dry Extended Detention Basins (see chapter 2.6) require pretreatment. Underground Stormwater Management Systems require pretreatment that meets TSS removal performance standards (see chapter #.#).

Planning Considerations

Pretreatment practices:

- are NOT stand-alone treatment practices,
- should hydraulically precede one or more primary stormwater management practices, and
- should not export pollutants/sediment through re-suspension and/or flushing.

By nature, pretreatment practices may require more frequent inspections and cleaning than the primary practice. As such, they should be readily accessible for maintenance and cleaning.

If it is necessary to capture fine silts, clays, and dissolved or colloidal pollutants, advanced treatment such as filtration, chemical reactions, or biodegradation should be considered.

Design Criteria – All Practices

Capacity - All pretreatment practices shall safely overflow or bypass flow in excess of the design capacity. An offline configuration is generally recommended. Any overflow or bypass resulting from clogging of the pretreatment practice should not be diverted from the primary treatment practice or treatment train. The effects of tailwater in the receiving practice or outlet on the capacity of the pretreatment practice should be considered.

Maintenance – All Practices

Because of the generally limited sediment storage capacity and limited ability to accumulate trash, inspection of pretreatment practices should be performed quarterly and after every significant (>1”) rainfall event.

PRETREATMENT SWALE

Description

Pretreatment swales are shallow, grass-lined earthen channels designed to convey flow while capturing a limited amount of sediment and associated pollutants. A Pretreatment Swale differs from a grass swale for treatment in that the Pretreatment Swale is not designed for a specified hydraulic residence time, but only for a minimum length.

To utilize Runoff Reduction credits, a grass swale must be designed to the criteria in the Grass Swale standard (Runoff Reduction Practice #.#)

Design Criteria – Pretreatment Swale

Capacity - Design the pretreatment swale to discharge the WQf at less than 1 ft/s and at a flow depth of 4” or less.

Stability – Pretreatment swales should be non-erosive for 10-yr, 24-hr event. An energy dissipater and level spreader should be used if the swale receives concentrated flow.

Cross-section Shape – Pretreatment swales shall be trapezoidal in cross-sectional shape with a 4 foot to 8-foot bottom width and minimum side slopes of 3:1. The swale bottom should be flat perpendicular to the direction of flow.

Length – Pretreatment swales receiving all or 90% of their inflow from a single inlet at the top of the swale shall be a minimum of 50 ft. in length. Swales receiving inflow distributed along one or both edges shall be a minimum of 100 ft. long such that the average flow length is 50 ft.

Slope – The maximum longitudinal grade is 4%.

Design Considerations – Pretreatment Swale

See Chapter #.#.

Maintenance – Pretreatment Swale

See Chapter #.#.

FOREBAY

Description

A forebay is an impoundment or basin located at the inlet of the primary treatment practice. A properly designed forebay includes measures to both:

(1) dissipate the energy and prevent scouring from incoming concentrated flow, and

(2) promote initial settling of coarse sediments.

Design Criteria - Forebay

Energy Dissipation – A forebay must include energy dissipation when receiving concentrated flow from a pipe or channel. Energy dissipation can be achieved through a submerged outlet pipe, rock apron or plunge pool.

Settlement Zone – A forebay should include a basin large enough to avoid resuspension of trapped sediment with a minimum depth of 3 ft. The depth of the forebay should gradually decrease towards the forebay's outlet {graphic}. A minimum length to width ratio of 1:1 is recommended to prevent short-circuiting.

Forebay Size – A forebay for a single inflow point should be 10 to 20% of the Water Quality volume. The forebay volume may be divided among multiple outlets with no single forebay less 5% of the normal pool area. Multiple inlets may require total forebay volume in excess of the minimum.

Forebay Outlet – Provide an outlet consisting of a level spreader or submerged level dike. A submerged dike separating the forebay from the main pool should be 6" to 12" below the normal water surface elevation and provide a non-erosive overflow. It should be planted with hardy emergent wetland vegetation. See the wetland extended detention pond section below for more information on planting. The design outlet discharge (q_o) should be equal to the inlet discharge (q_i).

A permanent vertical sediment depth marker should be included to facilitate inspection and cleanout.

Design Considerations - Forebay

To accommodate relatively frequent sediment cleanout, easy equipment access should be provided to the forebay (i.e. gradual slopes and free of obstructions). An access easement is recommended. A concrete or block-mat forebay bottom can facilitate cleanout. If necessary, a drain under the dike may also be included to facilitate maintenance.

Fully vegetated (wetland) forebays are effective in dissipating energy and retaining sediment.

Storage above the permanent pool may be included in the WQv.

Maintenance – Forebay

Construction – Forebay

FLOW-THROUGH TREATMENT DEVICES

Description

Several manufacturers offer a number of proprietary treatment devices that can provide pretreatment of stormwater runoff by settling, vortex flow, and/or filtration to separate trash and coarse and, in some cases, fine sediment before it enters the primary treatment practice. These devices typically treat stormwater as it flows through the practice with no significant storage or extended detention. Flow-Through Treatment Devices are often referred to as Manufactured Treatment Devices and can be classified as:

- Hydrodynamic separators,
- Oil/grit separators, or
- Media filters.

Design Criteria – Flow-Through Treatment Devices

Note: Design criteria are provided to assure compliance with post-construction stormwater requirements and sustain the stormwater system function over the long-term. In addition to this standard, engineers shall follow design specifications and recommendations provided by the manufacturer(s) of all proprietary pretreatment devices provided they meet or exceed the minimum specifications within this practice standard.

Capacity - Devices must be sized for the required efficiency at the appropriate water quality flow (WQf) for the contributing drainage area. Devices must be placed offline or fitted with an internal high-flow bypass. In some cases, flows exceeding the design rate may continue to receive reduced treatment; however, this must be weighed against the risk of resuspension at high flows. An off-line configuration is recommended. The effects of tailwater from the bypass, outlet or primary practice should be evaluated. Hydraulic losses within the system should also be evaluated.

Access – All flow-through treatment devices must have sufficient access for inspection and maintenance. Manholes provided for access should be of sufficient diameter to permit needed access as well as be labeled or identified. All sediment storage zones, filters, cartridges, or removable components must be easy to access.

All pipe joints and other connections must be watertight connections.

Design Considerations – Flow Through Treatment Devices

Underground practices should be designed for the appropriate traffic loading and dead loading at the surface.

Consider clearance and accessibility for maintenance.

Underground practices may not be suitable for locations where spill control is necessary.

Maintenance – Flow-Through Treatment Devices

All flow-through treatment devices must be inspected and maintained in accordance with the manufacturer's instructions and/or recommendations.

SUBSURFACE GEOTEXTILE FILTER SYSTEM

Description

A subsurface geotextile filter is a pretreatment practice that combines open-bottom underground storage vaults or chambers with a durable synthetic fabric which serves as a media to filter gross and suspended solids. The geotextile filter bed or area is sized to pass the Water Quality Flow. Solids accumulate on the geotextile surface and must be periodically removed to maintain system performance. These systems are utilized as pretreatment for underground stormwater management systems.

Design Criteria – Subsurface Geotextile Filter System

Geotextile Filter - The filter media shall include a minimum of two layers of woven geotextile (Maine DEP, 2016) meeting AASHTO M288 for Stabilization, Class I, <50% elongation. Geotextile should be placed over an aggregate base without damaging the geotextile. All geotextile ends, seams and splices shall be bound to prevent tearing or short-circuiting.

Geotextile Specifications (AASHTO M288 for Stabilization, Class I, Woven, <50% elongation)			
Test	Test Method	Units	Rating
Grab Strength	ASTM D 4632	lbf.	315
Tear Strength	ASTM D 4533	lbf.	113
Puncture Strength	ASTM D 6241	lbf.	620
Permittivity	ASTM D 4491	sec-1	0.05
Apparent Opening Size (AOS)	ASTM D 4751	mm (US Sieve)	0.43 (40 sieve)

Filter Area – The geotextile filter shall be sized to pass the WQf calculated for the practice's drainage area without bypassing. A maximum design hydraulic loading rate of 1.0 gpm per sq. ft. of filter area

(0.0022 cfs per sq. ft.) shall be used to size the geotextile filter area. The filter area is area of exposed geotextile at the open bottom of the storage vault or chamber.

Filter Outlet - The WQf through the geotextile filter must discharge into the extended detention storage (i.e. prior to the drawdown control device). The hydraulic capacity of any underdrains or manifolds connecting the pretreatment to the USWMS must exceed the capacity of the geotextile filter.

Access – Both the geotextile filter and WQf diversion or routing devices must be readily accessible from the surface for inspection and maintenance. Access points of sufficient size (generally ≥24 inches in diameter) should be located as necessary to remove the accumulated sediment from the entire filter area. An access point at each end of the filter is recommended. If multiple filter areas are used, each separate filter area shall have an access point for maintenance. Observation wells under 18 inches in diameter may be installed as necessary but should not be considered sufficient for maintenance access.

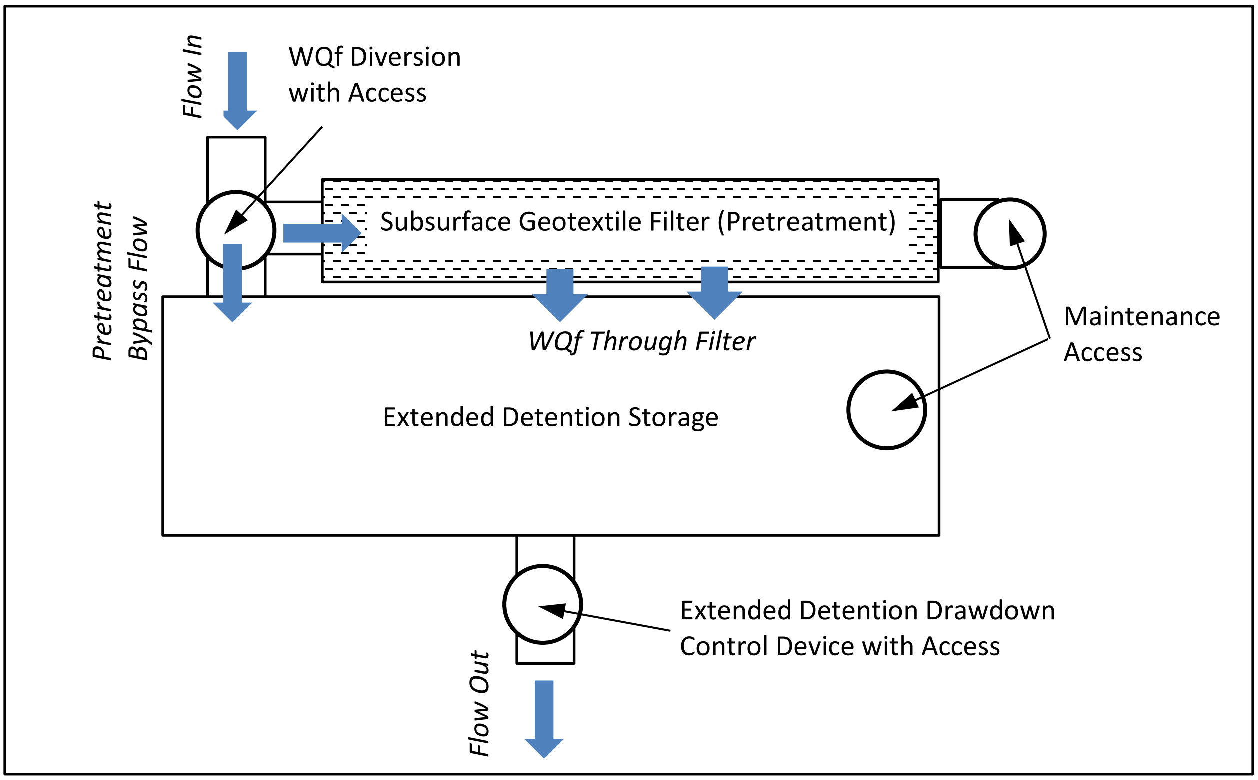

Figure 1: Schematic plan view of a subsurface media filter pretreatment system with a USWMS providing extended detention (after Maine DEP, 2016)

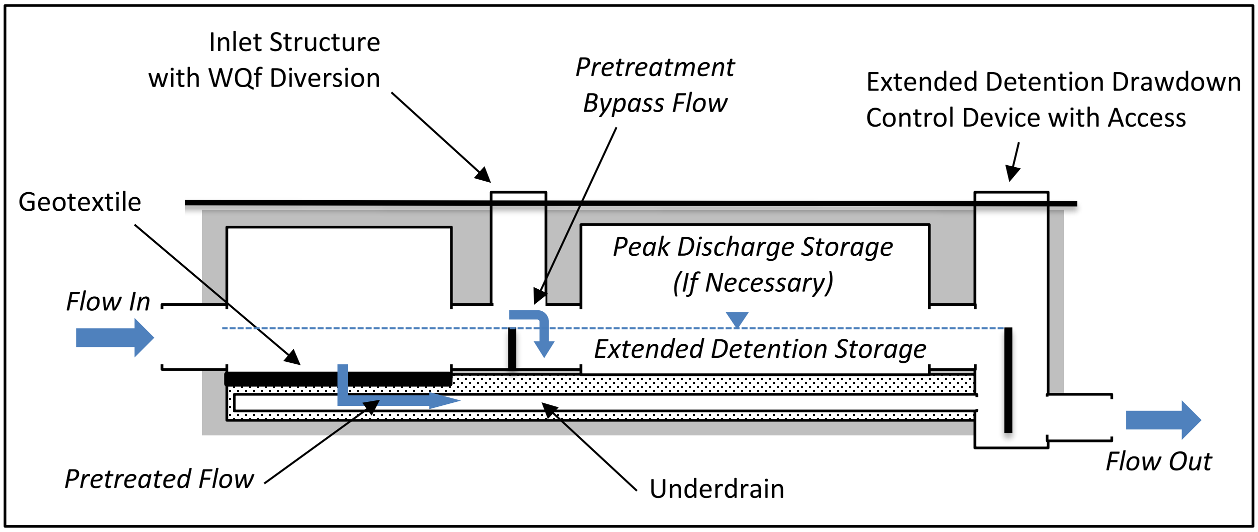

Figure 2: Schematic section of a subsurface media filter pretreatment system for a USWMS providing extended detention

Design Considerations - Subsurface Geotextile Filter System

The design engineer is responsible for the structural integrity of an underground stormwater system and any infrastructure it supports.

