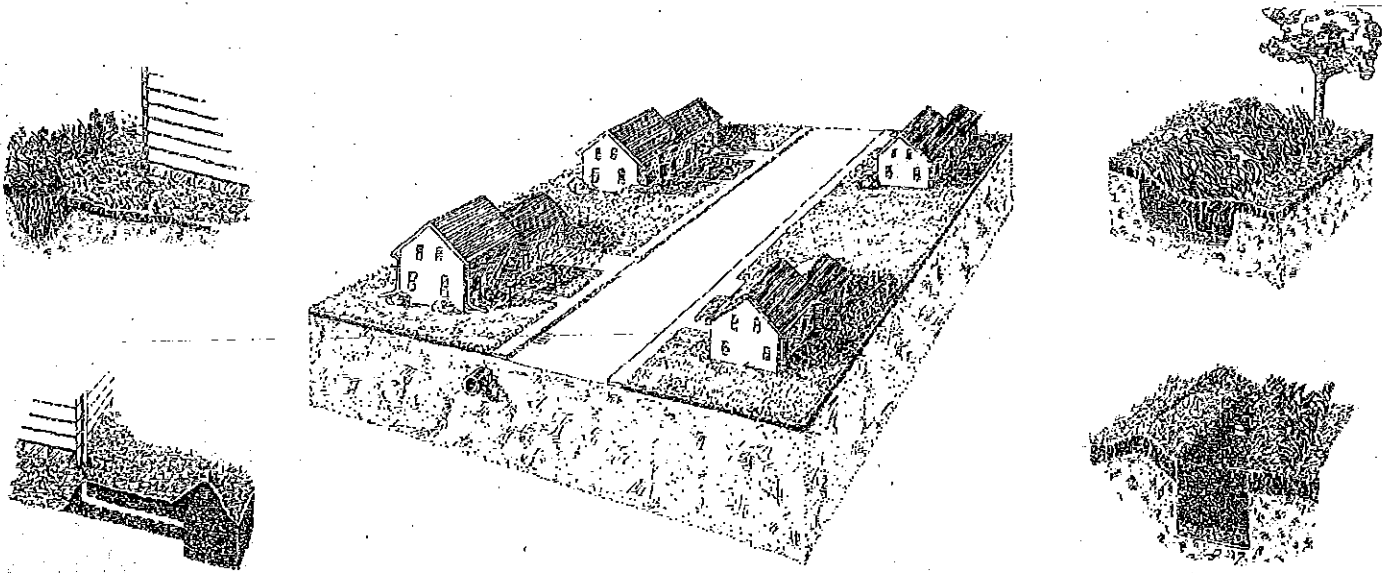


Putting **FAIR** Into Action

Filter • Absorb • Infiltrate • Retain
(the one-inch rain)



Recommended Guidelines
For Infiltration-Based Practices
To Achieve Better Water Quality
In Metro Area Communities

May 2006
DRAFT

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Practices Approved for FAIR

FAIR originates from the Metro Area Standards (MAS), which are currently used for new development projects in the urban communities of Cedar Rapids, Marion, Hiawatha and Robins. MAS Chapter 2, Section 6.6.2 states: "One-inch rainfall over the developed site shall be *detained* in the detention basin for 24 hours. The detention volume in cubic feet is determined by multiplying the site area in square feet, by one-inch (0.083 ft)."

FAIR Guidelines do not change this standard, as the one-inch rain over the developed site must still be managed on a post-construction basis. FAIR seeks to expand upon the meaning of the word "*detain*" to include proven alternatives that improve water quality by reducing polluted stormwater runoff.

The FAIR recommended guidelines:

- 1) Establishes a system of credits for infiltration-based stormwater management practices, effectively reducing the quantity of water that must be detained in the detention basin for 24 hours and possibly downsizing the overall land area dedicated to detention.
- 2) Develops consistent guidelines and design processes for integrating infiltration-based practices into post-construction stormwater management plans for design professionals.
- 3) Provides a consistent evaluation structure and basis for jurisdictions to use during the site plan review and approval.

Prior to these the MAS directed design professionals to an Environmental Protection Agency (EPA) website of alternative post-construction stormwater management practices: cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm, which provided information on the practices, but did not provide a framework for how they could be incorporated into the site design process or how they could be credited against the water quality volume requirements.

During 2005 the FAIR Technical Policy Committee studied alternative stormwater practices and approved those they felt were most practical for new development projects. It should be noted that the use of infiltration-based stormwater management practices **is completely voluntary** and infiltration is not limited to the practices contained in this guide.

Disclaimer: The information contained in this guide for infiltration-based stormwater management practices is a source of information for suggested design approaches. **The design professional is responsible** for checking with the jurisdictional engineer regarding the practices prior to design, for applying the information to individual sites and for making decisions regarding how the practices are integrated into the post-construction stormwater management plan.

Practices Approved for FAIR

Following is a list and *brief* description of the practices which have been approved for use by the FAIR Technical Policy Group for managing the water quality event in Metro Area Communities. Please note, detailed descriptions and recommended design guidelines immediately following this section.

PRIMARY PRACTICES

Bioretention Cell

Landscaped depressed areas with an engineered soil mix and vegetation designed to receive stormwater from relatively small contributing areas. Bioretention cells may or may not have a subsurface drain and are not designed as a conveyance system.

- **Recommended V_0 Credit:** Difference in volume entering as compared to exiting the bioretention cell as calculated by the design professional.

Bioswale

Bioswales incorporate the same design features as bioretention cells; however, bioswales are designed as part of a conveyance system and have relatively gentle side slopes and flow depths generally less than 12 inches.

- **Recommended V_0 Credit:** Difference in volume entering compared to exiting the bioswale as calculated by the design professional.

Dry Well

A dry well is a subsurface basin, typically associated with rooftop runoff, used to capture, temporarily store and eventually infiltrate stormwater runoff. It can be either a structural chamber and / or an excavated pit filled with uniformly-graded clean rock. The rock of the dry well can be left exposed at the surface or topped with vegetation to blend into the rest of the landscape.

- **Recommended V_0 Credit:** Total storage volume, taking into account void space of aggregate, calculated by design professional.

Infiltration Trench

Infiltration trenches consist of a long, narrow excavation ranging in depth from 3 to 12 feet and backfilled with clean rock. Runoff is stored in the void space between the aggregate, then infiltrates into the surrounding soil. An infiltration trench does not have a sub-surface drain; a French Drain does. As with a dry well, the rock of an infiltration trench can be left exposed or topped with vegetation to blend into the existing landscape.

- **Recommended V_0 Credit:** Total storage volume, taking into account void space of aggregate, calculated by design professional.

Porous Pavement

Porous pavement refers to pavement surfaces that allow water to pass through them rather than shed runoff. The porous pavement takes many different forms with four main types: porous asphalt, pervious concrete, grid pavers filled with rock and grass pavers.

- **Recommended V_Q Credit:** Storage capacity of stone reservoir if underlying soils are permeable enough to facilitate infiltration of storm water. Reduction of time of concentration if underlying soils do not support infiltration of stormwater runoff.

Post-Construction Soil Quality Restoration

Soil quality restoration is the process of restoring disturbed soils by reducing soil compaction and increasing soil organic matter to a minimum of 5% for areas that will be dedicated to turf and 10% for other landscaped areas. This consists of incorporating a soil amendment, such as compost, which increases soil porosity and water holding capacity (storage space).

- **Recommended V_Q Credit:** Amended Area (ft^2) \times 0.50 inch \times 1/12 = Volume (cf) at 5% soil organic matter content. Amended Area (ft^2) \times 1 inch \times 1/12 = Volume (cf) at 10% soil organic matter content.

Rooftop Disconnection

Impervious rooftops, that are separated from the storm sewer system by pervious surface or infiltration BMPs contribute less runoff and reduce pollutant loading. Rooftop runoff should be directed to designated areas for on-site storage, treatment, and volume control. In some cases, individual lots may need minor grading to meet minimum overland flow conditions.

- **Recommended V_Q Credit:** Based on disconnection length from the table below, disconnected downspouts can be subtracted from the developed site when computing Water Quality (V_Q) volume.

Vegetated Filter Strip

Vegetated filter strips treat sheet flow from adjacent surfaces and function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils.

- **Recommended V_Q Credit:** Filter Strip Area \times Infiltration Rate \times 24 hours (duration)

Native Soil / Vegetation Preservation

To minimize the impacts of development and enhance post-construction aesthetic benefits, native soil / existing vegetation (including trees, grasses, and other plants) should be preserved to the maximum extent practicable by preventing disturbance or damage to specified areas of a construction site.

- **Recommended V_Q Credit:** Preserved / protected area, in square footage, removed from storm water quality calculations.

Wet Pond

Wet ponds are also known as stormwater ponds, retention ponds, and wet extended detention ponds. They are all excavated areas or enhanced natural depressions designed to detain stormwater runoff. While there are several variations of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain storm water runoff to provide settling. Wet ponds need sufficient drainage area to maintain the permanent pool. typically 15 – 25:1. The United States Department of Agriculture (USDA) Pond Handbook No. 590 proposes a general rule of thumb of 6 acres of drainage area for each acre-foot of permanent storage.

- **Recommended V_a Credit:** Wet ponds are designed to control water quantity volume, with a secondary benefit of improving water quality. A wet pond does not decrease the overall volume of storm water runoff, therefore zero credit, against the water quality volume, has been given for this particular practice.

Additional Primary Practices

Integrating infiltration-based stormwater management practices is not restricted to those listed in this guide. However; the practices included in this guide are the only ones, at this time, that have an established credit system that the design professional can integrate into the post-construction stormwater quality management plan, as required as part of the Metro Area Standard Drainage Report. If you would like to review additional infiltration-based practices please visit the following website:

<http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm>

SUPPORTING PRACTICES

Engineered Planting Soil

If underlying soils or in-situ soils are compacted and / or lacking organic matter these soils should be amended or replaced with an engineered planting soil that consists of a compost / sand / topsoil blend to enhance the functionality and long-term success of bioretention based practices - bioswales and cells.

Flow Splitter

A flow splitter is necessary to bypass stormwater flows greater than what the infiltration-based practice is designed to treat.

Level Spreader

A level spreader is used to spread runoff over a wide area to prevent erosion and concentrated flow.

Pretreatment

Pretreatment refers to features designed to capture and remove coarse sediment particles before runoff enters the infiltration-based practice and include such practices as a sediment forebay, sediment basin, plunge pool, level spreader, filter strip, street / parking lot sweeping, or proprietary equipment, such as an oil/grit separator.

Subsurface Drain

A subsurface drain perforated pipe, tubing or tile installed below the ground surface to intercept and transport water to a downstream open conveyance, another infiltration-based practice (treatment train), outlet to a dispersion area using an effective flow dispersion practice, or to a storm sewer system.

Vegetation For Final Stabilization

There are three levels of vegetation to use for infiltration-based practices, with each level progressively better for stormwater management purposes, as the plant choices become deeper-rooted and taller and are better able to filter, absorb, infiltrate and retain more water both above and below ground.

Vegetation	Fair	Better	Best
Plant Species	Cool season turf grass, such as Kentucky Bluegrass	Cultivated plants, such as those found at the local nursery or garden center, shrubs, young trees	Native plants / flower, forbes, sedges, warm season grasses, and mature trees
Maintenance	"Mow" to high maintenance, depending on personal expectations for a green, weed-free lawn	Low to medium maintenance; consisting of watering until plants / shrubs / trees are established; deadheading, weeding and pruning occasionally thereafter	Medium to high through year 3 for native prairie plants; low to very little maintenance thereafter

Vegetation Rule of Thumb: The height of any given plant in an infiltration-based practice should be no taller than ½ the site width - i.e. plants / shrubs, etc. in a 4' wide rain garden should be get no taller than 2'

Taking Credit for FAIR Practices

The Metro Area Standards require a Drainage Report for all new developments, to "estimate and propose solutions for increased runoff due to proposed development" Chapter 2, Appendix 2-1 provides the Drainage Report Format. Footnote 3 of the Drainage Report Format allows "post-developed peak discharges to be reduced with water quality best management practices. Any proposed reduction must be adequately justified in the drainage report with narrative and calculations."

Two worksheets have been developed to assist design professionals in adequately justifying water quality best management practices included in the FAIR Recommended Guidelines: "The Sizing Summary Worksheet" and "The Practice Narrative Worksheet."

While the narrative will always be specific to the site being developed, a short, general description of each practice is provided at the start of the Approved Practices section. Stormwater calculations have been included for each primary practice in the Water Quality Volume Credit and Design Considerations section or can be found at the end of this guide in the Quick Reference for Stormwater Equations section. If the design professional varies from the equations it should be noted in the practice narrative.