Consider the surface clearance and accessibility requirements for maintenance equipment.

Subsurface Geotextile Filter System may have confined entry limitations per Occupational Safety and Health Administration (OSHA) regulations.

The design should prevent reverse flow through the geotextile filter from groundwater or detained stormwater.

Maintenance – Subsurface Geotextile Filter System

An Operation and Maintenance Manual shall be provided for the geotextile filter system that specifies the maintenance procedures and schedule. Annual cleaning and removal of accumulated sediment is recommended and shall occur at least once every five years.

Construction – Subsurface Geotextile Filter System

A Subsurface Geotextile Filter Systems USWMS should not be placed into service until major construction activities have ceased and the drainage area has been permanently stabilized.

DEEP SUMP TRAP OR CATCH BASIN

Description

A deep sump trap or catch basin is an overly deep manhole or vault-like structure designed to intercept trash and debris, as well as collect coarse sediment through limited settling. The sump may receive surface flow from an open grate or curb inlet or be a closed sump within a piped drainage system.

Design Criteria – Deep Sump Trap / Catch Basin

Capacity – Individual deep sump traps / catch basins should not receive more than 1 acre of impervious area runoff.

Outlet - The outlet pipe must be fitted with a "hood" designed to prevent floating materials from exiting the structure.

Sump – The minimum sump depth is 4 ft. or 4 times the outlet pipe diameter, whichever is greater. The inlet should be no more than 6 in. above the outlet pipe invert. The sump volume should be 10% of the WQv for the drainage area of the sump.

Cover – Unless receiving surface flow through a properly designed grate or curb inlet, the sump should be tightly covered to limit mosquito breeding.

Design Considerations – Deep Sump Trap / Catch Basin

Underground practices should be designed for the appropriate traffic loading and dead loading at the surface.

Consider the clearance and accessibility requirements for maintenance operations.

Maintenance – Deep Sump Trap / Catch Basin

PRETREATMENT GRASS FILTER STRIP

Description

Pretreatment grass filter strips are uniform areas of dense turf or meadow grasses with mild slopes that receive diffuse runoff from impervious surfaces. The dense turf within a grass filter strip improves the water quality of sheet flows from developed areas by slowing runoff velocity and causing deposition and filtration of suspended solids. Other pollutant removal mechanisms include nutrient uptake, adsorption and infiltration. Grass filter strips are generally not very effective for treating soluble pollutants.

To utilize Runoff Reduction credits, a grass filter strip must be designed according to the Sheet Flow to Grass Filter Strip or Conservation Area standard (Practice #.#)

Design Criteria – Pretreatment Grass Filter Strip

Filter Area - The filter width (perpendicular to direction of flow) should be equal to the width of the area draining onto it and flat. The minimum flow length (parallel to direction of flow) should be a minimum of

10 feet at slopes steeper than 10:1 (see figure). The flow length on slopes flatter than 10:1 may be as little as 5 ft.

Slope - To avoid concentrating flow, longitudinal slopes of 5:1 to 10:1 are recommended, slope should not be steeper than 4:1.

Grass Establishment – Maintain a dense, turf-forming grass cover at 4 in. to 6 in. in height. Recommend a mixture of climate appropriate grasses (may include: perennial ryegrass, tall fescue, red fescue, Kentucky bluegrass). Filter strips should be protected from vehicle or constant pedestrian traffic through the use of parking blocks and designated walkways. Flow should be diverted from the filter strip until 80% cover is established or an Erosion Control Blanket or matting should be used.

Flow Dispersion – The filter strip must receive only sheetflow from the contributing drainage area. A gravel verge or level spreader should be used at the beginning of the filter strip. Runoff may need to be redistributed where flow is restricted by parking stops/bumpers.

Design Considerations – Pretreatment Grass Filter Strip

See Sheet Flow to Grass Filter Strip or Conservation Area (Chapter #.#)

Construction – Pretreatment Grass Filter Strip

See Sheet Flow to Grass Filter Strip or Conservation Area (Chapter #.#)

Maintenance – Pretreatment Grass Filter Strip

See Sheet Flow to Grass Filter Strip or Conservation Area (Chapter #.#)

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

IMPERVIOUS AREA DISCONNECTION

DATE: 12/20/2018

Description

Impervious area disconnection is the practice of directing stormwater runoff from impervious surfaces through grassy lawn areas, rain gardens or stormwater planters before the runoff reaches the site's drainage network to reduce runoff volumes and discharge rates.

There are two categories of impervious area disconnection:

Simple Disconnection - Runoff directed from rooftops or paved areas (e.g., driveways, bike paths, parking areas) to appropriately sized, sloped and grassed pervious areas. A simple disconnection may be used to established sheet flow into a raingarden, grass filter strip, or structural practice in a treatment train.

Enhanced Disconnection - Runoff directed from impervious areas to an appropriately sized infiltration/filtration practice such as a rain garden or stormwater planter.

Condition Where Practice Applies

Simple disconnection applies to medium to low density residential or commercial sites where it will not create flooding, drainage or structural problems. Residential use should be restricted to lot sizes $\geq$ 6000 ft^2.

Enhanced disconnection may be used where there is insufficient pervious area for a simple disconnection, or a higher volume reduction credit is desired. Rain gardens are well-suited to capturing and treating rooftop runoff in residential applications where the landscaping and stormwater management function will be maintained. Bioretention (Practice Standard 2.10) is better suited for larger commercial or institutional applications. Stormwater planters (sometimes called "urban bioretention") are well-suited for treating rooftop runoff in commercial or ultra-urban settings.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Water Quality Pretreatment	Used in conjunction with filter strips or grass swales, Impervious Area Disconnection can provide pretreatment for primary post-construction BMPs such as bioretention, infiltration basin, infiltration trench, or dry extended detention basin	
Runoff Reduction Volume (RRv)	Simple Disconnection	Designed according to minimum criteria

Impervious Area Disconnection can be used to partially reduce the WQv requirement for the affected drainage area	HSG-A/B soils: 0.04 ft^3/ft^2 of disconnection grass receiving area HSG-C/D soils w/soil amendments: 0.04 ft^3/ft^2 of disconnection grass receiving area HSG-C/D soils: 0.02 ft^3/ft^2 of disconnection grass receiving area	
	<u>Enhanced Disconnection</u> RRv varies according to practice/design	Infiltration/filtration practice designed according to minimum criteria
Groundwater Recharge Volume (GWv)	Up to 100% of the RRv [RRv from stormwater planters is excluded unless hydraulically connected to underlying soil.]	

<u>Planning Considerations</u>

Impervious area disconnections must be considered early in the design process to make sure they are compatible with lot size, slope, grading, drainage network, etc. For residential sites, the surface grading of each lot, as well as pertinent architectural features (i.e. house footprint), should be specified on the project plans.

<u>Design Criteria – Simple Disconnection</u>

Contributing Impervious Area – The maximum impervious area discharging to a single disconnection point (i.e. downspout or curb cut) is 1,000 ft^2. The length of pavement discharging as sheet flow shall be a maximum of 100 ft in the direction of flow.

Grass Receiving Area – Roof Downspout Disconnection:

- The entire grass receiving area must meet the minimum topsoil replacement specifications as described in practice standard X.X, Soil Management. For HSG-C/D with soil amendment, the entire grass receiving area must meet the soil profile restoration specifications as described in practice standard X.X, Soil Management.
- The minimum setback from the structure foundation is 2 ft for ≥2% slopes greater than and 5 ft for <2% slopes (see figure 1)
- The slope of the grass receiving area must be less than 2% for the first 10 ft of flow length with the remaining length less than 20% slope (see figure 1).
- The minimum length in the direction of flow is 10 ft or 0.04 x the Contributing Impervious Area, whichever is greater.

- The grass receiving area width shall be equal to one-half of the length up to a maximum width of 20 ft.

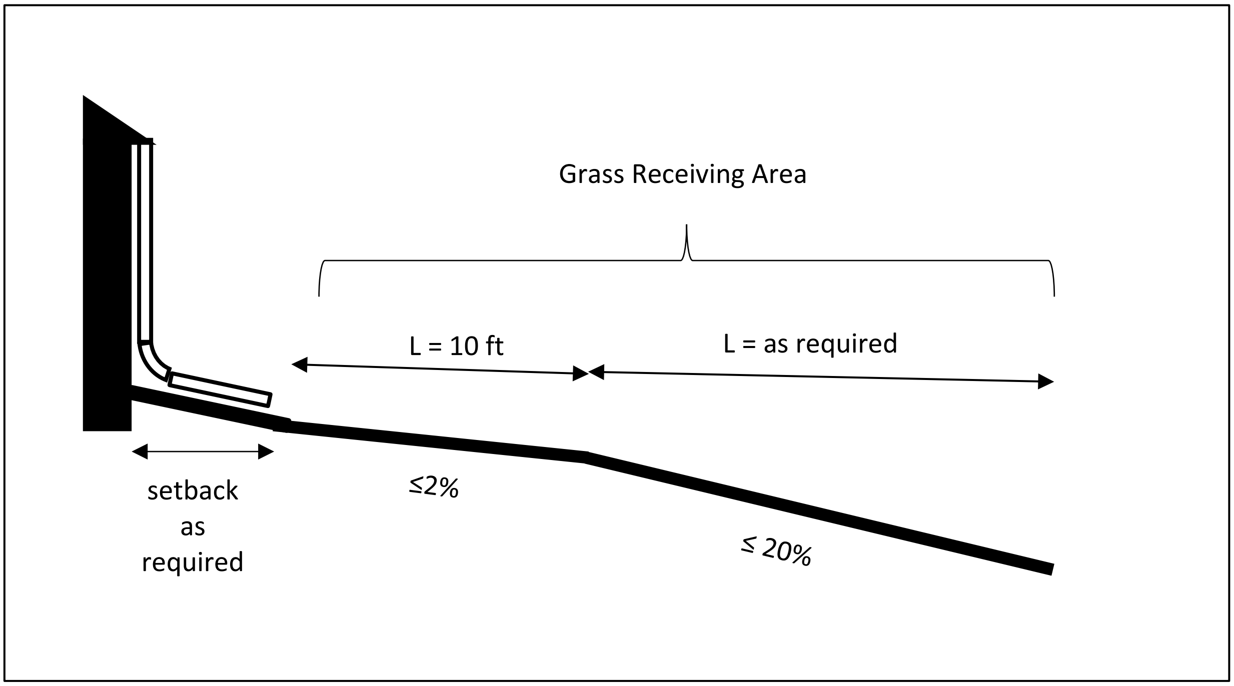

Figure 1: Profile of downspout disconnection (not to scale).

Grass Receiving Area – Pavement with Curb Cut Disconnection:

- The entire grass receiving area must meet the minimum topsoil replacement specifications as described in practice standard X.X, Soil Management. For HSG-C/D with soil amendment, the entire grass receiving area must meet the soil profile restoration specifications as described in practice standard X.X, Soil Management.
- The slope of the grass receiving area must be less than 2% for the first 10 ft of flow length with the remaining length less than 20% slope.
- The minimum length in the direction of flow is 10 ft or 0.04 x the Contributing Impervious Area, whichever is greater.
- The grass receiving area width shall be equal to one-half of the length up to a maximum width of 20 ft.
- A gravel verge must be used after the curb cuts to re-establish sheet flow.

Grass Receiving Area –Pavement with Full Sheetflow Disconnection:

- The entire grass receiving area must meet the minimum topsoil replacement specifications as described in practice standard X.X, Soil Management. For HSG-C/D with soil amendment, the entire grass receiving area must meet the soil profile restoration specifications as described in practice standard X.X, Soil Management.
- The slope of the grass receiving area must be less than 2% for the first 10 ft of flow length with the remaining length less than 20%.
- A gravel verge must be used to establish sheet flow.

- The minimum grass receiving area length in the direction of flow is 10 ft.
- The grass receiving area width (perpendicular to flow) must be equal to the pavement width.

Grass Cover and Establishment – The grass disconnection receiving area shall be permanently seeded or sodded according to Practice Standard 7.10 or 7.11 to establish a non-clumping, deep-rooted sod-forming grass appropriate for the regional climate and local site conditions (sun, partial sun, shade, etc.). Compatible legumes (e.g., white clover) may be included in the seed mix to provide nitrogen. Grass cover shall be considered established when the grass or grass-legume mix has achieved 90% coverage at 6" grass height. During grass cover establishment, soils shall be stabilized with erosion control matting until the permanent grass cover has established (minimum 90% coverage at 6" grass height). Runoff should be diverted until vegetative cover is established. As an alternative, grass sod may be used in place of seeding. Sod strips should be placed along the contour to prevent concentrating flow down the seams.

<u>Design Criteria – Enhanced Disconnection</u>

The following criteria apply to both rain gardens and stormwater planters:

Maximum Impervious Drainage Area = 2500 ft^2.

For impervious drainage areas greater than 2500 ft^2, full-size filter strips, grass swales and/or bioretention are more appropriate post-construction stormwater management options.

Pretreatment/Inflow Control – Must receive inflow as sheet flow through grass filter or include energy dissipater and level spreader for concentrated flow.

Minimum Filter Bed Area = $A_{practice} \geq 0.05 * A_{imp}$

Where:

$A_{practice}$ = the filter bed area of the infiltration/filtration practice (ft^2)

A_{imp} = contributing impervious area (ft^2)

Minimum Infiltration Rate – 0.5 in/hr verified by field tests or include underdrain.

Minimum Filter Media Depth – 18 inches.

Media Composition – must comply with bioretention media specifications.

Mulch Layer Depth – 2-3 inches.

Conveyance – The practice shall be designed to safely convey flows in excess of the design runoff event without causing erosion.

Landscaping – Rain gardens and stormwater planters should be landscaped under the direction of a qualified landscape architect, horticulturalist or other qualified professional for the anticipated ponding, soil moisture and other growing conditions. Native plants are recommended where possible.

<u>Design Calculations</u>

Simple Disconnection Example

For a residential development with ¼-acre (~11,000 ft^2) lots, the rooftop runoff from back half of 12 homes (a total of 24 downspouts) will be directed to disconnection areas on amended HSG-C soils. Each of the 24 downspouts will receive the runoff from approximately 300 ft^2 of rooftop. For each downspout, a 450 ft^2 (30 ft length x 15 ft width) simple disconnection receiving area will be established.

The RRv can be calculated from:

A_{disc} = 450 ft^2 x 12 = 5400 ft^2

RR Credit for HSG-C/D soils w/soil amendments = 0.04 ft^3/ft^2 of disconnection receiving area

RRv = A_{disc}*RR Credit = 5400 ft^2 x (0.04 ft^3/ft^2) = 216 ft^3

Construction

Impervious area disconnection within residential development requires coordination from plan development, through general site grading and layout, to home construction (WVDEP, 2012). Site developers and designers must identify and protect areas of each lot intended for disconnection receiving areas. Care should be taken during construction to protect disconnection receiving areas near proposed house and driveway locations. To minimize compaction, proposed disconnection areas should be protected from vehicular and construction equipment traffic during and after site development. These areas should be clearly delineated on plans and with temporary fencing prior to land disturbance. If compaction occurs, soils should be amended and tilled to alleviate compaction.

The following construction best-practices should be followed for simple disconnection (WVDEP, 2012):

- Before construction begins, disconnection receiving area boundaries should be clearly delineated.
- Material stockpiles shall not be located in the disconnection receiving area.
- Construction runoff should be directed away from the proposed disconnection receiving area using a diversion dike.
- Construction traffic in the disconnection receiving area should be limited to avoid compaction.
- The disconnection area may require light grading to achieve the desired elevations and slopes. This grading should be done with tracked vehicles to minimize compaction.
- If existing topsoil is removed during grading, it shall be stockpiled for later use.
- Topsoil and compost amendments should be incorporated evenly across the disconnection area, stabilized with grass seed, and protected by biodegradable erosion control matting or blankets.
- Stormwater should not be diverted into the disconnection receiving area until a dense turf cover is established.

Maintenance

Maintenance includes routine lawn and/or landscaping maintenance from the impervious discharge point to the outlet point. Landscaping maintenance staff and homeowners need education about the existence and purpose of the practice, and routine maintenance needs.

Easements

For commercial, industrial, institutional and multi-family residential, disconnection practices should be covered by drainage easements to allow inspection and maintenance. If the disconnection occurs on private residential lots, a maintenance agreement must be executed between the property owner and local stormwater authority. The agreement must specify the owner's maintenance responsibilities and authorize the authority's access for inspection or corrective action in the event proper maintenance is not performed (WVDEP, 2012).

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Detail Drawing/Specs

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

SHEET FLOW TO GRASS FILTER STRIP OR CONSERVATION AREA

DATE: 4/20/18

Description

Grass filter strips are uniform areas of dense turf or meadow grasses with mild slopes that receive diffuse runoff from roadways, roof downspouts, and parking lots, usually prior to runoff being collected by swales, ditches or storm drains and directed to another stormwater management practice. The dense turf within a grass filter strip improves the water quality of sheet flows from developed areas by slowing runoff velocity and causing deposition and filtration of suspended solids. Other pollutant removal mechanisms include nutrient uptake, adsorption and infiltration. Grass filter strips are generally not very effective for treating soluble pollutants. Grass filter strips also provide limited runoff volume reduction which can be used to reduce the required post-construction water quality treatment volume. They are also an ideal component of stream buffers or as pretreatment to a structural practice.

Conservation areas typically include perimeter areas, forested or prairie areas, and/or riparian buffers protected from the impacts of construction during the development process, and protected in perpetuity with conservation easements or protective covenants. Conservation areas can be established during construction through prairie plantings or re-forestation while maintaining or improving the existing soil.

The effectiveness of sheet flow to grass filter strips or conservation areas varies depending on the length of the filter area, slope, the quality of the underlying soil, the type and density of vegetation, and flow rates. It is critically important to maintain sheet flow through the filter area, otherwise the practice provides little to no treatment.

Condition Where Practice Applies

Grass Filter Strips - Grass filter strips can be incorporated throughout a development site, allowing multiple uses for turf areas. Grass filter strips cannot be used as the exclusive or primary post-construction stormwater control practice to manage the water quality volume (WQv) but they are quite adaptable and can be used for the following purposes:

- to provide water quality pretreatment ahead of other stormwater management practices, often the first practice in a “treatment train”,
- to disconnect impervious areas from the drainage conveyance infrastructure (channels or pipes), enhancing water quality and extending travel time,
- to provide limited runoff volume reduction to reduce the WQv,
- to treat runoff from perimeter areas that cannot be directed to a centralized BMP.

Conservation Areas – Conservation areas are ideal for: (1) receiving sheet flow from managed turf areas; (2) managing sheet flow leaving the perimeter of a development site; and/or (3) managing drainage that discharges to an external or internal (to the development site) stream/riparian buffer or wetland buffer. Jurisdictional wetlands may not serve as conservation areas. Wetlands are sensitive to increased inputs of stormwater runoff.

Perimeter Water Quality Treatment – Under certain conditions, a grass filter or conservation area at the perimeter of a site may meet water quality criteria in lieu of a centralized stormwater BMP. This would generally apply to small drainage areas where the filter strip or conservation area greatly exceeds the contributing impervious area size. This most frequently applies to residential developments where lots on some portion of the perimeter drains directly offsite and the majority of the lot runoff drains into a centralized BMP.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	Grass filter strip HSG-A/B soils: 6 ft^3/100 ft^2 of filter strip HSG-C/D soils w/soil amendments: 6 ft^3/100 ft^2 of filter strip HSG-C/D soils: 3 ft^3/100 ft^2 of filter strip Conservation area HSG-A/B soils: 9 ft^3/100 ft^2 of filter strip HSG-C/D soils: 4 ft^3/100 ft^2 of filter strip	Design according to minimum criteria in this standard.
Groundwater Recharge Volume (GWv)	Up to 100% of the RRv	

Planning Considerations – All Practices

Grass Filter Strips at the Source vs Buffer Strips at the Resource – Grass filter strips are used as close as possible to the source of runoff. They are integrated through a development site such as along the edges of parking lots. Buffer strips (a common type of conservation area) are frequently used adjacent to perennial or intermittent stream channels. Grass filter strips are planted to turf while buffer strips have diverse forest vegetation. Grass filter strips and buffer strips both treat sheet flow runoff, but buffer strips also provide many additional functions important to the riparian system: shading, bank stability, leaf litter and detritus.

Snow Storage - Filter strips can provide a convenient area for snow storage and treatment. If used for this purpose, salt-tolerant grasses should be selected.

Design Criteria – All Practices

Siting - The filter strip or conservation area must adjoin the drainage area to be treated.

Sheet Flow – All runoff must enter the filter strip or conservation area as sheet flow. Parking lot infrastructure such as gutters or curb cuts that would channelize runoff should be avoided. A gravel verge should be used to transition runoff from pavement to the filter strip. Runoff from roof downspouts may utilize impervious area disconnection.

Rock Trench – A rock trench level spreader shall be used at the top of the slope. The rock trench must have a minimum depth and minimum width of 1 foot. The rock trench shall be placed on a level contour. In addition to assuring sheet flow, the rock trench acts as a pretreatment device to settle out some sediment.

Maximum Flow Length of Contributing Drainage Area – To minimize concentration of runoff to the filter strip, the maximum flow length from impervious areas shall be 75 ft and from pervious areas 150 ft.

Controlling Traffic – In order to minimize soil compaction and maintain dense, healthy vegetation, filter strips shall not be located in areas expected to receive heavy pedestrian or vehicular traffic after the site is developed.

Establishing Vegetation – Dense vegetation is critical to effective filter strips and conservation areas. Poor stands of vegetation may result in a grass filter strip or conservation area eroding and becoming a source of pollution. Soil preparation and planting deserves special attention (see Specifications for Permanent Seeding). When selecting vegetation, select species that can withstand both wet and dry periods.

<u>Design Criteria – Sheet flow to Grass Filter Strip</u>

Length and Grade –The minimum length (i.e., distance in the direction of flow) of the grass filter strip will vary with the design grade:

- Slope = 1 - 4%: minimum 35 ft length
- Slope = 4 - 6%: minimum 50 ft length
- Slope = 6 - 8%: minimum 65 ft length

In all cases, the first 10 feet of the grass filter shall be 2% or less grade.

Soil Preparation – At minimum, the soil in the grass filter strip must meet the minimum topsoil specification (Section X.X). For HSG-C/D with soil amendment, the soil in the disconnection receiving area must be amended as described in Section X.X.

Grass Cover and Establishment – The grass filter strip shall be seeded with non-clumping, deep-rooted sod-forming grasses appropriate for the regional climate and local site conditions. Compatible legumes (e.g., white clover) may be included in the seed mix to provide nitrogen. Vegetative cover shall be considered established when the grass or grass-legume mix has achieved 90% coverage at 6” grass height. As an alternative, grass sod may be used in place of seeding. During vegetative cover establishment, soils shall be stabilized with erosion control matting until the permanent vegetative cover has established (minimum 90% coverage at 6” grass height). Runoff should be diverted until vegetative cover is established.

<u>Design Criteria – Sheet Flow to Conservation Area</u>

Length and Grade – Conservation areas should follow the natural topography. The minimum length (i.e., distance in the direction of flow) will vary with the natural grade:

- Slope = 0 -3%: minimum 35 ft length
- Slope = 3 - 6%: minimum 50 ft length
- Slope = 6 - 8%: minimum 65 ft length

In all cases, the first 10 feet of the conservation area shall be 2% or less grade. If this cannot be met, a 10’ grass filter should be installed upgradient of the conservation area.

Signage – Signs shall be posted that identify conservation areas as a stormwater management facility.

Limits of Disturbance – Conservation area limits of disturbance should be clearly delineated on all construction drawings and protected with temporary fencing and signage during construction.

Conservation Area Soil Protection – The conservation area shall not be stripped of topsoil. Light grading with tracked vehicles may be necessary at the conservation area boundary to transition from runoff areas.