A fairly new design concept introduced in this guide and shown on the Sizing Summary Worksheet divides the entire site being developed into small tributary areas based on the final drainage patterns of the new development project. Careful and innovative site grading is critical in creating small drainage areas conveyed to strategically placed infiltration practices that **reduce** the total amount of runoff being generated throughout the site. It is at this point where the greatest possibility of reducing the post-development peak flow and thereby potentially reducing the area dedicated to detention for the water quantity volume or flood control.

Design professionals are encouraged to utilize as many credits as they can on a site. Greater reductions in stormwater storage volumes can be achieved when many credits are combined together. However, credits cannot be claimed twice for an identical area of the site, for example using rooftop disconnection in conjunction with dry wells.

Software programs are available to illustrate how the water quality and volume are routed and retained on-site for use with submittals. Following is a website that may be of interest to you: www.iowastormwater.org for DURMM – Delaware Urban Runoff Management Model an Excel spreadsheet that models infiltration practices, which can be used in conjunction with Hydrocad - www.hydrocad.net/

Sizing Summary Worksheet

Filter Absorb Infiltrate Retain (the one-inch rain)

Projected Runoff

Base Detention Requirement

Entire Development Area (square feet)	One-Inch Rainfall (square feet x 0.083 = cubic feet)

Water Quality Infiltration Credits Taken, as a whole

Infiltration-Based Practice (no narrative needed here)	Credit Volume (ft ³)
Bioretention cell ^{(1); (2); (3); (4); (5); (6)}	
Bioswale ^{(1); (2); (4); (5); (6)}	
Dry well ^{(3); (5); (6)}	
Infiltration trench ^{(3); (5); (6)}	
Native soil / vegetation preservation	
Rooftop disconnection	
Porous pavement ^{(1); (6)}	
Post-construction soil quality restoration ⁽⁵⁾	
Vegetated filter strip ^{(2); (5)}	
Wet pond ^{(1); (2); (3); (5)}	
Other – (See EPA website) - cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm	
Total credits, in cubic feet, taken	

Note: Corresponding supporting practice to consider for each primary practice:

- (1) *Pre-treatment* to catch trash and sediment
- (2) *Level spreader* to prevent concentration of flows
- (3) *Flow splitter* to address overflows / high-flow storm events
- (4) *Engineered Planting Soil*
- (5) *Vegetation* for final stabilization
- (6) *Subsurface drain*

Tributary Areas Delineated (if applicable, provide map and drainage / flow patterns):

Tributary Area (square feet)	One-Inch Rainfall (cubic feet)	Credit Volume (ft ³)
A or 1		
B or 2		
C or 3		
(Additional tributary areas, as necessary)		

Practice Narrative Worksheet

address tributary / site specific conditions as they
relate to practices and volume (ft³) credit calculation procedures

Tributary Area (if applicable): _____

Infiltration-Based Practice Narrative	Credit Volume (ft ³)	Reviewer Comments
Bioretention cell ^{(1); (2); (3); (4); (5); (6)}		
Bioswale ^{(1); (2); (4); (5); (6)}		
Dry well ^{(3); (5); (6)}		
Infiltration trench ^{(3); (5); (6)}		
Native soil / vegetation preservation		
Porous pavement ^{(1); (6)}		
Post-construction soil quality restoration ⁽⁵⁾		
Rooftop disconnection		
Vegetated filter strip ^{(2); (5)}		
Wet pond ^{(1); (2); (3)}		
Other – See EPA website - cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm		

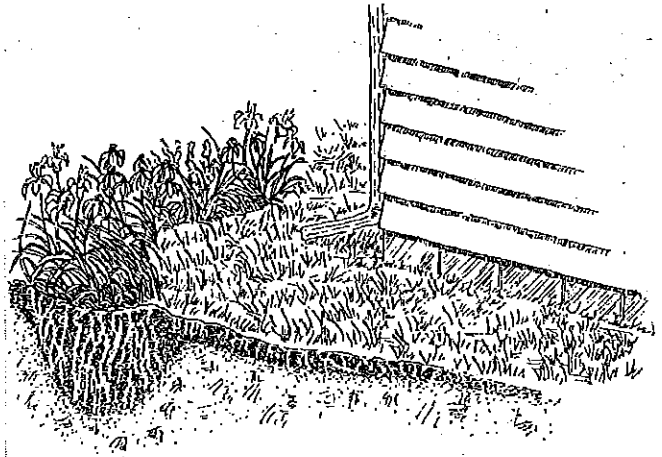
Note: Each practice narrative must address their corresponding supporting practice(s):

- (1) *Pre-treatment* to catch trash and sediment
- (2) *Level spreader* to prevent concentration of flows
- (3) *Flow splitter* to address overflows / high-flow storm events
- (4) *Engineered planting soil*
- (5) *Vegetation* for final stabilization
- (6) *Subsurface drain*

Bioretention Cells

Bioretention Cells are landscaping features adapted to provide on-site stormwater treatment. They are commonly located in parking lot islands, cul-de-sacs, commercial setbacks, open space, streetscapes, landscaping islands or within small pockets of residential land. Bioretention cells can be built either off-line or on-line, either one surface runoff is directed into shallow, vegetated depressions designed to incorporate

many of the pollutant removal mechanisms that operate in a forested ecosystem. During storms, water ponds on top of mulch and soil in the bioretention area. Runoff from larger storms is generally diverted past the facility to the storm sewer system. The remaining runoff filters through the mulch and soil. If the quantity of contributing stormwater warrants it, the filtered runoff is collected in a perforated subsurface drain and returned to the storm sewer system. Bioretention should be used on small site areas of 5 acres or less. When used to treat larger areas, pretreatment areas are vital, as they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.



Limitations

- Drainage area limited to five acres or less per cell.
- Not recommended for developments which have extensive cut and fill areas or areas with steep slopes, unless engineered soils are specified.
- Not recommended in areas of high water table, restrictive soils without an subsurface drain or bedrock.

Supporting Practice Considerations

- Pretreatment
- Level spreader
- Flow splitter
- Engineered planting soil
- Vegetation
- Subsurface drain

Recommended V_Q Credit

Difference in volume entering as compared to exiting the bioretention cell as calculated by the design professional.

Sizing Guideline

2. Compute the Water Quality Treatment Volume (V_Q) for drainage area

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

3. Size planting soil filter bed area

- 3.1. Computed using the following equation (based on Darcy's Law):

$$3.1.1. A_f = (V_Q) (d_f) / [(k) (h_f + d_f) (t_f)]$$

Where:

- A_f = surface area of ponding
 V_Q = volume to be captured (1 inch or less)
 d_f = filter bed depth (4 feet minimum)
 k = coefficient of filter media permeability (ft/day)
 h_f = average height of water above filter bed in feet;
(typically 3", which is $\frac{1}{2}$ of the 6" ponding depth)
 t_f = design filter bed drain time; recommend 24 hours

4. Calculate ponding time

- 4.1. The maximum design depth can be computed using the following equation:

$$4.1.1. d_{\text{max}} = (f) (T_p)$$

Where:

- d_{max} = maximum design depth
 f = soil infiltration rate (in/hr), and
 T_p = design ponding time (hours)

Recommended Guidelines

1. Design Considerations

- 1.1. Bioretention areas should have a maximum contributing drainage area of 5 acres or less; 0.5 to 2 acres are preferred. Multiple bioretention areas can be used for larger drainage areas.
- 1.2. When used in an off-line configuration, the water quality volume is diverted to the bioretention area through the use of a flow splitter. Stormwater flows greater than the Water Quality Volume should be diverted to other controls or downstream.
- 1.3. Bioretention systems are designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- 1.4. Recommended minimum dimensions of a bioretention area are 10 feet wide by 20 feet long. All designs except small residential applications should maintain a length to width ratio of at least 2:1.

- 1.5. Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
 - 1.6. Planting soil bed should have an infiltration rate of at least 0.5 inches per hour. Adequate access must be provided for all bioretention facilities for inspection, maintenance and landscaping upkeep, including appropriate equipment and vehicles.
 - 1.7. The bottom of the basin should be graded as flat as possible and keep subgrade as uncompacted as possible.
 - 1.8. Soil compaction can lead to facility failure; accordingly, minimize compaction of the base and sidewalls of the bioretention area.
 - 1.9. Excavation should not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the bioretention facility. Heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should not be allowed on the bottom of the bioretention facility.
2. Slopes
 - 2.1. Side slopes should not be steeper than 3:1 to prevent erosion.
3. Design flow
 - 3.1. Inlet and outlet flows should be no greater than .05 feet per second.
4. Groundwater
 - 4.1. Four (4) feet clearance from seasonal high water table is recommended, minimum 1 foot.
5. Drawdown time
 - 5.1. Recommended ponding depth: 6 - 12 inches
 - 5.2. Recommended surface pool drawdown time: 24 hours
6. Observation Well
 - 6.1. Not applicable
7. *Construction Considerations*
 - 7.1. Post-Construction Soil
 - 7.1.1. Recommended infiltration rate of existing soil is 0.5 inches / hour.
 - 7.1.2. Amending soils or an engineered planting soil may be necessary when existing soil conditions do not meet recommended infiltration rate.
 - 7.2. Inlet control
 - 7.2.1. Five primary flow entrances can be used for bioretention cells:
 - 7.2.1.1. Dispersed, low velocity flow across a landscaped area
 - 7.2.1.2. Dispersed, across pavement, past wheel chocks
 - 7.2.1.3. Curb cuts for roadside or parking lot areas
 - 7.2.1.4. Pipe flow
 - 7.2.1.5. Catch basin

7.3. Outlet control

7.3.1. If a subsurface drain is installed, the outlet pipe should outlet to an existing storm sewer, if possible. Due to the slow rate of filtration, outlet protection is generally unnecessary.

7.4. Overflow

7.4.1. The basin should be provided with a bypass system or overflow device to allow for the passage of flows that exceed storage capacity to a stabilized downstream area. If the system is located off-line, the overflow should be set about the shallow ponding limit.

7.5. Final stabilization

7.5.1. Appropriate plants should be selected for soil type, soil moisture, sun exposure, adjacent plant communities and property owner's maintenance commitment, especially during the first three years after planting. If native plants are used invasive species control may also be necessary.

7.5.2. Bioretention can be designed with or without a mulch layer; however there are advantages to providing a mulch application or a dense groundcover. A 3-inch layer of good quality shredded mulch is recommended; rock mulch should be avoided when plants are used; grass clippings or unshredded bark should not be used.

8. Maintenance Considerations

8.1. Annual

8.1.1. Drain time should be monitored to assure that the design infiltration rate is being achieved.

8.1.2. Bioretention areas require annual plant, soil and mulch layer maintenance to ensure optimum infiltration storage. In general, bioretention maintenance requirements are typical landscape care procedures and include:

8.1.2.1.1. *Watering* – Watering may be needed until the plants are established or during periods of prolonged dry periods; plants selected should be drought tolerant.

8.1.2.1.2. *Erosion control* – Inspect flow entrances, ponding areas, and surface overflow areas periodically.

8.1.2.1.3. *Plant material* – Inspect for coverage and dead plant material. Pruning and removing dead plant material may be necessary. Periodic weeding is necessary until plants are established, with weeding becoming less frequent over time.

8.1.2.1.4. *Mulch* - inspect for coverage and depth (recommended to be 3 inches of shredded, aged mulch).

8.2. Repairs

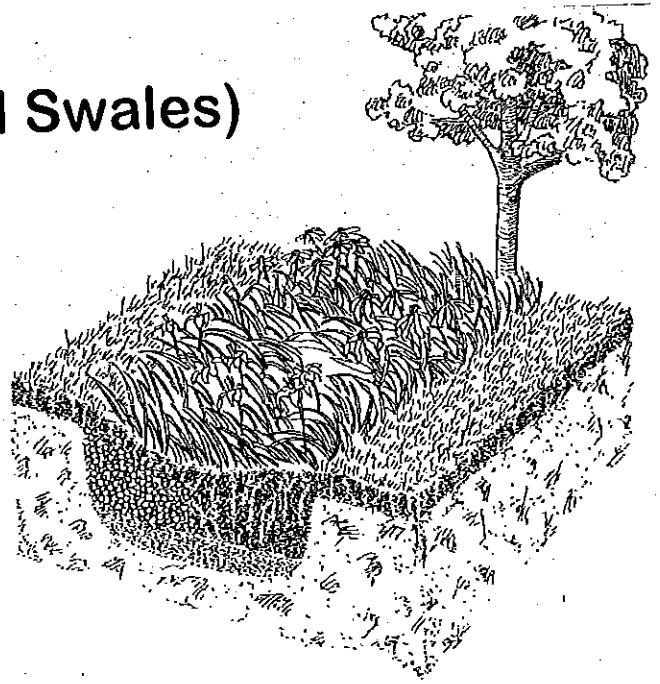
- 8.2.1. Replace soil, plant material and / or mulch layer if erosion has occurred. If erosion problems occur the following should be reassessed: (1) flow volumes; (2) flow velocities and gradients within the cell (3) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance.
- 8.2.2. If sediment is deposited in the bioretention area, immediately remove, determine source within the contributing area and stabilize to prevent recurrence.
- 8.2.3. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and replace with appropriate species.
- 8.2.4. Replace or add mulch as needed to maintain a 2 to 3 inch depth at least once every two years.