Conservation Area Pretreatment – Energy dissipaters and level spreaders, as needed, should be located outside the conservation area.

Legal Protection for Conservation Areas – All conservation areas must have some form of legal protection such as a perpetual conservation easement, deed restriction or protective covenant to maintain the stormwater management function in perpetuity. The legal protection must designate the responsible party to ensure no clearing, disturbance or future development occurs within the conservation area.

<u>Design Calculations</u>

Sheet Flow to Grass Filter Strip Example

Within a larger development project, an 0.40-acre (17,400 ft^2) parking lot slopes toward the south offering an ideal opportunity to direct sheet flow stormwater runoff to a grass filter strip for runoff reduction and water quality treatment. The maximum impervious area flow length is 60 feet, which is less than the maximum 75 feet. The final graded grass filter strip slope is 5% (0.05 ft/ft) which means the minimum filter strip length is 50 ft. The width of the filter strip (the distance perpendicular to flow direction) is 290 ft at the top of slope and 320 ft at the bottom of slope for an average width of 305 ft. The soils are HSG-C and will be amended to improve soil function and receive a higher runoff reduction credit.

The runoff reduction volume (RRv) can be calculated from:

A_{gfs} = 305 ft width x 50 ft length = 15,250 ft^2

RR Credit for HSG-C/D soils w/soil amendments = 0.06 ft^3/ft^2 of disconnection receiving area

RRv = A_{gfs}*RR Credit = 15,250 ft^2 x (0.06 ft^3/ft^2) = 915 ft^3

Where:

RRv = runoff reduction volume (ft^3)

A_{gfs} = grass filter strip area (ft^2)

Construction

Grass Filter Strips - To minimize compaction, proposed filter strips should be protected from vehicular and construction equipment traffic during and after site development. If compaction occurs, soils should be amended and tilled to alleviate compaction.

The following construction best-practices should be followed for grass filter strips (WVDEP, 2012):

- Grass filter strips should be clearly delineated on plans.
- Material stockpiles shall not be located in the grass filter strip areas.
- Construction runoff should be directed away from the proposed grass filter strip until (1) the contributing drainage area is stabilized and (2) until a dense turf cover is established.
- Construction traffic in the grass filter strips areas should be limited to avoid compaction.
- The grass filter strips areas may require grading to achieve the desired elevations and slopes. This grading should be done with tracked vehicles to minimize compaction.
- If existing topsoil is removed during grading, it shall be stockpiled for later use.
- Topsoil and compost amendments should be incorporated evenly across the filter strip area, stabilized with grass seed, and protected by biodegradable erosion control matting or blankets.

Establishing Vegetation – Dense vegetation is critical to effective filter strips. Poor stands of vegetation may result in a grass filter strip or conservation area eroding and becoming a source of pollution. Soil preparation and planting deserves special attention (see Specifications for Permanent Seeding).

Seeding of the filter strip should be completed no later than September 30 to assure sufficient vegetative cover by the end of October when growth is slowed by cold temperatures. Vegetation should be inspected over the first 30 days after seeding to assure an adequate stand of vegetation has established. If an adequate stand has not been established by October 31, temporary measures must be installed to divert stormwater flows around the filter strip until adequate vegetation and stabilization occurs.

No stormwater flows should be directed to a filter strip until both the filter strip vegetation is established and the contributing drainage area has been stabilized.

Conservation Areas - Site developers and designers must identify and protect conservation areas from vehicular and construction equipment traffic during and after site development.

- Conservation areas should be clearly delineated on plans.
- Before construction begins, conservation area boundaries should be clearly delineated and access blocked with temporary fencing.
- Material stockpiles shall not be located in the conservation areas.
- Construction runoff should be directed away from conservation areas using a diversion dike.
- Managed turf is not allowed in conservation areas.

Maintenance

Grass Filter Strips - A minimum amount of maintenance should be necessary to ensure continued functioning of grass filter strips.

- Determine responsible party to inspect and maintain the grass filter strip after construction.

- Where post-construction (pretreatment or runoff reduction) credit is provided, maintenance agreements must be executed between the property owner and local stormwater authority, specifying the owner's maintenance responsibilities, and authorizing the authority's access for inspection or corrective action in the event proper maintenance is not performed.
- Grass filter strips should be covered by drainage easements to allow inspection and maintenance.
- Inspect grass filter strips regularly and following heavy rains to look for signs of rills, gullying, rutting or other problems. Repair any damage to filter strips, and immediately stabilize with seed or sod, to eliminate concentrated flow.
- Inspect level spreaders and gravel verges after heavy rains for clogging and sediment build-up. Remove accumulated sediment as needed.
- Mow the grass filter strip regularly to maintain a healthy and vigorous stand of grass. Grass should be mowed when it reaches a height of 6-8" and be mowed to a height of 4-5" to maintain healthy root growth.
- Avoid mowing when the underlying soils are wet. Mowing wet will lead to rutting, and ponding or concentration of runoff.
- Fertilizers, herbicides and pesticides should be used infrequently, and only when necessary to maintain a vigorous stand of grass. They should be used only under ideal conditions and at manufacturer's recommended rate.
- Protect the grass filter strip from damage by vehicular or pedestrian traffic.

Conservation Areas – A long-term vegetation management plan must be prepared to maintain the conservation area in a natural vegetative condition. Typically, conservation area management plans discourage or disallow active management. A plan should be developed to manage unintended consequences of passive recreation, to control invasive species, and to provide tree and understory maintenance.

- Determine responsible party to inspect and maintain the conservation area after construction.
- Managed turf is not allowed in conservation areas.
- Inspect conservation areas regularly and following heavy rains to look for signs of gullying or other problems. Repair any damage to conservation areas to eliminate concentrated flow.
- Protect the conservation areas from damage by off-road vehicles or pedestrian traffic.

References

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ODNR. 2006. Grass Filter Strip. Section 2.9 Rainwater and Land Development Manual (RLD).

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Detail Drawing/Specs

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

GRASS SWALE (RUNOFF REDUCTION)

DATE: 4/20/18

Description

A grass swale is an engineered channel shaped and established with suitable vegetation to convey water at a non-erosive velocity. Grass swales may be designed as conveyance channels for permanent runoff control or as treatment channels that provide limited water quality treatment through sedimentation and infiltration. Grass swales designed as conveyance channels should refer to Chapter 4.1. Grass Swales for Permanent Runoff Control.

Conditions Where Practice Applies

This practice is applicable where the site topography and proposed land use allow surface waterways to convey stormwater. Grassed swales are suitable for small drainage areas on flat to gently rolling terrain. On steeper terrain, it may be difficult to design a stable waterway.

This practice is applicable where pretreatment of concentrated flow is needed prior to the primary treatment practice (see pretreatment chapter #.#). Swales designed according to this standard may be eligible for runoff reduction and/or groundwater recharge credits.

This practice does not apply to defined natural streams or channels receiving prolonged flow such that grass cannot be established and maintained. Flow is limited to stormwater runoff during and immediately following a storm event. Discretion must be used when replacing natural channels with constructed channels. Small intermittent and ephemeral drainageways, provide many hydraulic and environmental benefits not duplicated by a constructed swale. Refer to chapter 3, Channel Practices for natural channels having ephemeral, seasonal or perennial flow.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	Swales constructed on: HSG-A/B soils: 0.20 inches for the contributing drainage area draining to the swale HSG-C/D soils: 0.10 inches for the contributing drainage area draining to the swale HSG-C/D soils w/soil amendments: 0.20 inches for the contributing drainage area draining to the swale	Design according to minimum criteria of this chapter.
Groundwater Recharge Volume (GWv)	Up to 100% of the RRv	

Planning Considerations

Permits - A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for grass swales that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Stable Outlet - The swale should not be constructed until a suitable stable outlet is in place, and upstream erosion control is in place.

Design Criteria – All Practices

Grassed swales shall be planned, designed and constructed to comply with all Federal, State, and local laws and regulations.

Stability - All grass swales shall not erode when flowing at bank-full depth. Grade control structures (e.g. Check dams or rock check) may be incorporated to increase channel stability. See Chapter #.#, TITLE. Grade control structures may also be used to lower the channel grade, maximizing the detention time within the grassed swale to enhance water quality benefits. Turf reinforcement may also be used to increase stability.

Slope – Grass swales should not be designed for standing water. A minimum grade of 1% is required and a grade of 2% is recommended to maintain surface flow.

Grass Establishment - The grass swale shall be stabilized with seeding protected by erosion control matting or blankets, or with sod, as soon as possible after reaching final grade. It is recommended that, when conditions permit, temporary diversions or other means be used to prevent water from entering the grassed swale during the establishment of vegetation. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting)

Drainage – Swales must be at least 1 foot above the seasonal high-water table and completely drained within hours of end of the storm event to maintain a grass cover. Subsurface drains are recommended to decrease saturated conditions. Offset subsurface drains 3 feet from the top edge of the swale. The drain's flowline should be at least 1 foot below the centerline grade and maintain at least 2 feet of cover. Subsurface drains should be installed on both sides of the swale if a high-water table or other site conditions will create wetness on both sides. Backfill shall be place so that mounding or settling does not divert surface flow from the swale. See Chapter 4, part 7 Subsurface Drains for planning and design details.

Outlets- All grass swales shall have a stable outlet with adequate capacity to prevent damage from ponding or flooding. Where the swale bottom outlet is less than 2 ft above the receiving channel bottom, Rock protection should be used. Where the swale bottom outlet is more than 2 ft above the receiving channel bottom, a designed grade control structure shall be installed. It may be necessary to keep the swale outlet above receiving channels with continuous or prolonged flow to protect the swale from wet conditions.

Design Criteria

Capacity – To maximize treatment, grass within the channel must stay erect at the design flow. The swale slope and dimensions shall be designed to carry the water quality flow from the associated drainage area at a flow depth of $\leq$ 4” and a velocity of ≤ 1 foot per second.

Stability – The swale must convey the 10-yr, 24-hr storm at non-erosive velocity.

Cross-Sectional Geometry - Grass swales providing water quality treatment must be trapezoidal in shape to promote settling and infiltration. Side slopes shall be 3:1 or flatter; side slopes 4:1 or flatter are recommended to facilitate mowing. The minimum bottom width is 4 feet. If the swale needs to be wider than 8 feet, features shall be included to prevent flow from concentrating. Consider using multiple channels with bottom widths less than 8 feet to meet capacity.

Length – The length of the grass swale shall be as needed to achieve a hydraulic retention time of 9 minutes at the water quality flow. Where length is limited, it may be possible to increase retention time by incorporating grade control structures to lower the slope of the swale. {schematic needed}

Inlet - A stable inlet (rock apron or level spreader) is required to dissipate energy and disperse flow at concentrated inlets (culvert or pipe outlet). Deep sumps are recommended where roof or parking lot drains enter a swale.

Soils– Swales located on Hydrologic Soil Group (HSG) C or D soils may include soil restoration to improve treatment and increase Runoff Reduction Credits. The soils HSG can be determined through the NRCS Web Soil Survey. Refer to Chapter #.#, TITLE for further guidance on soil restoration.

Design Considerations

Swales should not be placed where excessive tree canopy will inhibit grass growth or lead to excessive accumulation of leaves and debris.

Access and ease of mowing should be considered during the design.

Overly deep swales may enter subsoils less conducive to grass growth. Additional seedbed preparations and/or soil restoration should be considered as necessary.

Avoid bends and abrupt changes in lateral direction.

Sample Design Calculations

CAPACITY:

$$\mathrm{WQF} = \mathrm{A} \times \frac{1.49}{\mathrm{n}} \times \mathrm{R}^{\frac{2}{3}} \times \mathrm{S}^{\frac{1}{2}}$$

Where,

A= cross-sectional area (ft2)
n = Manning's coefficient of roughness (note 1)
R = hydraulic radius (note 2)
S = longitudinal slope (ft/ft)
Note 1: Values for manning's coefficient n at through grass at very low depth vary among published guidance. The commonly recommended value for n at the WQf depth is 0.20 to 0.25.
Note 2: At the Water Quality Flow the hydraulic radius may be approximated as the depth of flow of 4".

9-MINUTE HYDRAULIC RESIDENCE TIME LENGTH: $L = HRT \times V$

Where,

HRT = 540 sec. [9 min. * 60 sec/min]
V = design velocity (ft/s)

STABILITY: $\tau_e \leq \tau_a$

Where,

τ_e = erosional effective stress (as calculated above)
τ_e =allowable effective stress (see table 1)

Table1

Category	Soil Classification	Allowable effective stress (lb/ft^2)
Easily Eroded	Sand	0.02
Erodible	Silt	0.03
Erosion Resistant	Clay	0.05

$$\tau_e = \gamma DS(1 - C_f)\left(\frac{n_s}{n}\right)^2$$

Where,

τ_e = erosional effective stress (lb/ft^2)
Υ = unit weight of water (62.4 lf/ft^3)
D = maximum depth of flow in the cross-section
C_f = vegetal cover factor (recommend 0.87)
n_s = roughness associated with grain size (recommend 0.0015)
n = manning's roughness coefficient (recommend 0.025 to 0.035)
S = channel slope bed (ft/ft)

RUNOFF REDUCTION VOLUME:

$RRv = A_{cda}*Rv*credit /12$
where,
RRv = Runoff Reduction Volume in ac-ft
A_{cda} = Contribution Drainage Area to the grass swale
Rv = Volumetric Runoff Coefficient of the contribution drainage area
credit = 0.1 in. for HSG C/D or 0.2 in. for HSG A/B or amended C/D.

Sample Calculations

RUNOFF REDUCTION VOLUME: A grass swale is properly designed to drain and treat 2 acres of which 1 acre is impervious parking lot. The swale will be constructed in HSG D soil and will be amended so that a credit of 0.2 in. can be taken:

i = 1ac. / 2 ac. = 0.50

Rv = 0.05 + 0.9(0.50) = 0.5

RRv = 2 ac. * 0.50 *0.20 in. / 12 = 0.017 ac-ft

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

• Determine responsible party to inspect and maintain the channel after construction.

• Protect the channel from damage by equipment and traffic.

• Fertilizers, herbicides and pesticides should be used infrequently, and only when necessary to maintain a vigorous stand of grass. They should be used only under ideal conditions and at manufacturer's recommended rate.

• Mow the channel regularly to maintain a healthy and vigorous stand of grass. Avoid mowing when the channel and underlying soils are wet. Mowing wet will lead to rutting, ponding of water, and poor function.

• Inspect grassed swales regularly, especially following heavy rains.

• Repair damage to channels immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired.

• Remove sediment deposits to maintain capacity of grassed swale. Seed and mulch any bare areas that develop. Note: excessive deposition or erosion of the swale may indicate the need to consider changes to the current design that will be appropriate to the water and sediment transport.

• Easements should be obtained to ensure the channel is maintained as constructed.

References

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

GREEN ROOF

DATE: 11/21/18

Description

A green roof is an alternative to traditional roofing materials that may be used to capture and reduce the volume of stormwater runoff. Other names for this practice include vegetated roof, living roof, and eco-roof. A green roof uses an engineered, blended growing media that (1) has high water absorption capacity to capture and store stormwater; (2) is lightweight to reduce the structural load on the building, and (3) supports plant growth. While a conventional roof sheds nearly all rainfall as runoff, a green roof is able to store and evapotranspire a portion of the rainfall, returning the site to a more natural hydrologic condition. A green roof can be used to:

- Manage the water quality volume (WQv),
- Help meet runoff reduction goals, and
- Mitigate peak discharge[1].

Green roof runoff reduction and peak flow mitigation* are provided through absorption by planting media. The absorption capacity of the planting media is recovered through plant uptake and transpiration or evaporation. The magnitude of runoff volume reduction benefits changes seasonally, with greater runoff reduction during the summer months and less volume reduction during the winter when plants are dormant and evaporation is low (Fassman-Beck et al., 2013). Green roofs are made up of a layered system with, from bottom to top, a waterproofing layer, a drainage layer, the green roof media, and plants. Water drains vertically through the plants and media. Rainfall that is not absorbed by the planting media moves through the drainage layer to the roof drains.

There are two types of green roof systems: intensive green roofs have a deeper soil or growing media layer that is typically greater than 6 inches and may be multiple feet deep. Because of this, intensive green roofs can support a wider variety of plants – however, they are often not designed for stormwater benefits and thus typically are not credited for stormwater detention/retention. Extensive green roofs have shallower growing media (typically 4-6 inches) which is planted with drought-tolerant vegetation (typically plants of the sedum genus). Extensive green roofs are much lighter and simpler to retrofit on existing structures.

[1] Green roofs effect on peak discharge (i.e. critical storm) requirements are subject to local regulations.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	A green roof can be used to receive a RRv credit of up to 100% of WQv design volume for the green roof area.	Green roof planting soil media depth $\geq$ 4 inches Note: Only extensive green roofs included here.

Condition Where Practice Applies

Green roofs are typically installed on commercial, institutional, municipal, and multi-family residential buildings, often in ultra-urban areas where space is limited for other BMPs.

Previously Developed Sites – Green roofs can be used to reduce the impervious area of previously developed sites lowering the WQv that must be treated by other BMPs. A structural engineer should be consulted before beginning roof design for stormwater management to ensure the existing roof can support a green roof.

Planning Considerations

Layers - Typical cross-sections of extensive green roofs are shown in. From the roofing membrane moving upward, a waterproof membrane is typically applied to keep the roof from leaking. A root barrier is often installed between the drainage layer and waterproof membrane. A drainage layer is placed on top of the root barrier to drain excess water (runoff that exceeds the field capacity of the media) from the green roof. This prevents the buildup of water on the roof, which might have negative consequences on plants and structural loading of the building. Even though this drainage layer exists, emergency overflows / roof drains should be included in the design to prevent inundation. A geotextile or other filter membrane is used to separate the green roof media from the drainage layer. The green roof is planted with plants capable of survival in the dry conditions prevalent in shallow, droughty green roof media.

Media - Typically, the green roof media is between 4 and 6 inches thick and is composed of lightweight aggregate and organic matter. The organic matter, typically specialized compost, must have a nutrient level low enough to limit nitrogen and phosphorus leaching (Hathaway et al., 2008). Less than 4 inches of media will increase the mortality of plants, particularly during dry periods (NCDEQ 2017).

Plants - The green roof plant community is typically composed of succulent plants and sedums that can withstand the severe conditions encountered on a green roof (MPCA 2018). Pre-grown mats of sedum are available which provide almost instant vegetation on the green roof but allow less flexibility in planting design. Native plants such as wild onion, sedges, and grasses have also been shown to grow well on green roofs in the Midwest. Several plant selection guides are available for Ohio and in the Midwest in general (Snodgrass and Snodgrass 2006; Getter and Rowe 2008; MPCA 2018.)

Rapid plant cover can be achieved by planting at high density, including in the plant palette some plants with high growth rates, and using hardened off plants raised in green roof media and allowed to acclimate to outside conditions for a few weeks (i.e., moved out of a greenhouse).

Green roof plants and media are unfamiliar to most landscape contractors, so it is recommended contractors have a basic level of exposure to these systems through stormwater control measure inspection and maintenance short courses. Consulting with a green roof horticulturalist during the design phase will reduce the maintenance burden, as they will account for growing media depth, roof exposure, shading, wind, roof pitch, roof access, and other factors to determine a plant palette.

Modular Systems - Modular, tray-type green roof systems also are available. These are typically plastic or metal trays delivered to the site filled with growing media and pre-planted. These systems are simple to install and allow for precision in design, but may require more frequent plant replacement due to heat retention (black plastic or metal), causing the soil to dry out faster.

Structural Capacity of the Roof - For both new construction and retrofit situations, a structural engineer should be consulted to ensure the building can support the dead and live loads applied by a green roof.

Roof Access - Adequate access to the roof must be available for routine maintenance. Designers should consider how construction material will be delivered to the roof (e.g., elevator or crane) and where materials will be stockpiled.

Roof Pitch - Storage within green roof media is maximized on a flat or nearly flat (1-2% pitch) roof. Green roofs can be installed on roofs with up to a 25% pitch. However, green roofs on high slopes are more challenging as wind can lead to loss of engineered media. Additionally, pitched roofs cause water to flow with higher velocity, potentially exacerbating slippage of the media. Baffles or other methods should be used to prevent slippage of the media and to ensure adequate retention of the design storm.

Setbacks - Green roofs should not be located near rooftop electrical or HVAC systems. A 2-ft wide vegetation free zone is recommended around the roof perimeter and a 1-ft zone around all roof penetrations to act as a fire break.

Local Building Codes - Building codes differ by municipality. The local planning and zoning authorities should be contacted to obtain proper permits for a green roof. Local building codes for roof drains and emergency overflow devices apply to green roofs.

Design Criteria

A number of international standards have been developed to assist with materials specification and design of green roofs. Green roof design shall proceed in accordance with ANSI/SPRI standards (ANSI/SPRI 2011, 2016, 2017) for wind design (RP-14), external fire design (VF-1), and resistance to root penetration (VR-1). ASTM E2398 – 15a should be used to assess the hydraulic properties of any synthetic drainage layer. The procedure applies to a synthetic sheet, mat, or panel that is specifically designed to convey water horizontally toward a roof deck, drains, gutters, or scuppers. ASTM E2396 - 15 should be used to determine the permeability of coarse granular materials used as drainage layers of a green roof system (e.g. pumice, gravel, or rock instead of a synthetic drainage product). ASTM E2397-15 and ASTM E2399-15 provide guidance for determination of live and dead loads for green roof structural calculations. A licensed structural engineer must be consulted to determine the required structural support needed for the green roof to meet local building codes.

Much like a normal roof, a green roof should include specifications for roof drainage including inlets, scuppers, gutters, and pipes. Drainage elements should be flush with or below the roofing membrane. Designers should plan for a minimum of 75% vegetative cover on an established green roof as plants are critical to evapotranspiration, helping to dry out the media for upcoming storms and cool the roof, while roots help to hold the media in place during windy conditions. Green roofs planted using plugs or short root trainers are recommended to be planted at a density of 2 plants per square foot. It is recommended that an expert in green roof plant selection be consulted during the design process.

The amount of water stored in a green roof media is related to the plant available water (PAW) and the depth of the green roof media. However, continuing to increase the soil media depth beyond 4 inches results in diminishing marginal returns for runoff storage. This is true because there is a non-uniform moisture distribution in the soil where deeper soil depths do not dry out as quickly due to lesser evapotranspirative effects. Consequently, increasing media thickness above 4 to 6 inches does not provide a significant increase in retention storage potential in many instances (MPCA 2018). Thus, it is recommended no less than 4 inches and no more than 6 inches of growth media be used for extensive green roofs.

Based on the typical retention of water in a green roof media, the media retention ratio in the design calculations (see example below) is assumed to be 0.25. If the supplier can provide testing of their media blend to show that the plant available water (PAW) of the media is greater than 0.25, then this value can be utilized in the calculations below. The PAW is the difference between the water in the media at field capacity (moisture remaining after gravity drainage has occurred) and permanent wilting point (water remaining in the media that cannot be transpired by plants). The PAW can be tested in private laboratories using standard measurement procedures. A minimum media saturated hydraulic conductivity of 1.5 inches per minute should be provided to prevent ponding and freezing on the green roof. This should be tested using ASTM E2399-15.

<u>Sample Design Calculations</u>

Runoff Reduction Volume (RRv)

$RRv = A_{gr} * d_{WQv} = WQv_{gr}$

Subject to the following criteria:

$d_{WQv} \leq d_{media} * PAW$

where:

RRv = runoff reduction volume (ft^3)

Rv = 0.95 for green roof area

P_{WQv} = water quality volume precipitation depth = 0.90 in

A_{gr} = area of green roof (ft^2)

WQv_{gr} = water quality volume of the green roof area ($Rv*P_{WQv}*A_{gr} = 0.95*0.90*A_{gr}/12$) ($ft^3$)

$d_{WQv} = P_{WQv}$ = 0.90 inches for green roof area (in)

d_{media} = media depth (minimum 4 inches, maximum 6 inches) (in)

PAW = plant available water (in/in)

Peak Discharge Volume Retention Credit

$V_{ret} = A_{gr} * d_{media} * PAW$

Where:

V_{ret} = peak discharge volume retention credit

A_{gr} = area of green roof (ft^2)

d_{media} = media depth (minimum 4 inches; maximum 6 inches for credit) (in)

PAW = plant available water (in/in)

Maintenance

Green roof maintenance is particularly important immediately following construction and during the first 2-5 years after planting.

Especially during hot summer months, weekly irrigation may be needed to establish plants. This irrigation typically needs to be applied overhead even on green roofs with internal drip irrigation, as during establishment the roots will not yet reach the driplines.

Fertilizer application should be very low (if at all) to minimize nutrient leaching from the green roof.

Once established, weeding is typically needed 2-3 times per year on a green roof if it is done before weeds set seed (MPCA 2018). Weeds should be pulled and not treated with herbicide to reduce impacts to the roofing membrane.

A spring cleanup is often needed to remove dried vegetation from the previous season to encourage plant growth. Some plant mortality with time is normal.

Areas with sparse coverage or poor diversity can be bolstered by harvesting cuttings, healthy plants, or seed from other areas of the green roof.

All rooftop drains should be maintained to keep vegetation or growing media from blocking them, as standing water can result in unanticipated structural burden on the roof.

Fall protection may be required.