Bioretention Cell Resources

- SUDAS Draft Design Section 2F-2.4: Bioretention Areas, February 2005
- LID Technical Guidance Manual for Puget Sound, January 2005, Chapter 6.1 Bioretention Areas
- Minnesota Stormwater Manual, March 2000, Chapter 4.63 - Infiltration Basins
- Georgia Stormwater Management Manual; Volume 2 (Technical Handbook) 3.2-48
- Pennsylvania Stormwater Best Management Practices Manual, Draft January 2005, BMP 6.2: Infiltration Basin

Bioswales (Vegetated Swales)

Bioswales also vegetated swales are open channel management practices designed specifically to treat and attenuate stormwater runoff. As stormwater runoff flows through these channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix, and / or infiltration into the underlying soils. Variations of the vegetated swale include the grassed channel, dry swale and wet swale. The specific design features and methods of treatment differ



in each of these designs, but all are improvements on the traditional drainage ditch. Swales are well suited for treating street runoff. Vegetated swales should generally treat small drainage areas of less than 5 acres. Design rule of thumb: The total surface area of the swale should be one percent of the area (500 square feet for each acre) that drains to the swale.

Grassed Channels are modified drainage channels that provide water quality treatment for the small, frequent storm event. The flow rate is the principle design criteria for grass channels ("rate-based" system).

Dry & Wet Swales have the same principle pre-treatment process as bioretention filters which combines physical filtering and adsorption with bio-geochemical process to remove pollutants. Both are designed to treat or retain stormwater for a 24-hour period ("volume-based" systems).

Dry Swales are designed to rapidly dewater through a highly permeable layer and then collect by a subsurface drain.

Wet Swales act as long, linear, shallow wetland treatment systems. Wet swales typically occur when the water table is located very close to the surface.

Limitations

- Can be difficult to avoid channelization without a level spreader / check dam.
- Cannot treat very large drainage areas (limit to 5 acres or less); large areas may be divided and treated using multiple swales.
- A thick vegetative cover is needed for these practices to function properly.
- They are impractical in areas with steep topography.

Supporting Practice Considerations

- Pretreatment
- Level spreader
- Flow splitter
- Engineered planting soil
- Subsurface drain

Recommended V_Q Credit

Difference in volume entering compared to exiting the bioswale as calculated by the design professional.

Sizing Guidelines

1. Compute the Water Quality Treatment Volume (V_Q) for the given land surface.

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

2. Identify the required swale bottom width, depth, length and slope necessary to convey the water quality volume with a shallow ponding depth, no greater than 5" for peak 10-year discharge.
3. Width of swale should be limited to determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.30.
4. Sizing Equations:

Grass Channel	Wet Swale	Dry Swale
$V = (1.49/n) R^{2/3} S^{1/2}$ <hr/> $R = A / P$	$A_f = \text{Vol} \cdot (d_f) / [k \cdot (h_f + d_f)(t_f)]$	$\text{Vol} = A \times L$
Variables	Variables	Variables
V = Velocity, should be less than 1 cfs	A_f = Required surface area of the dry swale (cf)	Vol = Retention Volume (cf)
N = Roughness coefficient (tabulated values)	Vol = Treatment volume (cf)	A = Cross sectional area (sf)
R = Hydraulic radius (ft)	d_f = Depth of the filter medium (ft)	L = Length of swale (feet)
A = Cross sectional area (square feet)	k = Hydraulic conductivity (feet / day)	
P = Wetted perimeter (ft)	h_f = Average height of water above the bottom of dry swale (feet); maximum 18" ponding	
S = Longitudinal slope	T_f = Design time to filter the treatment volume through the filter media (usually set at 24 hours)	

5. Compute the 2 year and 10 year frequency storm event peak discharges.
6. Check the 2 year velocity for erosive potential (adjust swale geometry, if necessary, and reevaluate WQV design parameters).
7. Check the 10 year depth and velocity for capacity (adjust swale geometry, if necessary, and reevaluate WQV and 2 year design parameters).
8. Provide minimum freeboard above 10 year stormwater surface profile (6-inch minimum recommended).

Recommended Guidelines

1. Design Considerations

- 1.1. The subsurface of the swale should be carefully constructed to avoid compaction of the soil. Compacted soil reduces infiltration and inhibits growth of grass. Damaged areas should be restored immediately to ensure that the desired level of treatment is maintained and to prevent further damage from erosion of exposed soil.
- 1.2. Accuracy in grading is essential, as departure from design slopes will easily affect effectiveness of treatment.
- 1.3. Temporary erosion and sediment best management practices should be utilized during construction.
- 1.4. After seeding, immediately install erosion control blanket. This is essential in order to stabilize channel before turf has become established.

2. Slopes

- 2.1. Maximum slope 4%; if 2% or less a sub-drain may be necessary; with a minimum slope of 0.5%.
- 2.2. Check dams may be placed in the channel to reduce flow velocity.
- 2.3. Swale should have a trapezoidal or parabolic cross section with 4:1 or flatter side slopes to maximize the wetted perimeter (length along the edge of the channel cross-section in contact with runoff) thus enhancing treatment.

3. Design flow

- 3.1. The design flow should be limited to 5 cfs; check permissible velocities of selected vegetation to ensure the two-year frequency storm velocity is non-erosive.
- 3.2. Swales should be designed so that the water level does not exceed 2/3rds the height of the grass, or 4 inches, which ever is less, at the design treatment rate.

4. Groundwater

- 4.1. Four (4) feet clearance from seasonal high water table is recommended, minimum 1 foot.

5. Detention time

Grass Channel	Wet Swale	Dry Swale
Length necessary for 10 minute residence time	Designed to temporarily accommodate an 18" maximum ponding depth	Should be designed so 18-24" ponding dissipates within 24-hours.

6. Observation well

6.1. Not applicable

7. Construction Considerations

7.1. Post-construction soil

7.1.1. Top foot of soil should have an infiltration rate of 0.5 inches per hour.

7.1.2. May be necessary if existing soil infiltration rate minimum is not met.

7.2. Aggregate material

7.2.1. Used as check dam, to promote additional infiltration, increase storage and to reduce flow velocities.

7.2.2. Check dams should be installed every 50 feet if the longitudinal slope exceeds 4%.

7.3. Filter fabric

7.3.1. Not applicable

7.4. Inlet control

7.4.1. Not applicable

7.5. Outlet control

7.5.1. Not applicable

7.6. Overflow

7.6.1. The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line."

7.7. Final stabilization

7.7.1. Depending on the swale location, grasses may be designed to be mown like a typical lawn or only annually. Grass species should be selected for vigorousness; rigid, upright habit (even during flow times); with a height of 6" or less to prevent grasses from flattening out as water flows over them. If mowing regularly use park grade Kentucky bluegrass or fescue. Otherwise, use native species can be used, such as switchgrass, big bluestem, little bluestem, Indian grass or side-oats gama.

7.7.2. Fine, uniform, dense grasses increase the surface area of the vegetation exposed to the runoff, which improves the effectiveness of the swale.

8. Maintenance Considerations

8.1. Semi-Annually

8.1.1. Inspect swale several times the first few months to ensure vegetated cover is establishing well. If not, reassess or plant an alternative species. Once established, continue to inspect semi-annually for erosion problems.

8.1.2. If rock is used as a drainage component, annually inspect for clogging from excess sediment. Remove sediment and correct associated problems.

8.1.3. Remove trash and debris accumulated in the swale.

8.2. As Needed (Frequent)

8.2.1. Mow turf grass to a height of four to six inches. If native grasses are used, mow only once a year in early spring to remove dead vegetation. Mowing the native grasses the first year is critical in order to eliminate competition from annual weeds.

8.2.2. Remove clippings if mowed infrequently.

8.3. As Needed (Infrequent)

8.3.1. Remove sediment buildup on the bottom of swale once it has accumulated to 25 percent of original design volume.

8.3.2. Reassess as necessary to maintain dense vegetation.

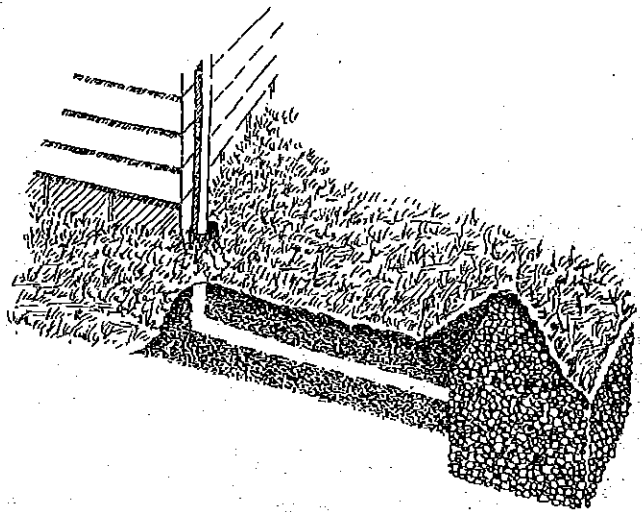
8.3.3. Grass in swales should be fertilized rarely, if at all, to avoid unnecessary export of nutrients.

Bioswale Resources

- Bay Area Stormwater Management Agencies Association, Site Design Techniques to Meet Development Standards for Stormwater Quality - Swale Size Calculations source: The Urban Runoff Quality Management ASCE / WEF Manual - Guidelines for Selection and Design of Passive Treatment Controls)
- Minnesota Urban Small Sites BMP Manual
- California Stormwater BMP Handbook New Development and Redevelopment
- EPA Stormwater Technology Fact Sheet - Vegetated Swales; 832-F-99-006, September 1999
- Hydrologic Criteria and Drainage Design Manual

Dry Wells

Dry wells are similar to infiltration trenches, a dry well is a small, excavated pit, backfilled with clean stone aggregate that receives and temporarily stores roof runoff.



Limitations

- Restricted in Natural Resource Conservation Service Hydrologic Soil Group (HSG) C & D soils as well as Karst topography
- Not appropriate for roofs where high pollutant or sediment loading is anticipated.
- High risk areas where stormwater runoff is exposed to hazardous or toxic materials / substances / products.

Supporting Practice Considerations

- Flow splitter
- Vegetation
- Subsurface drain

Recommended V_Q Credit

Total storage volume, taking into account void space of aggregate, calculated by design professional.

Sizing Considerations

1. Compute the Water Quality Treatment Volume (V_Q) for the given rooftop.

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

2. Size dry well

$$\frac{CF}{0.4^*} = \text{dry well volume}$$

(*varies – 40% void ration is rule of thumb for rock backfill)

Dry well volume = Depth (D) x Width (W) x Length (L)

Depth = well depth is typically limited to 3.5 feet

Recommended Guidelines

1. Design Considerations

- 1.1. For buildings with basement or crawl space the practice should be located a minimum of ten feet from building foundation to avoid seepage problems.
- 1.2. Should be performed after all other areas of the site are stabilized to avoid clogging.
- 1.3. During construction, compaction of the sub-grade soil should be avoided, and construction should be performed with only light machinery.

2. Slopes

- 2.1. Not applicable

3. Design flow

- 3.1. Dry wells should be designed to accept 1 inch of runoff over the contributing roof area; generally installed at each drainpipe.

4. Groundwater

- 4.1. Four (4) feet clearance from seasonal high water table is recommended, minimum 1 foot.

5. Detention time

- 5.1. A dry well must fully drain runoff volume within 72 hours.

6. Observation well

- 6.1. Dry wells should include an observation well constructed of a perforated 4" diameter PVC pipe secured in position by placing a section of rebar through a perforation in the bottom of the pipe, prior to filling the well with stone aggregate.

7. Construction Considerations

7.1. Post-construction soil

- 7.1.1. The minimum design permeability rate of the surrounding soil is 0.5 inches per hour. The permeability rate must be determined by field or laboratory testing.

7.2. Aggregate material

- 7.2.1. Clean-washed aggregate 1.5 to 3-inch diameter.
- 7.2.2. Aggregate should be placed within 6 to 12 inches of the finished surface elevation, leaving sufficient depth for topsoil replacement.