References

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Detail Drawing/Specs

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

RAINWATER HARVESTING SYSTEMS

DATE: 4/20/18

Description

Rainwater harvesting systems use cisterns or other reservoirs to capture and store stormwater for subsequent use and thereby reduce stormwater runoff from an area. Rooftops are the primary area utilized for rainwater harvesting due to the advantages of cleaner water and an elevation that can feed other portions of the storage and distribution system. If approved by the local regulatory authority, rainwater harvesting systems have been used to provide water for toilet flushing, landscape irrigation, urban garden irrigation, vehicle washing, cleaning buildings or sidewalks, street sweepers, fire suppression (sprinkler) systems, or replenishing decorative water features.

To be allowable for runoff reduction credit, a rainwater harvesting system must include designated uses and/or methods for consistent and year-round drawdown shortly after storm events. Because of this, the decision to incorporate a rainwater harvesting system may be based more on the cost-savings associated with the use of the rainwater rather than the value of the runoff reduction credit towards reducing the water quality volume. Cisterns can be fitted with passive or active outlets to drain all or part of storage in preparation for subsequent storm events. Drawdown water then can be discharged slowly to an appropriately sized infiltration practice such as a grass filter strip or rain garden.

Credits

Purpose/Objective	Credit Available	Requirements and Notes
Runoff Reduction Volume (RRv)	Rainwater harvesting systems can receive a runoff reduction volume (RRv) credit to reduce the water quality volume (WQv) requirement up to 100% of the WQv volume for the contributing drainage area.	The system must be designed to manage any first flush pollutants generated by the collection area. The storage volume credited must be fully available after 48 hr. Assumes the development of a water budget for use and draw down, an operation and maintenance plan and incorporation of required infiltrative practices.
Groundwater Recharge Volume (GWv)	Up to 100% of the RRv	Same assumptions as RRv.

Condition Where Practice Applies

This practice applies where a year-round use of rainwater can be developed and maintained, and where adequate space for storage of water, adequate elevation for gravity flow and distribution to the planned use and where bypassing flows to the regular stormwater system can be planned and managed.

While rainfall harvesting has many potential uses, local or state plumbing and building codes limit these. Most are non-potable uses that require complete separation from the normal indoor plumbing systems with appropriate labeling.

Planning Considerations

Dedicated Water Use – The decision to incorporate rainwater harvesting should be based on having a dedicated use or uses for the collected stormwater. Landscape irrigation and vehicle washing (with proper disposal of wash water) are two common heavy water users that may offset the cost of a rainwater harvesting system.

Regulations for Use of Harvested Rainwater – State and local regulations and treatment requirements for indoor and/or outdoor use of collected stormwater should be understood before a rainwater harvesting system is considered. Providers of stormwater harvesting infrastructure can help understand the regulatory agencies, requirements and costs.

Location – These systems should be located close to where the water will be used (e.g., a rainwater harvesting system at a school maintenance facility to be used for washing school buses). Consider whether space is available for the tank near the area from which runoff will be collected and near where water will be used, as well as any area where secondary infiltration practices will be located to receive storage tank draw down.

Contributing Drainage Area – The type, use and condition of the impervious area draining to the tank has a significant impact on the collected stormwater. For this reason, most rainwater harvesting systems utilize rooftop runoff routed directly to the rainwater harvesting system using closed roof drain systems and storm drain pipes. Roofing material affects the quality of the harvested stormwater and should be consistent with the intended use of the water.

Aboveground or Belowground Storage Tank – Rainwater harvesting systems can be designed with tanks located above or below ground. Aboveground tanks may include less infrastructure to connect to the rooftop, more hydraulic head and reduced chance of tanks floating (due to groundwater), while tanks below the ground surface save space and maintain steady temperatures.

Water Table – Underground storage tanks are appropriate in areas where the tank can be buried above the water table. Tanks located above the water table will not be subject to flooding or “floating”.

Underground Utilities – Situate tanks, piping and distribution system to avoid conflicts with underground utilities.

Collection and Conveyance System – Gutter systems are typically designed to normal capacity with positive drainage. Gravity flow connecting pipes should have a minimum slope of 1.5% and have sufficient capacity to carry the same design storm as the sum of those contributing to them.

Pretreatment – Plan methods of removing debris, sediment and other materials that must be incorporated into the system upstream of the tank(s). Without these, material will accumulate and become a source of organic enrichment in tanks. Methods may include first flush diverters, screens, roof washers, sumps, and other filters which should be evaluated for their different levels of effectiveness and maintenance requirements. Diverted first flush flows should go to a stormwater water quality practice.

Storage Tank – Tank must be of suitable capacity to store the volumes budgeted for the planned use and runoff reduction volume and include additional capacity for overflow volumes and freeboard. Tank volume is determined after evaluating what permanent level will remain in the tank between storms, the storage needed for regular water demand, and the drawdown needed between storm events. Tank(s) must be fitted with appropriately sized and located orifices to provide these volumes.

Tank Overflow – Overflow piping and surface flow paths should have at a minimum the capacity of the inflow into the storage tank(s). Screen the overflow opening to prevent animals from entering the tank. Plan routing of large storm flows that exceed tank capacity and will bypass it.

Treatment in Secondary Runoff Reduction Practice –No runoff reduction credit is available without having an identified drawdown in the storage tank either through the dedicated water uses or discharge to an infiltration area. If other runoff reducing practices are utilized for the drawdown, these should be designed according to proper specifications and shown in plans. (See Impervious Surface Disconnections, Sheet Flow to Grass Filter Areas/Conservation Area, Infiltration Basin, Infiltration Trench, Bioretention or Grass Swale.)

Design Criteria

The emphasis in this specification is on developing an accurate water use plan (water budget) and identifying and sizing secondary practices that will be used to provide appropriate runoff reduction crediting toward calculation of the downstream water quality volume. The result should provide an answer to this question: What quantity of rainfall for the contributing (rooftop) area will be removed from the downstream water quality volume on a regular basis? This will be the runoff reduction volume available and is limited to the water quality volume for that specific contributing area.

More comprehensive resources and tools are available that focus on the planning, sizing, materials and other issues surrounding design and construction of rainwater harvesting systems. Some of these are referenced below and their use is recommended for developing detailed construction plans. Additionally, there are publicly available calculators or spreadsheets that will be helpful in developing a water budget and sizing storage tanks such as that developed for the Virginia Water Resources Research Center (VWRRC, 2013).

Developing an accurate water budget should account for the contributing area, losses related to first flush diversion or screening, available storage, the intended uses and the available capacity of secondary infiltration practices where water (not used) drawn down will subsequently flow. A water budget should be developed regarding both a rainfall event basis and in terms of annual storage and usage. The volume utilized for the runoff reduction credit is developed using the rainfall collected and utilized or made available within 48 hours of last filling.

1. Roof area utilized for rainfall capture (square feet)?

2. If a first flush diverter is utilized, what amount of every event is diverted (percent loss or inches loss?

3. Inches of rainwater being captured and stored for use and subsequent drawdown (combination of 1 & 2)?

4. Cubic feet of rainwater being captured and stored for use and subsequent drawdown (combination of 1 & 2)?

5. What secondary infiltration practices will be used? What size or capacity is associated with each practice?

Stormwater Pollution Prevention Plans should show the entire rainwater harvesting system including: the identified contributing drainage area, conveyance, pretreatment, storage tanks, distribution system outside of buildings, and secondary infiltration practices (including capacities, and details),

RUNOFF REDUCTION VOLUME

RRv = A_{cda} (ft^2) *RWH (in) /12

where,

RRv = Runoff Reduction Volume in ft^3
A_{cda} = Contribution Drainage Area to the Rainwater Harvesting System in ft^2
RWH_{in} = Rainfall captured provided that:

- diversions (#3 above) have been subtracted;
- < 0.855”;
- Only that which is provided sufficient drawdown within 48 hours after rainfall events.

Maintenance – All Practices

Rainwater harvesting systems must have an operation and maintenance plan developed that details what actions will be necessary to ensure continual function of the system. Some local government stormwater management authorities may require easements and maintenance agreements for the system.

Inspections – The table below presents recommended inspection and maintenance activities and an associated frequency.

Table # Recommended Maintenance Tasks

Schedule	Activity
2 times a year	Clear gutters and downspouts of debris
2 – 4 times a year	Inspect and clean first flush diverters, filters and screens
Annually	Inspect overflow pipes, filter path and secondary runoff reduction practices
Annually	Inspect lids, vents and animal or mosquito screens for clogging, fit, holes and gaps.
Annually/Semiannually	Inspect contributing drainage area for debris, sources of debris (e.g. overhanging vegetation)
Every 3 years	Inspect tank for sediment buildup.
Every 3 years	Inspect tank, pumps, pipes and plumbing system (including backflow preventers), electrical system for integrity

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL PRACTICE STANDARD #.#

SOIL MANAGEMENT

DATE: 12/20/18

Description

Good soil quality and healthy vegetation are the most important determinants of stormwater runoff from urban and suburban pervious areas. The vigorous root growth that comes with healthy vegetation - whether trees, lawn or landscaping- helps maintain soil structure and associated soil conditions (collectively called soil tilth) that, in turn, provide the right combination of nutrients, air and water for healthy plant growth.

Good soil structure promotes infiltration of rainfall and runoff, and supports the vigorous root growth that maintains soil infiltration over time. Mass soil grading and compaction that accompanies most site development destroys this soil structure by breaking down soil aggregates into individual soil particles and closing off pathways for air, water and root growth. The increased soil density makes it much more difficult for plant roots to play their role in re-building good soil health and hydrologic function.

Unless effort is made to alleviate compaction and restore a healthy root zone, graded soils act more like an impervious surface than pasture land or meadow to which they are often equated. It is expected for all development sites, post-construction soil conditions will be restored to a minimum set of criteria that allow healthy plant growth without fertilizers or irrigation and which provides hydrologic function consistent with open space in good hydrologic condition (NRCS, 1986) and a volumetric runoff coefficient (Rv) of 0.05 (Ohio EPA, 2018). Two levels of soil management are specified:

1. Topsoil Replacement – this is the minimum allowable restoration of the shallow (8”-10”) soil root zone often referred to as “topsoil” or the soil’s A horizon.
2. Soil Profile Restoration (Amended Soil) – this is a more extensive alleviation of soil compaction and improvement of soil hydrologic function through restoration of a deeper soil root zone and the incorporation of soil amendment (compost) using subsoiling (also called “soil ripping”) and other appropriate tillage.

Condition Where Practice Applies

The replacement of topsoil or restoration of the soil profile with tillage and soil amendments should be used wherever soil grading and/or compaction of pervious open space has occurred.

Credits

Topsoil Replacement is required for all site pervious areas where the soil was graded or compacted. Soil Profile Restoration is required to receive the higher credit for the following runoff reduction practices on C/D soils:

- Simple disconnection to amended soils
- Sheetflow to amended soils

- Grass swale with amended soils

Planning Considerations

Restoring soil function during construction is critical but will never be able to fully recover the structure and function of natural soils. Where healthy soil and trees are present, it is more effective to preserve existing soil and protect trees during construction activities.

- Clearly identify and protect areas that can be left undisturbed or those critical to landscape function (e.g., riparian areas, conservation areas, watercourses and drainageways, wetlands, and areas with mature trees).
- Fence all trees to be saved off at a distance equal to 1.5 times the radius of the drip line (Hanks and Lewandowski, 2003).

Soil compaction can be lessened by using low pressure, tracked equipment and traffic control which also results in less effort and cost to restore soil function.

Planning Considerations - Residential Subdivision Development

Soil disturbance in the development of a residential subdivision usually occurs in two separate phases: first, the site clearing and mass grading that occurs with the installation of roads and infrastructure and, second, house construction and final lot grading. Additional disturbances can occur through the development process. Soil restoration in residential developments should occur such that soil profile restoration is completed during the initial development phase. Once primary construction traffic is relegated to paved streets, topsoil replacement can occur within individual lots at the conclusion of major construction activities or when sodding and landscaping occurs.

Design Criteria – Topsoil Replacement

Healthy lawns have dense turf that minimizes soil erosion from stormwater runoff and maintains soil infiltration capacity without the need for excessive watering and fertilization. Healthy lawns are difficult to establish and maintain without first establishing the proper rooting environment. Healthy rooting environments require a minimum 6 inches of friable loamy topsoil and a minimum 12 inches of uncompacted rooting zone. This can be accomplished by:

(1) preserving or protecting the natural soil profile during and following construction;

(2) removing and stockpiling topsoil before any grading; post grading, the subgrade should be tilled to a depth of 6 inches and 6 inches of topsoil replaced (without compaction);

(3) removing and stockpiling topsoil before any grading; post grading, the graded/compacted soil should be tilled to a depth of 6 inches, 4 inches of topsoil replaced (without compaction), and sod placed.

The topsoil must meet the following specifications:

- Topsoil must have minimum 6” depth of loose, friable soil
- Topsoil texture – Loam, silt loam or sandy loam texture
- Clay content must be less than 20%

- Organic matter content must be >5% (by weight) – determine by loss-on-ignition or equivalent test

- Bulk density – the dry, settled (i.e., after placement and wetting) bulk density must be within the following ranges:

Soil Texture	Dry Bulk Density (settled)
	g/cm^3 (lb/ft^3)
Silt Loam	1.20 – 1.35 (75.0 – 85.0)
Loam	1.25 – 1.40 (78.0 – 87.5)
Sandy Loam	1.30 – 1.45 (81.0 – 90.5)

- The soil profile to a depth of 12" must have penetration resistance less than 200 psi (1.4 MPa) [As measured by a cone penetrometer inserted at 0.8 in/s (2 cm/s)] (ASABE, 1999)

- The area should be immediately seeded, sodded or planted in accordance with ###. Straw mulch or erosion control blankets should be used in accordance with ### to protect the soil until vegetation matures.

- Topsoil replacement is considered complete when 90% vegetative cover is established.

<u>Design Criteria – Soil Profile Restoration</u>

Undisturbed soil profiles provide extensive hydrologic function (infiltration and retention of rainwater, groundwater recharge, stream baseflow maintenance) through a combination of a healthy root zone and micro- and macro-pore structure developed over hundreds or thousands of years in the subsurface horizon (called the B horizon by soil scientists) through weathering, freeze-thaw cycles and the action of roots, earthworms and other soil biota. The beneficial hydrologic functions provided by the soil profile are wiped away by soil grading and compaction. Without some assistance to kickstart the restoration of beneficial soil characteristics, urban lawns can take decades to begin to recover hydrologic function that could be called "open space in good hydrologic condition" [which NRCS (1986) equates to intact pasture soils in good hydrologic condition].

Deep tillage and compost amendments are the most expedient tools available to begin to recover soil hydrologic function throughout the soil profile. [Add footnote on deep rooted plants] Compost serves two primary roles in the restoration of the soil profile. First, when a layer of compost is applied before deep tillage some of the compost is worked down into the trenches created by the subsoil tillage. Without the compost mixed down into these tillage slots, the soil would quickly settle back into its compacted state. The compost helps to maintain pathways for root growth, and air and water entry, into the deeper part of the soil profile. Secondly, compost provides nutrients for soil organisms and plant roots that will re-build healthy soil structure.

The soil restoration process for amended soil consists of several steps designed to (1) begin to recover and build soil structure and root function in the graded subsoil; (2) restore 8-10 inches of loamy, friable topsoil rooting zone; and (3) establish an excellent stand of deep-rooted grasses (minimum 90% vegetative cover). This can be accomplished through the following steps/operations:

(1) remove and stockpile topsoil before any grading;

(2) post grading, spread/place a 2-3” layer of compost over the entire surface of the graded/compacted soil;

(3) using a subsoiler, break up the graded/compacted soil to a minimum 18” depth, working the compost into the soil profile; the compacted area shall be subsoiled to form a two-dimensional grid of deep-ripped “channels” with one of the directions following the contour (Figure XX) – for slopes steeper than 4:1 (>25%), a single subsoiling pass following the contour is recommended; the subsoil channels shall be created with a commercially available parallelogram solid-shank ripper with the channels spaced a maximum of 18 inches apart.

(4) using a chisel plow or offset disk, loosen the resulting soil surface to a depth of 6” to loosen the soil and incorporate the remaining compost [Alt: mix in the remaining compost];

(5) replace the stockpiled topsoil to a depth of 6 inches over the entire soil surface;

(6) seed with deep-rooted sod-forming grasses; mulch as appropriate; soil restoration requires vegetated cover greater than 90%.

To receive credit consistent with a restored soil profile, the amended soil must meet the following specifications:

- The topsoil must have 8-10” depth of loose, friable soil
- Topsoil texture – Loam, silt loam or sandy loam texture
- Topsoil clay content must be less than 20%
- Topsoil organic matter content must be >5% (by weight) – determine by loss-on-ignition or equivalent test
- Topsoil bulk density – the dry, settled (i.e., after placement and wetting) bulk density must be within the following ranges:

Soil Texture	Dry Bulk Density (settled)
	g/cm^3 (lb/ft^3)
Silt Loam	1.20 – 1.35 (75.0 – 85.0)
Loam	1.25 – 1.40 (78.0 – 87.5)
Sandy Loam	1.30 – 1.45 (81.0 – 90.5)

- The subsoil to a depth of 20” must have loose, friable soil
- The entire soil profile to a depth of 20” must have penetration resistance less than 200 psi (1.4 MPa) [As measured by a cone penetrometer inserted at 0.8 in/s (2 cm/s) (ASABE, 1999)
- Vegetated cover must be greater than 90%

Compost Specification

Following the U.S. Compost Council (2005) the compost material shall be a well decomposed, stable, and weed free organic matter source. It shall be derived from: agricultural, food, or industrial residuals; biosolids (treated sewage sludge); or yard waste (grass clippings, leaves). The product shall contain no substances toxic to plants and shall be reasonably free (< 1% by dry weight) of man-made foreign matter. The compost shall possess no objectionable odors and shall not resemble the raw material from which it was derived. The product shall be certified through the U.S. Composting Council's (USCC) Seal of Testing Assurance (STA) Program.

The compost shall meet the following criteria (U.S. Composting Council, 2005; VA DEQ, 2016):

- 100% of the compost material must pass through a half-inch screen
- The pH of the material shall be between 6.0 and 8.5
- Soluble salt content shall be less than 10 mmhos/cm
- Inert material (plastic, concrete, ceramics, metal, etc.) contaminants shall be less than 1% by weight
- The organic matter content shall be between 35% and 65%
- Maturity shall be greater than 80%
- Stability shall be less than 8

Construction

Maintenance

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<u>Detail Drawing/Specs</u>

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RAINWATER AND LAND DEVELOPMENT PROVISIONAL APPENDIX A-#

INFILTRATION ESTIMATES FOR STORMWATER PRACTICE PLANNING

DATE: 12/20/18

NOTE: These estimates should be used for initial project planning and conceptual layout only – that is, to assess feasibility and develop a ballpark estimate of the area allocated to infiltration practices. The estimates are not adequate for final sizing or design of BMPs. Sizing and design of infiltration practices requires appropriate field measurement of field saturated hydraulic conductivity at the development site, at the specific location of proposed practices and at the proposed depth of excavation for the practices (See Appendix XX: Soil Infiltration Testing).

NOTE: These estimates are intended for undisturbed sites and should not be used for sites where the soil previously was subjected to cutting, filling, or grading.

Introduction

This guidance provides subgrade infiltration rate estimates for development projects that include infiltrating stormwater practices such as bioretention, pervious pavement, infiltration trenches and underground infiltration systems. The method outlined below is appropriate only for initial project conceptualization and planning.

Subgrade infiltration rate estimates for your site requires, at minimum:

1) Estimating the excavated depth of proposed infiltration practice(s);
2) Identifying the (USDA) soil texture at the proposed depth of excavation.

We recommend reviewing properties of all soil layers to identify best opportunities for infiltration.

1. Estimating the Depth of Excavation for the Proposed Infiltration BMP

It is often challenging early in the site planning and development process to know exact grading, drainage patterns and BMP locations. Typically, a rough estimate of final surface grade and the required design excavation depth for proposed infiltration BMPs will give us enough information to identify the soil layers (typically B or C horizons) where the excavated bottom of the BMP is likely be located (Figure XX). Examples for developing rough, first estimates are presented here:

1) Bioretention - Total section depth (i.e., drainage layer, aggregate layer, soil media, and mulch layer) for bioretention is a minimum of 42" and often reaches 54" or more. By adding that depth to the typical 18” to 30” surface basin depth (ponding plus freeboard) results in estimated excavation depths between 60” and 84”. In the absence of more definitive design information, assuming a BMP excavation depth between 60" and 72" depth is a good place to start.

2) Permeable Pavement - Total section depth (i.e., the pavement surface and all underlying aggregate) for permeable is a minimum of 15" below finish grade, and may be 40" or more to account for frost

penetration depth, an infiltration sump, and/or detention of larger storm events for peak discharge control. In the absence of more definitive design information, assuming an BMP excavation depth between 24" and 30" depth is a good place to start.
3) Infiltration Trench – A typical section depth for an infiltration trench will be 48 inches.

4) Underground Detention with Infiltration - Total section depth (i.e., the pavement surface, underlying aggregate and storage units) can range from 4 ft to over 8 ft depending on a number of factors. Calculating the required storage volume and the available BMP footprint is necessary to determine excavated depth.

2. Identifying the Soil Texture at the Proposed Depth of Excavation

There are two approaches to identifying the soil texture at the proposed depth of excavation for planned BMPs: (1) collect soil samples at the proposed depth of excavation and send to a laboratory for soil textural analysis (soil particle size distribution); or (2) use the USDA-NRCS Web Soil Survey to identify the soil texture at the proposed excavation depth for the mapped soil(s) at the project site.

Collecting Field Samples for Soil Texture Analysis

NOTE: The soil texture used for estimating soil infiltration rate is based on the USDA soil texture classification system (represented by the USDA soil textural triangle) (reference) and not AASHTO or USCS Classification Systems in common use for soil engineering evaluations.

Samples for soil texture analysis can be collected using a truck-mounted soil probe or a handheld auger. It is recommended the entire soil profile from the surface to at least two feet below the expected depth of practice be described, noting layering (horizonation) of distinct soil layers with both physical and qualitative descriptors (texture, coloration, organic matter content, structure, density, depth of water table or bedrock, if present).

Oftentimes geotechnical soil borings are used early in project development to evaluate site soils and/or geology for soil engineering properties and structural considerations. Soil samples at the depth(s) of interest are collected and submitted to a soils laboratory for USDA textural analysis. If soil boring samples are already being characterized for particle size distribution (PSD), the PSD can be used to establish USDA soil texture.
[See https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs142p2_054167]

Another option is to hire a professional soil scientist (https://www.ohiopedologist.com/consultant-list.html) to collect and submit samples at the proposed excavation depth(s).

Identifying Soil Texture through Web Soil Survey

1) Using your internet browser go to:
http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

[Note: Web Soil Survey will not work under certain browser security settings. You may need to change the security settings on your browser to use Web Soil Survey.]

2) Click on the Green “Start WSS” button. This activates the Web Soil Survey (WSS).

3) Navigate to your Area of Interest (AOI). [There are several ways to navigate to your AOI - feel free to explore WSS to find which works best for your situation. One method is presented here.] Click on the “State and County” line left of the U.S. map. Enter “Ohio” and your county of interest, then click “View”. Your county of interest should appear.

Using the zoom tool (magnifying glass with +), progressively zoom in until your site is visible on the viewer. This may take a couple zooms.

Once your site can be clearly identified in the viewer, outline your site using one of the two Area of Interest (AOI) buttons at the top of the viewer. If your site fits neatly into a rectangle, use the left AOI button. If your site has an irregular shape, use the right AOI button.

Click on the appropriate AOI button, then select the first corner of your AOI. Use successive clicks until you have outlined the area, then double click to “set” or complete the Area of Interest. At this point you can save your AOI if you like (Recommended).

4) Click on the Soil Map tab. The Map showing all Map Unit Symbols within your area of interest will be generated. In addition, a Map Unit Legend table will be shown to the left of the map with Map Unit Symbols, Map Unit Names, Acreages within your AOI, and Percentage of AOI.

5) Within the Map Unit Legend table, click on the Map Unit Name for a soil of interest. A Map Unit Description will pop-up. In the lower half of the Map Unit Description will be a “Typical Profile” that will list depth and texture of typical soil layers for this soil. Record the soil texture at the depth(s) of interest.

[Note: Through the Soil Data Explorer tab, all of the available soil survey data for the mapped soils can be accessed and reports generated.]

6) Using the texture(s) identified, select the most limiting (lowest) infiltration rate from Table XXX.

<u>Estimated Infiltration Rate by Texture</u>

The following chart provides good estimates of subgrade infiltration rate based on texture.

Subgrade USDA Soil Texture	Clay Content %	Infiltration Rate (in/hr)
Sand	< 8	2.8
Loamy Sand	< 15	2.0
Sandy Loam	< 20	0.80

Loam	< 20	0.25
Loam	20 - 27	0.06
Silt Loam	< 20	0.10
Silt Loam	20 - 27	0.03
Silt	< 12	0.05
Sandy Clay Loam	20 - 35	0.07
Clay Loam	27 - 40	0.02
Silty Clay Loam	27 - 40	0.02
Silty Clay	40 - 50	0.01
Sandy Clay	35 - 50	< 0.005
Clay	> 40	< 0.005

How the Infiltration Rate Estimates Were Generated

Subgrade infiltration rate estimates were generated using a tool called the Soil Water Characteristic Calculator (Saxton and Rawls; http://hydrolab.arsusda.gov/soilwater/Index.htm) through the following steps:

(1) Organic matter was set to 0.5% to account for lower organic matter content in subsurface horizons.
(2) Compaction was set to 1.10 (Dense) to account for higher bulk density in subsurface horizon.
(3) Except for Loam and Silt Loam, the sand, silt and clay content was set by selecting the soil Texture Class from the pulldown menu. For Loam and Silt Loam, sand, silt and clay contents were selected by eye-balling a somewhat centrally located texture for the area below 20% clay and for the area between 20% and 27% clay content.
(4) Infiltration rate estimate was the resulting Saturated Hydraulic Conductivity generated by the Calculator.