7.3. Filter fabric

- 7.3.1. Only non-woven filter fabrics shall be used.
- 7.3.2. Fabric installation shall provide sufficient length to cover the bottom, sides and top of the aggregate. Filter fabric shall be wrapped over the top of the aggregate such that it becomes completely enclosed and tied with wire or nylon twine or otherwise tightly secured around the horizontal inflow pipe where the pipe protrudes through the fabric.

7.3.3. Fabric shall be overlapped six inches in "shingle" fashion when more than one section is required to enclose aggregate.

7.4. Inlet control

7.4.1. Downspout serves as the inlet control.

7.5. Outlet control

7.5.1. Not applicable

7.6. Overflow

7.6.1. All dry wells must be able to safely convey system overflows which can be done by installing an overflow pipe on the downspout.

7.7. Final stabilization

7.7.1. 6" – 12" of topsoil can be placed over the dry well and vegetated to blend into the rest of the landscape.

8. *Maintenance Considerations*

8.1. Periodically

8.1.1. Dry well should be inspected at least four times annually as well as after large storm events during the first year; annually thereafter.

8.1.2. All inlets and outlets should be inspected semi-annually for clogging debris (i.e., leaf litter).

8.2. Repairs

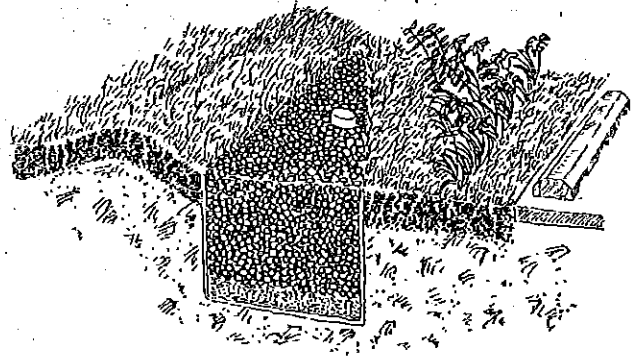
8.2.1. If water is standing in a pipe more than 3 days after a storm event, clogging has most likely occurred and the dry well requires repair or replacement.

Dry Well Resources

- New Jersey Stormwater Best Management Practices Manual, chapter 9.3: Standard for Dry Wells Final Draft December 2003
- Rhode Island Stormwater Manual, 4.3.4.5: Dry Wells

Infiltration Trench

Infiltration trenches are filled with rock with no outlet that receives stormwater runoff, a French drain is a rock-filled trench with a sub-drain installed for overflow. Stormwater runoff passes through some combination of pre-treatment measures, such as a swale into the trench. Runoff is stored in the



void space between the aggregate and infiltrates into the surrounding soil. The desired infiltration time is 24 hours. The primary pollutant removal mechanism of this practice is filtering through the soil. Infiltration trenches have select applications due to concerns such as potential groundwater contamination, soils and clogging. Infiltration trenches generally can be applied to relatively small sites less than 5 acres, with relatively high impervious cover. Application to larger sites generally causes clogging, resulting in high maintenance. A design variation is a dry well to control small volumes of runoff, such as rooftop runoff (see dry well design standard).

Limitations

- Potential failure due to improper siting, design (including inadequate pretreatment), construction, and maintenance. Infiltration trenches usually fail for one or more of the following reasons (Wisconsin DNR, 2000);
 - Premature clogging
 - A design infiltration rate greater than the actual infiltration rate
 - The practice was first used for site construction erosion control
 - Soil was compacted during construction
 - Upland area was not stabilized with vegetation, and sediment was delivered to the practice
- Drainage area should be limited to a 5 acre (2 acres is recommended)
- Restricted in Natural Resource Conservation Service Hydrologic Soil Group (HSG) C & D soils as well as Karst topography
- Requires scheduled inspection and maintenance

Recommended V_d Credit

Total storage volume, taking into account void space of aggregate, calculated by design professional.

Supporting Practices Required

- Flow splitter
- Vegetation
- Subsurface drain

Sizing Guideline

1. Compute the Water Quality Volume (V_Q) for the given land surface:

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

2. Determine infiltration trench volume:

$$A = \frac{V_Q}{nd + (kT / 12)}$$

Where:

A = Surface area of infiltration trench

V_Q = Volume to be infiltrated

n = porosity (default = 0.32)

d = trench depth (feet)

k = infiltration rate (inches/hour)

T = time it takes practice to fill with water 2 hours can be used as fill time for most designs

Recommended Guidelines

1. Design Considerations

- 1.1. To provide for easier maintenance, trench depths should be limited to 6 feet. Trench width should be 3 to 8 feet. Broader, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- 1.2. Infiltration trenches must be designed with a positive overflow.
- 1.3. Infiltration trenches should not be used as temporary sediment traps during construction.
- 1.4. Infiltration trenches should only be built after tributary area is stabilized.
- 1.5. Once a location is sited for the infiltration practice it should be marked and protected from construction traffic to prevent soil profile from compaction. During excavation and trench construction, only light equipment such as backhoes or wheel and ladder type trenchers should be used, to minimize compaction of the surrounding soils.
- 1.6. The trench surface should evenly distribute the runoff entering the trench, it may consist of exposed rock or vegetation with inlets. Depress the trench surface or place a berm at the down-gradient side of the trench to capture runoff.
- 1.7. Smearing of the soil at the interface with the trench bottom and sides must be avoided. Trench bottom can be corrected by raking or tilling to relieve compaction.

2. Slopes

- 2.1. Limit contributing slope to 5% or flatter.
- 2.2. The bottom slope of a trench should be flat across its length and width to distribute flows evenly, to encourage uniform infiltration through the bottom, and reduce the risk of clogging.

3. Design Flow

- 3.1. If stormwater is conveyed to the trench as uniform sheet flow, the length of the trench perpendicular to the flow direction should be maximized.
- 3.2. If stormwater is conveyed as channel flow, the length of the trench parallel to the direction of flow should be maximized.

4. Groundwater

- 4.1. Four (4) feet clearance from the seasonal high water table is recommended, minimum 1 foot.

5. Drawdown time

- 5.1. Trenches should be designed to provide a detention time of 6 to 72 hours. Although trenches may be designed to provide temporary storage of stormwater, the trench should drain prior to the next storm event.

6. Observation well

- 6.1. An observation well at the center of the trench is recommended to monitor drawdown time. The observation well is typically a 4 to 6 inch diameter PVC pipe with a lockable cap anchored to a foot plate at the bottom of the trench. A visible floating marker should be provided to indicate water level.

7. Construction Considerations

7.1. Post-construction soil

- 7.1.1. Underlying soil should be permeable with a combined silt/clay content of 40% or less in NRCS hydrologic groups A, B or C.
- 7.1.2. A minimum of two soil borings should be taken at the actual location of the proposed infiltration trench to identify localized soil conditions.
- 7.1.3. Trenches over 10 feet in length should include at least one additional sample for each 50 foot increment.
- 7.1.4. If soil conditions are not appropriate soil quality should be restored or engineered planting soil should be specified.

7.2. Aggregate material

- 7.2.1. Clean-washed aggregate 1.5 to 3-inch diameter.
- 7.2.2. Aggregate should be placed within 6 to 12 inches of the finished surface elevation, leaving sufficient depth for topsoil replacement.

7.3. Filter fabric

- 7.3.1. Only non-woven filter fabrics shall be used.
- 7.3.2. Fabric installation shall provide sufficient length to cover the bottom, sides and top of the aggregate. Filter fabric shall be wrapped over the top of the aggregate such that it becomes completely enclosed and tied with wire or nylon twine or otherwise tightly secured around the horizontal inflow pipe where the pipe protrudes through the fabric.
- 7.3.3. Fabric shall be overlapped six inches in "shingle" fashion when more than one section is required to enclose aggregate.

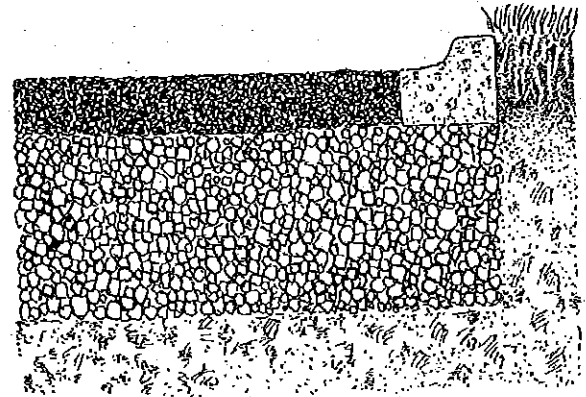
- 7.4. Inlet control
 - 7.4.1. Inlet control is needed when the infiltration trench is covered with vegetation to ensure runoff entering the trench is evenly distributed.
- 7.5. Outlet control
 - 7.5.1. Not applicable
- 7.6. Overflow
 - 7.6.1. A bypass (flow splitter) should be implemented for all infiltration trenches. The overland flow path of surface runoff exceeding the capacity of the trench should be provided, including measures to provide non-erosive flow condition on the down slope.
- 7.7. Final cover
 - 7.7.1. A minimum of 6" of topsoil can be placed over the trench and vegetated to blend into the rest of the landscape.
- 8. *Maintenance Considerations*
 - 8.1. Periodically
 - 8.1.1. Inspect to ensure trench is draining properly.
 - 8.1.2. Remove accumulated sediment in pretreatment area as needed.
 - 8.2. Repairs
 - 8.2.1. Clogging in trenches occurs most frequently on the surface. If clogging appears only to be at the surface, it may be necessary to remove and replace the first layer of stone aggregate and the filter fabric.
 - 8.2.2. Pondered water inside the trench (as visible from the observation well) after 24 hours or several days after the storm even often indicates that the bottom of the trench is clogged. In this case, remove stone aggregate and filter fabric or media. Strip accumulated sediment from trench bottom, scarify or till trench bottom to help induce infiltration. Replace fabric and clean stone aggregate in the rehabilitated trench area.

Infiltration Trench Resources

- EPA Stormwater Technology Fact Sheet, No. EPA 832-F-99-019, September 1999
- 2005 Minnesota Stormwater Manual, Version 1.0 Chapter 12-INF Volume 2
- Pennsylvania Stormwater Best Management Practices Manual, Draft January 2005
- Minnesota Urban Small sites BMP Manual / Metropolitan Council / Barr Engineering Co., 3-169, Infiltration Trenches
- SUDAS, Design of Infiltration Practices, DRAFT Section 2F-5-1 Infiltration Trench, January 2005
- Georgia Stormwater Management Manual; Volume 2 (Technical Handbook), 3.2.5 Infiltration Trench <http://www.georgiastormwater.com/vol2/3-2-5.pdf>

Porous Pavement

Porous pavement systems consist of a pervious surface with an underlying rock reservoir to temporarily store surface runoff before it infiltrates into the surrounding subsoil. This porous surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment. Porous pavement



options include porous asphalt, pervious concrete and various pavers. Porous asphalt and pervious concrete appear to be the same as traditional pavement from the surface, but are manufactured without "fine" materials, and incorporate void spaces to allow infiltration. The ideal application for porous pavement is for low-traffic or overflow parking areas. The base of the stone reservoir should be below the frost line to reduce the risk of frost heave. Porous pavement cannot be used where sand is applied because sand will clog the surface of the material. Care must also be taken when applying road salt to a porous pavement surface as chlorides from road salt may migrate into the groundwater.

Limitations

- Areas where soil infiltration capacity is less than .3" per hour.
- Areas of steep slopes (>15%)
- Certain land use areas; such as drinking water aquifer recharge areas, or where petroleum products, greases, or other chemicals will be used, stored, or transferred, areas that receive significant amounts of sediment or areas that require sand and salt application for winter deicing.
- The use of porous pavement must be carefully considered in areas where the pavement may be seal coated or paved over due to lack of awareness, such as individual home driveways.

Supporting Practices Consideration

- Pretreatment
- Subsurface drain

Recommended V_Q Credit

- 1) Storage capacity of stone reservoir if underlying soils are permeable enough to facilitate infiltration of storm water.
- 2) Reduction of time of concentration if underlying soils do not support infiltration of stormwater runoff.