RAINWATER AND LAND DEVELOPMENT PROVISIONAL APPENDIX A-#

INFILTRATION TESTING FOR STORMWATER PRACTICE DESIGN

DATE: 12/20/18

Introduction

This guidance provides procedures for field determination of subgrade infiltration rates that can be used for the design of infiltrating stormwater practices such as bioretention, pervious pavement, infiltration trenches, infiltration basins and underground infiltration systems. Subgrade infiltration tests often are part of a broader geotechnical investigation to evaluate soil characteristics and soil layering at locations proposed for infiltrating stormwater practices that will help the designer understand site and soil suitability or limitations.

Geotechnical Investigation

Information collected during geotechnical investigations is necessary to determine whether infiltration practices are a viable option. In addition to establishing infiltration rates for design, geotechnical investigations are used to evaluate slope stability, depth to bedrock or groundwater table, constructability and other site characteristics that affect infiltration practice suitability (WDOE, 2012).

Before - or in conjunction with - subgrade soil infiltration testing, soil borings or test pits should be used to evaluate the entire soil column from the soil surface to a depth (often 10-15 feet below original grade) that allows characterization all soil layers and identification of any impediments to infiltration including clay-dominated soil layers, compacted glacial till, water tables and/or bedrock. This investigation will also allow identification of more permeable sand or gravel layers, if present, that might be accessed to facilitate enhanced infiltration.

Infiltration Test Report

The infiltration test report should include (at minimum) (adapted from COIC, 2010):

- A map that identifies:
    - Project boundaries; [TOPO MAP??]
    - Surveyed soil map units;
    - General location(s)/outline(s) of proposed infiltration practices and outlets;
    - Location of infiltration tests;
    - Locations of soil borings or test pits;
    - Existing natural or constructed drainage features;
    - Proposed site structures and infrastructure including parking areas, roadways and drainage features;
- Logs of borings and/or test pits including groundwater elevation, if encountered);
- Results of infiltration tests including raw data, assumptions and calculations;
- Photograph(s) of the test pit and test set-up;

- Any pertinent field notes that help characterize the site and soil being tested;
- Conclusions and recommendations.

Infiltration Test Methods

Note: By law, everyone MUST contact the Ohio Utilities Protection Service (OUPS; http://www.oups.org/), 8-1-1 or 1 800 362 2764 to mark utilities at least 48 hours but no more than 10 working days (excluding weekends and legal holidays) before beginning ANY digging project.

Two infiltration methods are considered acceptable by Ohio EPA for determining design infiltration rate estimates for Table 4b post-construction stormwater practices (Ohio EPA, 2013):

(1) Single-ring Infiltrometer Method; or
(2) Pit Method.

Note: Bore hole infiltration tests and other similar small-diameter, 3-dimensional percolation methods are not acceptable methods for determining design infiltration rates for Table 4b Infiltration Practices (Ohio EPA, 2018). These methods overestimate subgrade infiltration rates by several orders of magnitude resulting in undersized infiltration bed areas that will not meet design drawdown requirements.

Single-Ring Infiltrometer Method

The Single-Ring Infiltrometer Method ponds water at a constant head in a ring (typically a section of steel pipe with a beveled edge) driven into the ground at the excavated depth for the proposed infiltration practice.[2]

Procedure (following Reynolds, 2008; Reynolds et al., 2002; and COIC, 2010)

1. Excavate a pit to the depth of excavation for the proposed infiltration practice. The pit must be large enough to conduct multiple tests in without disturbing the subgrade soil to be tested – a 4-foot wide by 6-foot long test pit bottom typically is sufficient for this purpose. The sides of the pit can be laid back or stepped as needed to facilitate entry/exit.
2. In the bottom of the test pit, use a hoe or other square-edged scraping tool to create a level soil test surface larger than the diameter of the infiltrometer ring. Make note of rocks, roots, macropores, smearing or any other conditions that might affect the test or intake rate. Photograph the test pit and area to be tested before the ring is placed.
3. Place the infiltration ring having a minimum inside diameter of 12 inches and a beveled leading edge [typically manufactured from a short (12” to 18” length recommended) section of steel

[2] Constant-head ring infiltrometer tests can be conducted using a single ring (Single-ring Infiltrometer) or two concentric rings (Double-ring Infiltrometer). It is recommended the tester utilize the Single-ring Infiltrometer Method with corrections for flow divergence and soil sorptivity. If a double-ring test is conducted: (1) the test must comply with ASTM D3385 (ASTM, 2009); (2) the inner ring must be a minimum 8-inch diameter and the outer ring a minimum 15-inch diameter; and (3) the infiltration rate used for design should be the final (steady state) constant-head infiltration rate divided by 2 to account for the effects of flow divergence and sorptivity.

pipe] on the level testing area and drive the ring into the subgrade soil surface a minimum 3 inch depth, leaving approximately 9” to 12” of pipe exposed above the soil surface (FIGURE XX). Check the surface of the soil inside and outside of the ring, especially near the wall of the ring, for cracking or separation of the soil from the ring wall. If there are signs of excessive cracking or disturbance, move and re-install the ring at another location. If the surface of the soil is only slightly disturbed along the ring, lightly tamp the soil inside and outside the wall to close the gap against the ring wall.

4. Place a double-layered section of plastic window screen inside the ring on the soil at the bottom of the ring to protect the soil from eroding when first introducing water into the ring. The screen should be slightly bigger than the ring area so that no soil is exposed to flowing water.
5. It is recommended for denser or tighter (clay loams or silt loams) that a Mariotte bottle be used to supply water and maintain a constant ponded head in the ring. In addition to maintaining a constant head, Mariotte bottles allow precise reading/recording of intake volume and intake rate. For coarser soils (sands, sandy loams and loams) with higher infiltration rates, a larger water reservoir (e.g., 5-gal bucket or 50-gal tank) with a spigot may be used to supply water – this water supply apparatus must be fitted with a flow meter or other precise method for measuring volume and rate of water supplied.
6. Ponding in the ring should be quickly brought up to a minimum of 6 inches (maximum 12 inches) and maintained at constant depth for the remainder of the constant head test. It typically will be most efficient to bring the ponding depth to within 1 inch of the target ponding depth by pouring water from a bucket rather than from a Mariotte bottle or other flow metering device, then using the metered water source to make fine adjustments to establish ponding at the target depth for the constant head test.
7. The time the constant ponding depth is reached should be noted, and this time denoted as “time zero” for purpose of the constant head test. The exact ponding depth to the nearest 0.1 inch should be noted and recorded at the first (time zero) and each subsequent reading to confirm consistent head is being maintained. Photograph the set-up during the test.
8. The volume of water supplied to the infiltrometer ring should be recorded at time increments sufficient to capture changes in the intake rate (i.e., the rate the water moves into the soil). Shorter time increments typically are necessary at the beginning of the test and can be extended as soil within the ring saturates and intake rate slows. For clayey soils (e.g., clay loam, silty clay loam) an initial time increment of 15 minutes may be sufficient, extending the time increment to 30 minutes between readings as intake rate slows. In contrast, sandy soils may require readings every minute or every 5 minutes throughout the test.
9. Water supply to the ring and readings recording the volume supplied should continue until a constant or steady state intake rate has clearly been established. A good rule of thumb is to discontinue the constant head test after one hour at constant intake rate (i.e., 3 consecutive readings of volume supplied with the readings taken at 30 minute increments) for tighter, clayey soils. This field saturated intake rate may take 3-4 hours (or more) to be reached. For sandier soils, a constant intake rate may be established within 1-2 hours.
10. Though not required, it is recommended once the constant head portion of the test is concluded, the water supply should be shut off and the depth of ponding recorded until the ponded water fully infiltrates into the ground or, if infiltration is slow, at 30 minute increments for two hours. This is an excellent check on intake rate.

11. To convert the final, steady state intake rate from (9) above into a field saturated infiltration rate to use in practice design, the field measured intake rate and test set-up (ring diameter, insertion depth, ponding depth) must be used to adjust the value to account for flow divergence and soil sorptivity. A spreadsheet is provided to make this conversion.

Pit Method

The PIT (Pilot Infiltration Test) method consists of excavating a large hole of known dimensions to, or just below, the depth of excavation for the proposed infiltration practice, inundating the resulting "pit" with water to simulate ponding within the proposed practice, and recording the volume and rate of water entering the soil. Henceforth, this test will be referred to as the Pit Method.

Procedure (adapted from COIC, 2010; WDOE, 2012, 2013)

1. Excavate a rectangular test pit with a bottom area between 25 and 40 ft^2 (e.g., 5 feet by 6 feet). The pit should be excavated such that the bottom of the test pit is located at the proposed excavated depth of the infiltration practice. Excavate the pit to as clean dimensions as possible, removing any sloughed soil, organics and other debris. The bottom 12" of the pit (minimum) should have vertical sidewalls, but above 12" the walls can be laid back (e.g., 1:1 slope) or stepped to facilitate entry.
2. Make note of rocks, roots, macropores, smearing or any other conditions that might affect the test or intake rate. Photograph the test pit.
3. Measure and record the dimensions (depth, length, width) of the test pit.
4. Taking care not to compact or smear the bottom of the pit, use a soil auger to "drill" a 2" diameter hole 6" below the bottom of the pit. Place a self-logging pressure transducer in the augered hole, recording at a 1 minute interval. Also place a vertical measuring stick (either a yardstick with markings at tenths and hundredths of a foot, or a metric yardstick with cm and mm markings, works well for this purpose) in the hole and note the height on the stick that coincides with the bottom of the test pit. [Note: If, because of soil type, the sidewalls of the pit are prone to sloughing when exposed to water, the sidewalls of the pit should be lined with porous, non-woven geotextile filter fabric (Spec??) and the pit backfilled with clean, uniform open-graded gravel (e.g., #57 or #4). If the pit is backfilled with gravel, it is recommended a 1-1/4 inch diameter PVC water level observation pipe be placed in the augered hole (with the vertical measuring stick) in which to place the recording pressure transducer. The PVC pipe should be capped at the bottom and have ¼-in holes drilled every 1-inch on center for the first 12 inches of pipe. Place the observation well and measuring stick first, then backfill the bottom of the pit around the observation well to a depth of 12 inches. The sidewalls of the pit should approximate vertical for the bottom of 12 inches of the pit but can be laid back (e.g., 1:1 sideslope) above 12 inch depth to facilitate placement of the filter fabric, if needed.]
5. Introduce clean water into the test pit using a hose connected to a rigid pipe with a splash plate on the bottom to discharge water into the pit without causing soil scouring or side-wall erosion. Excessive scouring or erosion will cause clogging of the infiltration bed, reducing measured infiltration rates.
6. Add enough water to the pit to bring the water level up to 12 inch (30 cm) depth, then shut off the water supply to pre-soak the infiltration bed. Pre-soaking is considered complete when the

water completely infiltrates into the ground or after 3 hours if water is still standing in the pit. [Depending on the soil, season and number of tests to be conducted, it may make sense to construct and pre-soak test pits one day then conduct infiltration measurements the following day.]

7. After completion of the pre-soaking, the tester should complete two falling head tests starting at 12 inch (30 cm) ponding depth. Raise the water level to a 12 inch (30 cm) depth. Record the volume of water needed to raise the water level to 12 inches. If there is still standing water (i.e., the pre-soak did not fully infiltrate), record water depth before filling begins. The time the 12 inch ponding depth is reached should be noted, and this time denoted as "time zero" for purpose of the infiltration test. Shut off the water supply and record the drop in water level at appropriate time increments for the rate of drawdown (this might be every minute for sandy soils or every half hour for clayey soils) until the water is fully infiltrated. The use of a self-logging pressure transducer as mentioned above will be taking this measurement, but such measurements should be taken with a stopwatch and readings from the measuring stick as well.
8. Photograph the set-up/conditions during the test.
9. After the water has completely infiltrated, repeat step 7.

Minimum Number of Pits and Infiltration Tests

Surface Area of Infiltration BMP (ft^2)	Number of Test Pits	Pit Tests	Single-ring Infiltrometer Tests (2 tests/pit)
<5000	2	2	4
5000-10000	3	3	6
>10000	4	4	8

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