Sizing Guidelines

1. Compute the Water Quality Treatment Volume (V_Q) for the given pavement:

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

Infiltration Volume Equation	24,000 SF Parking Lot Example
$1 \text{ inch} \times \text{SF} / 12 = \text{CF}$ $\frac{\text{CF}}{0.4^*}$	$1 \times 24,000 \text{ SF} = 24,000 \text{ SF} / 12 = 2,000 \text{ CF}$ $2,000 / .40 = 5,000 \text{ cubic feet storage needed}$ $\text{Depth} = 3.5 \text{ feet; Length} = 100 \text{ feet}$ $5,000 \text{ cu ft} = 3.5 \text{ deep} \times 100 \text{ long} \times 15 \text{ wide}$
<p>* to account for 40% void ratio in aggregate used to fill rock reservoir</p>	

Recommended Guidelines

1. Design Considerations

- 1.1. Soil investigation and infiltration testing required.
- 1.2. The overall site shall be evaluated for potential porous pavement / infiltration areas early in the design process, as effective porous pavement design requires consideration of grading.
- 1.3. Porous pavement should not be placed on areas of recent fill or compacted fill. Any grade adjustment requiring fill shall be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for porous pavement.
- 1.4. The sub-base should not be compacted; however the rock reservoir is placed in 8" lifts and lightly rolled according to the specifications.
- 1.5. The bottom of the rock reservoir must be level. Sloping bed bottoms will lead to areas of ponding and reduced distribution.
- 1.6. Infiltration areas should be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands shall also be considered in porous pavement placement.
- 1.7. Control of sediment is critical. Installation and maintenance of erosion and sediment control measures is required to prevent sediment deposition on the pavement surface or within the rock reservoir. Non-woven geotextile may be folded over the edge of the pavement until the site is stabilized. The designer should consider the placement of porous pavement to reduce the likelihood of sediment deposition. Surface sediment shall be removed by a vacuum sweeper and shall not be power-washed into the rock reservoir.

- 1.8. Porous pavement installations must have a backup method for water to enter the rock reservoir in the event that the pavement fails or is altered. In uncurbed lots, backup drainage may consist of an unpaved 2 ft wide stone edge drain connected directly to the bed between the wheel stop. In curbed lots, inlets with sediment traps may be required at low spots. Backup drainage elements will ensure the functionality of the infiltration system if the porous pavement is compromised.
- 1.9. The rock reservoir and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, the detention basin may be eliminated or significantly reduced in size.
- 1.10. Roof leaders and area inlets may be connected to convey runoff water to the rock reservoir. A filtering device / screen should be used to prevent the conveyance of sediment and debris into the rock reservoir.
- 1.11. While most porous pavement installations are underlain by a rock reservoir, alternative subsurface storage products may also be used, such as interlocking plastic units that contain greater storage capacity than rock, at an increased cost.
2. Slopes
 - 2.1. Rock reservoirs may be placed on a slope by benching or terracing parking bays.
 - 2.2. Orienting parking bays along existing contours will reduce site disturbance and cut/fill requirements.
3. Design flow
 - 3.1. Not applicable
4. Groundwater
 - 4.1. Four (4) feet clearance is recommended from the seasonal high water table with a minimum of 1 foot.
5. Drawdown time
 - 5.1. Water stored in the rock reservoir should infiltrate within 72 hours.
6. Observation well
 - 6.1. Not applicable
7. *Construction Considerations*
 - 7.1. Post-construction soil
 - 7.1.1. In areas with poorly-draining soils, rock reservoirs below porous pavement may be designed to slowly discharge to adjacent bio-retention areas. Only in extreme cases (i.e. industrial sites with contaminated soils) may the rock reservoir be lined to prevent infiltration.

7.2. Aggregate material

7.2.1. The rock reservoir is typically 12-36 inches deep and comprised of clean, uniformly-graded aggregate with approximately 40% void space. AASHTO No.3, which ranges 1.5-2.5 inches in gradation, is often used. The reservoir depth is a function of stormwater storage requirements, frost depth considerations, and site grading.

7.3. Filter fabric

7.3.1. A layer of non-woven geotextile filter fabric separates the aggregate from the underlying soil, preventing the migration of fines into the rock reservoir.

7.4. Inlet Control

7.4.1. Not applicable

7.5. Outlet control

7.5.1. The underlying rock reservoir is typically sized to manage the runoff generated from the 1" in 24 hour storm. Control in the underlying rock reservoir is typically provided in the form of an outlet control structure. A modified inlet box with an internal concrete weir and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always must include positive overflow from the system.

7.6. Overflow

7.6.1. All systems shall be designed with an overflow system. Water within the rock reservoir should never rise to the level of the pavement surface. Inlet boxes can be used for cost-effective overflow structures.

7.7. Final stabilization

7.7.1. Not applicable

8. *Maintenance Considerations*

8.1. Immediately clean any soil deposited on pavement to prevent clogging.

8.2. Vacuum pavement twice per year.

8.3. Clean inlets draining to the stone reservoir twice per year.

8.4. Do not apply abrasives, i.e. sand or cinders, on or adjacent to pavement.

8.5. Snow plowing should be done as not to damage pavement surface.

8.6. Salt application is acceptable, although more benign deicers are preferable.

8.7. Repairs

8.7.1. Patch small areas (> 50 SF) with porous or standard asphalt; larger areas (< 50 SF) with an approved porous asphalt.

Porous Pavement Resource:

- Pennsylvania Stormwater Best Management Practices Manual; DRAFT - JANUARY 2005 Section 6, Comprehensive Stormwater Management: Structural BMPs

Rooftop Disconnection

Disconnecting rooftops from the drainage collection systems by pervious surfaces or infiltrating Best Management Practices. This practice contributes less runoff and reduces pollutant loading by isolating surfaces to promote infiltration of stormwater runoff.

Recommended V_Q Credit

Based on disconnection length from the table below, disconnected downspouts can be subtracted from the developed site when computing Water Quality (V_Q) volume.

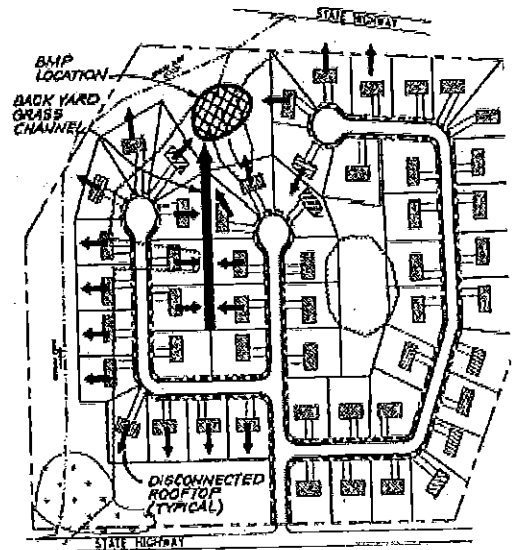


Illustration Source: Maryland Stormwater Credit for Innovative Site Planning Manual

Recommended V_Q Credit for Rooftop Disconnection

Disconnection Length	0-14 ft	15-29 ft	30-44 ft	45-59 ft	60-74 ft	>75 ft
V_Q credit for disconnection	0%	20%	40%	60%	80%	100%
V_Q to be managed through infiltration best management practices	100%	80%	60%	40%	20%	0%
Practice storage volume required to manage V_Q not managed through disconnection	42 CF	34 CF	26 CF	18 CF	10 CF	0 CF

Source: Georgia Stormwater Management Manual
Rooftop Disconnection Compensation Storage Volume Requirement (Per Disconnection)

Recommended Guidelines

1. Design Considerations

- 1.1. Each individual rooftop must be assessed separately to determine if it can be effectively disconnected.
- 1.2. Each downspout should drain no more than 600 square feet of rooftop.
- 1.3. Up to the first inch of runoff from a residential rooftop may be disconnected to a pervious surface, such as a lawn, rain garden or dry well.
- 1.4. The disconnections should drain continuously through a vegetated channel, swale or filter strip to the property line or structural stormwater control with a recommended length of pervious area over which rooftop runoff is spread of at least 75 feet.
- 1.5. In all cases, the length of the disconnected area should be equal or greater than the contributing length.

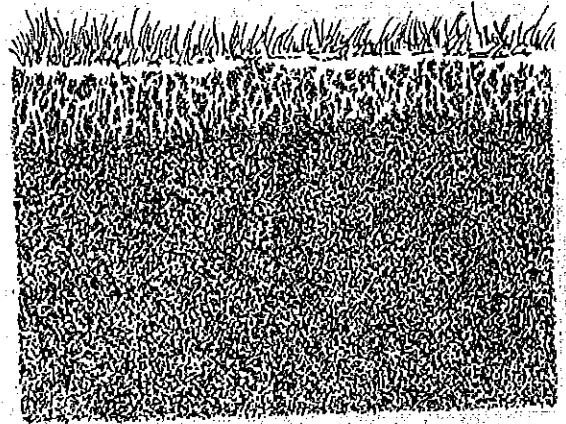
- 1.6. If shorter disconnection lengths are anticipated, then a runoff storage device such as a dry well or rain garden is needed, subject to the storage-compensation rules shown in the rooftop disconnection table.
- 1.7. The entire disconnected area should maintain a slope less than or equal to 5 percent.
- 1.8. Downspouts should be at least 10 feet away from the nearest impervious surface (i.e. driveway) to discourage re-connections to those surfaces.
- 1.9. Vegetation between pervious areas can be turf grasses, native grasses and landscape plants.

Rooftop Disconnection Resources

- Georgia Stormwater Management Manual, Rooftop Disconnection Compensation Storage Volume Requirement
- Rhode Island Stormwater Manual, 4.3.3.5 Disconnecting Impervious Area
- 2005 Minnesota Stormwater Manual, Version 1.0, Chapter 11, Vol. 2

Post-construction soil quality

As soil types vary widely, general construction activities may have a serious impact on soil structure and its ability to infiltrate and store water. Amendments can be added to a soil to improve its physical properties, such as water retention, permeability, infiltration, drainage, aeration and structure. Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. This in turn reduces runoff. The amendment of soils changes physical, chemical and biological characteristics so the soils become more effective in maintaining water quality. Compared to compacted, un-amended soils, amended soils provide greater infiltration and subsurface storage and thereby help to reduce a site's overall runoff volume, helping to maintain the predevelopment peak discharge rate and timing. The volume of runoff that needs to be controlled to replicate natural watershed conditions changes with each site based on the development's impact on the site's curve number (CN).



Limitations

- Establishing a minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved onsite management of stormwater flow and water quality.
- Soil organic matter can be attained through numerous materials such as compost, composted yard waste, industrial by-products; wood residuals. It is important that the materials used to improve post-construction soil quality be appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoil improve soil conditions and do not have an excessive percent of clay fines.

Recommended V_0 Credit

Amended Area (ft²) x 0.50 inch x 1/12 = Volume (cf) at 5% soil organic matter content.

Amended Area (ft²) x 1 inch x 1/12 = Volume (cf) at 10% soil organic matter content.

Sizing Guideline

To achieve targeted soil organic matter content:

$$CR = D (X) \frac{SBD (SOM\% - FOM\%)}{SBD (SOM\% - FOM\%) - CBD (COM\% - FOM\%)}$$

Where:

CR = Compost application rate (inches)

D = Depth of incorporation (inches)

SBD = Soil bulk density (lb/cubic yard dry weight) *

SOM% = Initial soil organic matter (%)

FOM% = Final target soil organic matter (%)

CBD = Compost bulk density (lb/cubic yard dry weight) #

COM% = Compost organic matter (%)

*To convert soil bulk density in g/cm³ units to lb/yard, multiply by 1697

To convert compost bulk density from lbs/ yard "as is" to lbs./yard dry weight, multiply by solids content

Recommended Guideline

1. Design Considerations

- 1.1. Post-construction turf areas should strive for a 5% soil organic matter content.
- 1.2. Post-construction planting bed / landscape areas should strive for a 10% soil organic matter content.
- 1.3. Soil quality restoration should be established toward the end of construction and once established, should be protected from compaction, such as from large machinery, and from erosion.

2. Construction Considerations

2.1. Soil organic matter content

2.1.1. Existing topsoil

- 2.1.1.1. Stockpile on-site topsoil from cleared and graded areas to replace prior to planting.
- 2.1.1.2. On-site topsoil should be stockpiled and protected from heavy traffic and / or compaction.
- 2.1.1.3. Stockpiled topsoil should be tested and amended with organic matter to achieve recommended organic matter.
- 2.1.1.4. Uniformly distribute stockpiled topsoil to a minimum 8-inch depth before planting.

2.1.2. Amend existing soil

2.1.2.1. Place composted organic matter, to achieve recommended organic matter content over the surface area and incorporate to an 8-inch depth.

2.1.2.2. A rule of thumb to achieve a 5% soil organic matter content is to incorporate 2 inches of compost to a 8 inch depth.

2.1.2.3. A rule of thumb to achieve a 10% soil organic matter content is to incorporate 4 inches of compost to a 6 inch depth.

2.1.3. Import topsoil

2.1.3.1. Imported topsoil should be tested and amended with organic matter to achieve recommended organic matter.

2.1.3.2. Uniformly distribute imported topsoil to a minimum 8-inch depth before planting.

3. Soil compaction

3.1.1. Care should be taken to prevent or mitigate soil compaction before final stabilization of the site is complete.

3.1.2. To alleviate soil compaction, subsoiling, ripping, spading or tilling of the soil is recommended wherever the subsoil has been compacted by equipment operation.

3.1.3. Amending existing soil mitigates sub-soil compaction when compost is incorporated to an 8-inch depth.

4. Composted organic matter

4.1. Composted organic matter should have the following characteristics:

4.1.1. Organic matter between 35 and 65 percent, as determined by loss of ignition test method (ASTM D 2974)

4.1.2. pH between 5.5 and 7.0

4.1.3. Carbon to nitrogen (CN) ratio between 10:1 and 35:1 (a CN ratio of 35:1 is preferred for native plantings)

4.1.4. Maximum electrical conductivity of 3 ohms/cm

4.1.5. Moisture content range between 35 and 50 percent

4.1.6. No viable weed seeds

4.1.7. Manufactured inert material (plastic, etc.) should be less than 1 percent on a dry weight or volume basis

4.2. Specifying the use of compost products that are certified by the U.S. Composting Council's Seal of Testing Assurance (STA) Program will allow for the acquisition of products that are analyzed on a routine basis, using specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products.

5. Final stabilization

5.1. Soils should be planted and mulched after recommended soil organic matter content has been achieved.

6. *Maintenance Considerations*

6.1. When possible, turf should be mulch mowed and clippings left on the soil surface to replenish soil organic matter.

6.2. If area has heavy foot traffic, an annual soil core aeration followed by a ¼" topdressing of composted organic matter is recommended.

Post-construction Soil Quality Resources

- Western Washington Stormwater Guidelines for Implementing Soil Depth & Quality (BMP T.5.13)
- Draft Pennsylvania Stormwater Management Manual, April 2006, BMP 6.19: Soil Amendment and Restoration
- LID Technical Guidance Manual for Puget Sound, January 2005, BMP 6.2: Amending Construction Site Soils

Vegetated Filter Strips

Filter strips use vegetation to absorb and filter sheet flow runoff from adjacent impervious surface areas. Filter strips trap sediment by slowing runoff velocities. Water can also be infiltrated into filter strips. Filter strips function best if planted to deep-rooted vegetation, but can also be planted to turf. Filter strips differ from grassed swales in that swales are concave, channelized, vegetated conveyance systems, whereas filter strips provide treatment by sheet flow over level-to-gently sloped surfaces.

Limitations

- Filter strips can be short-circuited with concentrated flows.
- Must maintain sheet flow to treat runoff.

Supporting Practice Considerations

- Level spreader
- Vegetation

Recommended V_Q Credit¹

Filter Strip Area x Infiltration Rate X 24 hours (duration)

Sizing Guideline

1. Compute Water Quality Treatment Volume (WQV) for the given treatment area.

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

2. Calculate peak flow

$$q = (1.486/n)(A)(R^{0.667})(S^{0.5}) \text{ where:}$$

Where:

q = Design runoff flow rate (cfs)

n = Manning's coefficient (dimensionless, i.e. $n = .25$)

A = Cross-sectional area (ft²)

R = Hydraulic radius (ft)

S = Longitudinal slope (ft/ft)

3. The design flow depth should be limited to 0.5 inches to maintain sheet flow. For a wide, shallow channel the hydraulic radius is approximately equal to depth (y).

¹ Draft Pennsylvania Stormwater Management Manual

4. Manning's roughness coefficient (n) should be selected on the basis of vegetative species and density. A roughness coefficient of approximately 0.25 to 0.30 is often appropriate for sheet flow through a filter (USDA-SCS, 1984). When design flow has been established the continuity and Manning's equation can be used to calculate width (perpendicular to flow).
5. Length rule of thumbs include:
 - 5.1. Use the same length of vegetated strip as contributing impervious area.
 - 5.2. The width of the strip (perpendicular to flow) should be a minimum of 20 feet. The length of the strip should be a minimum of 50 to 75 feet with an increase of 4 feet for every one percent slope on the strip.

Recommended Guidelines

1. Design Considerations

- 1.1. If constructed prior to construction completion, filter strips should be protected until the site been sufficiently stabilized.
- 1.2. The natural infiltrative capacity of the soils should be protected from compaction during construction by using oversize tires and light-weight equipment.
- 1.3. Concentrated flows should be prevented through the following measures:
 - 1.3.1. The width of the filter should generally be measured perpendicular to the overland flow, and equal to the width of the treated drainage area.
 - 1.3.2. The flow length through the filter system should be a minimum of 25 feet and at maximum no more than 300 feet.
 - 1.3.3. The flow length of the drainage area to be treated is usually limited to 75 feet for impervious area or 150 feet for pervious area.
- 1.4. Vegetated filter strips may be designed to discharge to a variety of features, including natural buffer areas, vegetated swales, infiltration basins, or other structural best management practices.
- 1.5. A level spreader at the upper end of the filter strip with provisions to prevent flows from bypassing the strip should be included.
- 1.6. The use of berms every 50 to 100 feet perpendicular to the top edge of the strip will help prevent channelized flow across the top and direct the flow more uniformly across the strip.
- 1.7. Evenly grading the top is important.

2. Slopes

- 2.1. Limit slopes to 6% or less.
- 2.2. Vegetated filter strips are not appropriate for steep or highly impervious areas because of high runoff velocity.
- 2.3. 1% is the maximum lateral slope of filter strip.

3. Design flow
 - 3.1. Design flow for filter strip should be the peak 2-year discharge.
 - 3.2. The filter strip should be designed so flow depth is no more than 0.5 inches.
 - 3.3. The filter strip should be designed so runoff velocity is 0.50 feet per second or less.
 - 3.4. The ratio of contributing drainage area to filter strip area should never exceed a 6:1 ratio.
4. Groundwater
 - 4.1. Not applicable
5. Drawdown time
 - 5.1. The filter strip needs to drain within 24 hours.
6. Observation well
 - 6.1. Not applicable
7. *Construction Considerations*
 - 7.1. Post-construction soil
 - 7.1.1. Recommended infiltration rate of existing soil is 0.5 inches / hour.
 - 7.1.2. Amending soils or an engineered soil may be necessary when existing soil conditions do not meet the recommended infiltration rate of 0.5 inches / hour.
 - 7.2. Aggregate material
 - 7.2.1. Not applicable
 - 7.3. Filter fabric
 - 7.3.1. Not applicable
 - 7.4. Inlet control
 - 7.4.1. Not applicable
 - 7.5. Outlet control
 - 7.5.1. Not applicable
 - 7.6. Overflow
 - 7.6.1. Not applicable
 - 7.7. Final stabilization
 - 7.7.1. The vegetation in a filter strip must be dense and healthy turf grass; meadow grass, shrubs, and native vegetation, including trees.
 - 7.7.2. Vegetation should be selected for ease of establishment, ability to create a dense mat, erosion resistance, water tolerance and non-invasive qualities.

8. *Maintenance Considerations*

- 8.1. Inspect vegetation for signs of erosion and, if found, correct immediately.
- 8.2. Mow / maintain vegetation to control unwanted / obnoxious weeds.
- 8.3. Periodic removal of solids / sediment to maintain sheet flow and vegetation.
- 8.4. Repairs should be made as soon as possible to re-establish sheet flow.

Vegetated Filter Strip Resources

- SUDAS Draft Design Section 2F-7: Filter Strips, November 2004
- Natural Resource Conservation Service Planning and Design Manual
- Minnesota Stormwater Management Manual, March 2000, Chapter 4 - 4.61: Filter Strips
- Rhode Island Stormwater Manual, Chapter 4 – 4.3.4.1 Vegetated Filter Strips
- The Wisconsin Stormwater Manual: Filter Strips

Native Soil / Vegetation Preservation

Preserving native soil / existing vegetation in a forested area (including trees, grasses, and other plants) by preventing disturbance or damage to specified areas of a construction site to the maximum extent practicable will minimize the impacts of development on storm water runoff and enhance aesthetic benefits.

Limitations

- It may constrict the area available for construction activities.
- It may not be cost-effective in areas with high land values.

Recommended V_Q Credit

Preserved / protected area, in square footage, removed from storm water quality calculations.

Recommended Guidelines

1. General Considerations

- 1.1. Design the site to maximize preservation of natural vegetation through to minimize the impact of construction activities on existing vegetation.
- 1.2. If feasible, the preserved area should be located down-slope from the building sites, since flow control and water quality are enhanced by flow dispersion through undisturbed soils and native vegetation.
- 1.3. Areas to be preserved should be identified in the plans and clearly marked in the field before any site disturbance begins.
- 1.4. Clearly mark all trees to be preserved, and protect against ground disturbance within the drip-line of each marked tree as shown on the attached figure. The drip-line marks the edge of the tree's foliage where drips from rainfall would drop. Most of the tree's roots lie within the drip-line and are vulnerable to damage.
- 1.5. Preserving natural vegetation may affect some aspects of staging, work sequencing, and construction cost. In addition, control measures may be needed around the perimeter of the preserved area to maintain adequate water flow and drainage and to prevent damage from excessive erosion or sedimentation. These factors should be taken into consideration when preparing site plan and cost estimates.
- 1.6. Consider the use of design exceptions to enable preservation of natural vegetation in certain areas where it would typically be removed and where its preservation would not pose safety problems.
- 1.7. Do not modify existing drainage patterns through or into any preservation area unless specifically directed by the plans or approved by the local permitting authority.

2. Construction Considerations

- 2.1. Keep all construction equipment, materials, and waste out of the designated areas.
- 2.2. Perform maintenance activities as needed to ensure that the vegetation remains healthy and able to aid in erosion control and sediment collection.

3. Maintenance considerations

- 3.1. Inspect at regular intervals to make sure the preserved vegetated areas remain undisturbed and are not being overwhelmed by sediment.
- 3.2. Implement maintenance or restorative actions as needed. Different species, soil types, and climatic conditions will require different maintenance activities such as mowing.
- 3.3. Maintenance should be performed regularly, especially during construction.

Native Soil / Vegetation Preservation Resources

- Naval Facilities Engineering Service Center, Environmental Services
<http://enviro.nfesc.navy.mil/stormwaterbmp/HTML/BMP112.htm>
- Storm Water Management Manual for Western Washington
- <http://www.ecy.wa.gov/pubs/9915.pdf>
- Minnesota Urban Small Sites BMP Manual
- http://www.metrocouncil.org/environment/Watershed/BMP/CH3_RPPConstSequenc.pdf
- Estimating Soil Storage Capacity for Storm Water Modeling Applications by By Michael A. Gregory, Brett A. Cunningham, Michael F. Schmidt, and Brian W. Mack

Wet Ponds

There are several different variants of wet pond design, the most common of which include wet extended detention pond, micro-pool extended detention pond and multiple pond systems. They are all a constructed basin that have a permanent pool of water. Ponds treat incoming storm water runoff by settling solids and algal uptake. The primary removal mechanism is settling as storm water runoff resides in this pool, and pollutant uptake, particularly nutrients, also occurs through biological activity in the pond. While there are several different versions of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain storm water runoff to provide settling.



Illustration Source: Metropolitan Council / Barr Engineering Co.

Limitations

- Minimum contributing drainage area of 25 acres; 10 acres for a micro-pool extended detention pond.
- Need for base flow or supplemental water if water level is to be maintained.
- Mosquito and midge breeding is likely to occur in pond.
- Cannot be placed on steep, unstable slopes.
- Wet ponds allow sunlight to increase water temperature, which may have a detrimental effect on aquatic life in the receiving water body.
- Depending on volume and embankment height, pond designs may require approval from Iowa Department of Natural Resources (Re: Iowa Technical Bulletin 17).
- Provisions must be made to dredge, test, and properly dispose of sediment that settles on a regular basis.
- Precautions should be taken to discourage swimming and entry to the pool area.

Supporting Practice Considerations

- Pretreatment
- Level spreader
- Flow splitter

Recommended V_Q Credit

Wet ponds are designed to control water quantity volume, with a secondary benefit of improving water quality. A wet pond does not decrease the overall volume of storm water runoff, therefore zero credit, against the water quality volume, has been given for this particular practice.

Sizing Guideline

The area required for a wet pond is generally 1 to 3 percent of its drainage area. Wet ponds should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events. Pond surface area, as a percent of the tributary drainage area and percent of total imperviousness within the drainage area:

Land Use / Description / Management	Total Impervious (%)	Permanent Pool Surface Area (% of Watershed)
Residential		
<2.0 units/acre (>1/2 acre lots)	8 - 28	0.7
2.0 - 6.0 units / acre	28 - 41	0.8
>6.0 units/acre (high density)	41 - 68	1.0
Office park / Institutional / Warehouse	<60	1.6
(Non-retail related business, multi-storied buildings, usually more lawn/landscaping not heavily traveled, no outdoor storage/manufacturing)	60 - 80	1.8
	>80	2.0
Shopping / Manufacturing / Storage	<60	1.8
(Large heavily used outdoor parking areas, material storage or manufacturing operations.)	60 - 80	2.1
	>80	2.4
Parks / Open Space / Woodland / Cemeteries	0 - 12	0.6
Highways / Freeways (includes right of way area)		
Typically grass banks / conveyance	<60	1.4
Mixture of grass and curb/gutter	60 - 90	2.1
Typically curb/gutter conveyance	>90	2.8

The Wisconsin Stormwater Manual: Wet Detention Basins (G3691-4)

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Recommended Guidelines

1. Design Considerations

- 1.1. In general, pond designs are unique for each site and application. Criteria for selecting the site for installation of the pond should include the site's ability to support the pond environment, as well as the cost effectiveness of locating a pond at that specific site.
- 1.2. The pond should be located where the topography of the site allows for maximum storage at minimum construction costs.
- 1.3. Site specific constraints for pond construction may include wetland impacts, existing utilities (e.g., electric or gas) that would be costly to relocate, and underlying bedrock that would require expensive blasting operations to excavate.
- 1.4. Pollutant removal efficiency is primarily dependent on the length of time that runoff remains in the pond, which is known as the pond's Hydraulic Residence Time (HRT). Once the design HRT has been determined, the actual dimensions of the pond should be calculated to achieve the design HRT. The primary factor contributing to the pond's HRT is its volume.
- 1.5. Because many wet ponds are restricted in area, pond depth can be an important factor in the pond's overall volume.
- 1.6. Wet ponds should be designed with a length to width ratio of at least 2:1 wherever possible. If the length to width ratio is lower, the flow pathway through the wet pond should be maximized.
- 1.7. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- 1.8. Water depth of the wet pond should not exceed 8 feet, to minimize thermal stratification and short-circuiting and prevent sediment re-suspension, reduce algal blooms and maintain aerobic conditions.
- 1.9. The mean depth of the permanent pool is calculated as the pond volume measured at one foot below the permanent pool elevation divided by the surface area at that elevation.
- 1.10. All areas that are deeper than 4 feet should have two safety benches, totaling 15 feet in width. One should start at the normal water surface and extend up to the pond side slopes at a maximum slope of 10 percent. The other should extend from the water surface not the pond to a maximum depth of 18 inches, also at slopes no greater than 10 percent.
- 1.11. To enhance habitat value, visual aesthetics, water temperature, and pond health, a 25-foot buffer should be added from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Existing trees within the buffer should be preserved. If soils in the buffer become compacted during construction, soil restoration should take place to aid buffer vegetation.
- 1.12. An elongated pond in the direction of strong prevailing winds should give extra consideration to reinforce banks, extend safety shelves or other measures to prevent embankment deterioration due to wave action.

- 1.13. A dewatering outlet with a shutoff valve should be installed in the basin to allow the permanent pond and settling basin to be drained for structural maintenance. A maintenance right-of-way (utility easement) to the pond for access by heavy equipment should be built into the design. Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%.
2. Slopes
 - 2.1. Slopes steeper than 4:1 can cause safety problems due to slippery footing and hazardous operating conditions during maintenance.
 - 2.2. Slopes flatter than 10:1 may present drainage problems and provide mosquito habitat.
3. Design flow
 - 3.1. The velocity flow through the inlet sediment control structure and pond should not exceed 2.5 feet per second.
4. Groundwater
 - 4.1. Four (4) feet clearance from seasonal high water table to bottom of the swale is recommended, minimum 1 foot.
5. *Construction Considerations*
 - 5.1. Post-construction soil
 - 5.1.1. Generally hydrologic soil groups "C" and "D" are suitable without modification, "A" and "B" soils may require modification to reduce permeability. Soil permeability must be tested in the proposed wet pond location to ensure that excessive infiltration will not cause the wet pond to dry out.
 - 5.1.2. Engineered planting soil could be used for shallow areas within wet ponds. Engineered soil can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species.
 - 5.2. Inlet control
 - 5.2.1. The shallow and narrow end of the pond should be located near the inlet.
 - 5.2.2. If runoff enters the pond via a pipe, the invert of the inlet pipe should be located within 1 foot of the permanent pool elevation to reduce mixing of incoming runoff with the permanent pool and to reduce erosion at the inlet.
 - 5.2.3. It is best to avoid submerged inlets because deposition can occur in the pipeline or ice buildup can block the pipe opening.
 - 5.2.4. Prevention of scour at the inlet is necessary to reduce maintenance problems and prevent damage to basin floor vegetation.
 - 5.2.5. Energy dissipation should be provided at the inlet (and outlet) to prevent scour and reduce the velocity of storm water.

5.3. Outlet control

- 5.3.1. The deeper and wider end of the pond should be located near the outlet.
- 5.3.2. Outlet control devices should draw from open water areas 5 to 7 feet deep to prevent clogging and allow the wet pond to be drained for maintenance.
- 5.3.3. Outlet devices are generally multistage structures with pipes, orifices, or weirs for flow control.
- 5.3.4. A reverse slope pipe terminating 2 to 3 feet below the normal water surface, minimizes the discharge of warm surface water and is less susceptible to clogging by floating debris.
- 5.3.5. Orifices, if used, should be at least 2.5 inches in diameter and should be protected from clogging.
- 5.3.6. Outlet devices should be installed in the embankment for accessibility. If possible, outlet devices should enable the normal water surface to be varied. This allows the water level to be adjusted (if necessary) seasonally, as the wet pond accumulates sediment over time, if desired grades are not achieved, or for mosquito control.
- 5.3.7. The outlet pipe should generally be fitted with an anti-seep collar through the embankment.

5.4. Overflow

- 5.4.1. All outflow / overflow should be conveyed downstream in a safe and stable manner.
- 5.4.2. Emergency spillways should be located on undisturbed, non-fill soil wherever possible. If the spillway must be located on fill soils, then it must be horizontally off-set at least 20 feet from the principal outlet and be designed with a riprap lining, reinforced-turf lining or a non-flexible lining.
- 5.4.3. The maximum grade of the spillway's exit channel may not exceed 20% unless a non-flexible lining is used to control erosion within the channel. Vegetation, reinforced turf, riprap, and modular blocks are considered flexible linings. All linings should be evaluated for stability at the channel grade chosen.
- 5.4.4. There should be no large woody species growing in the emergency spillway that could interfere with its function.
- 5.4.5. The design flow depth in the exit channel may not exceed one-half the stone size for channels lined with riprap and three inches for channels lined with un-reinforced vegetation. The channel shall be designed to remain stable through the full range of design flows.

5.5. Final stabilization

- 5.5.1. Construction of pond must be complete with side slopes and banks stabilized with grass or conservation mix seeding before allowing the pond to fill with water.

5.5.2. Vegetation is an integral part of a wet pond system. Vegetation in and adjacent to a pond may enhance pollutant removal, reduce algal growth, limit erosion, improve aesthetics, create habitat, and reduce water warming (Maillin et al., 2002; JN DEP, 2004); University of Wisconsin, 2000). Wet ponds should have varying depths to encourage vegetation in shallow areas. The emergent vegetation zone (areas not more than 18" deep) generally supports the majority of aquatic vegetation and should include the pond perimeter. Robust, non-invasive, perennial plants that establish quickly are ideal for wet ponds. Monoculture planting must be avoided due to the risk from pests and disease.

5.5.3. A landscape architect or wetland biologist should be consulted when planning the vegetation of a wet pond.

6. Maintenance Considerations

6.1. Post-Construction Agreement

6.1.1. A legal entity should be established with responsibility for inspecting and maintaining the wet pond. The legal agreement establishing the entity should list specific maintenance responsibilities and provide for the funding to cover long-term inspection and maintenance.

6.2. Periodically

6.2.1. Inlets and outlets should be checked periodically to ensure that flow structures are not blocked by debris. All ditches and pipes connecting ponds in series should be checked for debris that may obstruct flow. Inspections should be conducted monthly during wet weather conditions from March to November. It is important to design flow structures that can be easily inspected for debris blockage.

6.3. Annually

6.3.1. Inspect ponds for instability and erosion, including destabilization of side slopes, embankment settling and other signs of structural failure. Corrective action should be taken immediately upon identification of problems.

6.3.2. Remove rodents that burrow into embankment.

6.4. Dredging

6.4.1. Wet ponds lose 0.5 – 1.0% of their volume annually due to sediment accumulation. Dredging is required when accumulated volume loss reaches 15%, approximately every 15 – 20 years.

Wet Pond Resources

- The Wisconsin Storm Water Manual: Wet Detention Basins (G3691-4)
- SUDAS Section 2F-4: Wet Pond, Draft 2005
- DRAFT Pennsylvania Stormwater Management Manual, BMP 6.14 Wet Pond / Retention Basin

Engineered Planting Soil

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

Recommended Guidelines

1. The bioretention facility may not be constructed until all contributing drainage area has been stabilized.
2. Soil should be engineered to a uniform mix containing:
 - 2.1. 40 - 60% construction sand
 - 2.2. 20-30% topsoil with less than 5% maximum clay content
 - 2.3. 20-30% organic compost
3. Engineered planting soil should be free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances shall be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of noxious weeds.
4. Final engineered planting soil should meet the following criteria:
 - 4.1. pH range 5.2 - 7.0
 - 4.2. organic matter 5 - 10%
 - 4.3. soluble salts not to exceed 500 ppm
5. Depth of the engineered planting soil is a function of estimated storage required to manage the volume of water being directed to the bioretention facility.
6. It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, use excavation hoes to remove original soil.
7. If bioretention areas are excavated using a loader, the contractor should use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and storage volumes and is not acceptable.
8. Compaction will significantly contribute to design failure.

9. Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.
10. When back filling the bioretention facility, place soil in lifts 12" or greater. Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand.
11. Grade bioretention materials by hand or with light equipment such as a compact loader or a dozer/loader with marsh tracks.
12. Final cover should consist of a 2 – 3" of shredded hardwood mulch.

Engineered Planting Soil Resources

- New York Stormwater Management Design Manual Appendix C
- <http://www.epa.gov/ORD/NRMRL/pubs/600r04121/600r04121asect7.pdf>

Flow Splitter

Off-line best management practices (BMP) often need to restrict stormwater flows and bypass them around the practice because they are designed to treat runoff from small storm events. Bypassing the larger flows helps prevent re-suspension of sediment, hydraulic overload, or erosion of the primary practice.

Flow splitters are used to direct the first fraction of runoff (commonly called the "first flush") into an end-of-pipe BMP facility, while bypassing excess flows from larger events around the facility into a bypass pipe or channel. The bypass typically enters a detention pond or the downstream receiving drainage system, depending on flow control requirements.

Off-line BMP systems that require flow-splitter consideration include:

1. Bio-Retention Cells
2. Dry well
3. Infiltration Trench
4. Wet Ponds

Recommended Guidelines

1. Bypass Elevation

- 1.1. Determine where the bypass elevation will be placed. One recommended method is to set the bypass elevation equal to the design storage elevation in the BMP facility. Using this method, flow will only start to bypass the BMP once the inflow pipe has conveyed the design runoff volume. Although this ensures that the design volume will be captured, it also means that the water level in the BMP may exceed the design level for large infrequent storms that utilize the bypass. The larger events may result in additional height in the BMP pond.

2. Bypass Capacity

- 2.1. Given that the bypass elevation is set equal to the design storage elevation in the BMP facility, the maximum elevation in the facility depends on the rate of bypass. And, the rate of bypass varies with depth.

3. Influent Pipe Capacity

- 3.1. The capacity of the influent pipe into the BMP facility determines when a bypass occurs for intense storms, and it adds to the head loss between the bypass and the BMP. The design of the influent pipe depends on the intensity of the design storm that defines the capacity of the BMP facility. The size of the influent pipe should be chosen in accordance with the design storm event.

4. The operation of the bypass must be assessed for the design event used to size the upstream pipe network – 6 month rain (1" in 24 hours). In some cases, the upstream pipe network may even convey the 100 year storm event. In all cases, the splitter operation during the upstream pipe design event must be assessed.

5. Special applications, such as roads, may require the use of a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.
6. The baffle wall must be made of reinforced concrete or another suitable material resistant to corrosion, and have a minimum 4-inch thickness. The minimum clearance between the top of the baffle wall and the bottom of the manhole cover must be 4 feet; otherwise, dual access points should be provided.
7. Metal parts should be corrosion resistant. Examples of preferred materials include aluminum, stainless steel and plastic. Zinc and galvanized materials are discouraged because of aquatic toxicity. Painted metal parts should not be used because of poor longevity.

Flow Splitter Resource

- Minnesota Urban Small Sites BMP Manual

Level Spreader

Level Spreaders are measures that reduce the erosive energy of concentrated flow by distributing runoff as sheet flow to stabilized vegetated surfaces, as well as promote infiltration and improved water quality. There are two applications for level spreaders:

- Inflow level spreaders to evenly distribute flow entering into a structural best management practice.
- Outflow level spreaders, which can stand alone to distribute runoff from an impervious surface or used in conjunction with a structural best management practice.

Level spreaders can take many forms including vegetated filter strips, concrete sills (or lips) curbs, concrete trough, a plastic tile cut in half, rock check dams, and treated lumber.

Limitations

- Level spreaders are not effective treatment by themselves and should be used as part of an integrated, decentralized storm water management system.
- If not designed and / or constructed correctly flow may eventually become concentrated and erosive.
- It is meant for small flows, less than 5 cubic feet per second.
- Level spreaders with a vegetated lip needs to be protected from traffic (lawn mowers) in order to maintain a smooth level surface.

Recommended Guidelines

1. Design Consideration

- 1.1. It is easier to keep flow distributed than to redistribute it after it is concentrated.
- 1.2. The length of the level spreader is a function of the calculated flow rate, a rule of thumb:
 - 1.2.1.1. 15 feet for every 0.1 cubic feet per second (cfs) and 10 feet for each 0.1 cfs thereafter to a maximum of 0.5 cfs per spreader.
- 1.3. Multiple spreaders should be used for higher flows.
- 1.4. The width of the spreader should be at least 6 inches deep, uniform across the entire length.
- 1.5. Level spreaders must be LEVEL, constructed at zero grade across a slope.
- 1.6. Vegetated lip for level spreader should not be constructed from fill material.
- 1.7. Level spreaders should not be constructed on newly deposited fill dirt. Native / undisturbed soil is more resistant to erosion than fill.
- 1.8. The downside of the level spreader should be clear of debris.

- 1.9. Discharge area below the level spreader must be uniform with a slope of less than 20%.
- 1.10. The final 20 feet leading to the level spreader shall be less than or equal to 1% to reduce velocities.
- 1.11. Low-growing turf or native grasses can be used as a level spreader in some instances.

Level Spreader Resources

- North Carolina Department of Transportation Level Spreader Workshop Materials 2001 http://www.bae.ncsu.edu/cont_ed/main/handouts/lsworksheet.pdf
- City of Tacoma Washington, Stormwater Management Manual, 4.2 Runoff Conveyance and Treatment BMP C206: Level Spreader <http://www.ci.tacoma.wa.us/WaterServices/permits/Volume2/SWMM%20V2-C4b.pdf>
- Pennsylvania Stormwater Best Management Practices Manual, Draft January 2005, BMP 6.20: Level Spreader

Pretreatment

Pretreatment constructed as part of the infiltration-based practices prevents premature failure. It is crucial that the design of stormwater treatment devices relying on infiltration include a pretreatment device or method that will trap sand and sediments before they clog the treatment mechanism. Infiltration of stormwater from the treatment device into underlying soils is an important beneficial component of the device. The benefits of pretreatment include decreased risk of re-suspending sediment, increased pollutant removal efficiency, reduced maintenance frequency and reduced BMP failure. The pretreatment is constructed at the incoming discharge point to allow sediment to settle from the stormwater runoff before it is delivered to the balance of the best management practice.

Practices typically used for pretreatment include:

- Vegetated filter strips
- Settling basin
- Proprietary products, such as grit chambers

Design Considerations

1. Pre-treatment should be designed to reduce anticipated pollutants, such as grease and oil.
2. Pre-treatment should be designed and located where it is easily accessible to facilitate inspection and maintenance.
3. A settling basin should be capable of storing between cleanout periods equaling 1% of the practice volume multiplied by the time between cleanout.
4. A settling basin should have a surface area equal to 12% of the primary practice surface area.
5. Rule of thumb to calculate annual sediment / sand loading of a given area:

$$\text{Area to be sanded (acres)} \times 500 \frac{\text{pounds}}{\text{acre-storm}} \div 90 \frac{\text{pounds}}{\text{ft}^3} \times 10 \frac{\text{storms}}{\text{year}} = \text{cubic feet of sediment/year}$$

Pretreatment Resources

- Comprehensive Environmental Inc., Design Guidelines & Criteria for Stormwater Management, November 2003
<http://nh.gov/oep/resourcelibrary/referencelibrary//lowimpactdevelopment/documents/designcriteria.pdf>

Subsurface Drain

A subsurface drain is a perforated pipe, tubing or tile installed below the ground surface to intercept and transport water to a satisfactory outlet. The subsurface drain can be connected to the storm sewer system or another infiltration-based practice.

Subsurface drains should be installed with infiltration based practices when the area is:

- When post-construction soil infiltration rates are not adequate.
- Located near sensitive infrastructure and potential for flooding is likely.
- Used for filtering storm flows from gas stations or other pollutant hotspots (requires an impermeable liner in the infiltration-based practice itself).

Recommended Guidelines

9. Design Considerations

9.1. Slope

9.1.1. Subsurface drains should be sloped at a minimum of 0.5 percent.

9.2. Design flow

9.2.1. The drain should be graded to achieve the minimum velocity required to prevent silting, 1.4 cubic feet per second.

9.3. Post-construction soil

9.3.1. The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

10. Construction Considerations

10.1. Subsurface drain

10.1.1. The pipe diameter will depend on hydraulic capacity required - minimum diameter is 4 inches, with 4 to 8 inches being most common. The subsurface drain must carry the required capacity without pressure flow.

10.1.2. The use of a perforated pipe to collect and transport excess runoff is optional.

10.2. Aggregate

10.2.1. The basic infiltration trench uses aggregate to promote filtration. The aggregate is normally 1 to 3 inches in diameter, which provides a void space of 40 percent.

10.2.2. The stone aggregate should be washed to remove dirt and fines before placement in the trench.

10.2.3. 3/8" to 1/2" pea gravel can be substituted as the aggregate in the top foot of the trench, as it improves sediment filtering and maximizes pollutant removal.

10.2.4. Where the subsurface drain will be in contact with soil, wrap the drain tile in filter fabric extending 2 feet on either side of the subsurface drain. The fabric should overlap each side of the trench in order to cover the top of the aggregate layer.

10.3.Outlet control

10.3.1. The subsurface drain can be connected to a downstream open conveyance (bioswale); another bioretention cell, daylighted to a dispersion area, or connected to a storm sewer system.

10.4.Observation well

10.4.1. A 6-inch rigid non-perforated observation pipe or other maintenance access should be connected to the subsurface drain every 250 to 300 feet to provide a clean-out port, as well as an observation well to monitor dewatering rates.

11.Maintenance Considerations

11.1.Drain outlets should be inspected periodically to verify they are in good working order.

Subsurface Drain Resources

- City of Tacoma, 2001, Volume II – Construction Stormwater Pollution Prevention
- Minnesota Stormwater Manual, March 2000, Chapter 4.11 Flow Controls: Subsurface Drains
- LID Technical Guidance Manual for Puget Sound, January 2005, Chapter 6.1 Bioretention Areas

Vegetation for Final Stabilization

There are three levels of vegetation to use for infiltration-based practices, fair, fairer and fairest of all. Each level is progressively better for stormwater management purposes, as the plant choices become deeper-rooted and taller and are better able to filter, absorb, infiltrate and retain more water both above and below ground.

Vegetation	Good	Better	Best
Plant Species	Cool season turf grass, such as Kentucky Bluegrass	Cultivated plants, such as those found at the local nursery or garden center, shrubs, young trees	Native plants / flower, forbes, sedges, warm season grasses, and mature trees
Maintenance	"Mow" to High Maintenance, depending on personal expectations for a green, weed-free lawn	Low to Medium Maintenance – Watering until plants / shrubs / trees are established; Deadheading, Weeding and Pruning occasionally thereafter	Medium to High through year 3 for native prairie plants; Low to Very Little Maintenance thereafter

Recommended Guidelines

Practice	Selection			
	Exposed Rock	Turf	Cultivated Plants	Native Plants
Bioretention Cells			X	X
Bioswale		X	X	X
Dry Well		X		
Engineered Soil		X	X	X
French Drain / Infiltration Trench	X	X		
Vegetated Filter Strip		X		

Vegetation Rule of Thumb: The height of any given plant in an infiltration-based practice should be no taller than ½ the site width - i.e. plants / shrubs, etc. in a 4' wide bioretention cell should be get no taller than 2'

Vegetation for Final Stabilization Resource

- Personnel Communication, Dr. Eileen Robb, Des Moines, IA

Quick References

Storm Water Equations

1. Compute the Water Quality Treatment Volume (V_Q) for drainage area

$$V_Q = \text{Drainage Area in Square Feet} \times 0.083 \text{ (1 inch rain)}$$

Bio-Retention Cell

2. Size planting soil filter bed area

- a. Computed using the following equation (based on Darcy's Law):

- i. $A_f = (V_Q) (d_f) / [(k) (h_f + d_f) (t_f)]$

Where:

A_f = surface area of ponding

V_Q = volume to be captured (1 inch or less)

d_f = filter bed depth (4 feet minimum)

k = coefficient of filter media permeability (ft/day)

h_f = average height of water above filter bed in feet;
(typically 3", which is $\frac{1}{2}$ of the 6" ponding depth)

t_f = design filter bed drain time; recommend 24 hours

3. Calculate ponding time

- a. The maximum design depth can be computed using the following equation:

- i. $d_{\text{max}} = (f) (T_p)$

Where:

d_{max} = maximum design depth

f = soil infiltration rate (in/hr), and

T_p = design ponding time (hours)

Bioswale

2. Identify the required swale bottom width, depth, length and slope necessary to convey the water quality volume with a shallow ponding depth, no greater than 5" for peak 10-year discharge.
3. Width of swale should be limited to determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.30.
4. Sizing Equations:

Grass Channel	Wet Swale	Dry Swale
$V = (1.49/n) R^{2/3} S^{1/2}$	$A_f = Vol_f(d_f) / [k_f(h_f + d_f)(t_f)]$	$Vol = A \times L$
$R = A / P$		
Variables	Variables	Variables
V = Velocity, should be less than 1 cfs	A_f = Required surface area of the dry swale (cf)	Vol = Retention Volume (cf)
N = Roughness coefficient (tabulated values)	Vol = Treatment volume (cf)	A = Cross sectional area (sf)
R = Hydraulic radius (ft)	d_f = Depth of the filter medium (ft)	L = Length of swale (feet)
A = Cross sectional area (square feet)	k = Hydraulic conductivity (feet / day)	
P = Wetted perimeter (ft)	h_f = Average height of water above the bottom of dry swale (feet); maximum 18" ponding	
S = Longitudinal slope	T_f = Design time to filter the treatment volume through the filter media (usually set at 24 hours)	

5. Compute the 2 year and 10 year frequency storm event peak discharges.
6. Check the 2 year velocity for erosive potential (adjust swale geometry, if necessary, and reevaluate WQV design parameters).
7. Check the 10 year depth and velocity for capacity (adjust swale geometry, if necessary, and reevaluate WQV and 2 year design parameters).
8. Provide minimum freeboard above 10 year stormwater surface profile (6-inch minimum recommended).

Dry Well

2. Size dry well

$$\frac{CF}{0.4*} = \text{dry well volume}$$

(*varies – 40% void ration is rule of thumb for rock backfill)

Dry well volume = Depth (D) x Width (W) x Length (L)

Depth = well depth is typically limited to 3.5 feet

Infiltration Trench

2. Determine infiltration trench volume:

$$A = \frac{V_Q}{nd + (kT / 12)}$$

Where:

A = Surface area of infiltration trench

V_Q = Volume to be infiltrated

n = porosity (default = 0.32)

d = trench depth (feet)

k = infiltration rate (inches/hour)

T = time it takes practice to fill with water (2 hours can be used as fill time for most designs)

Porous Pavement

Infiltration Volume Equation	24,000 SF Parking Lot Example
$\frac{1 \text{ inch} \times \text{Square Feet}}{12}$ <p>= Cubic Feet (CF)</p> <p><u>Cubic Feet</u></p> <p>0.4*</p> <p>*to account for 40% void ratio in stone used to fill underground reservoir</p>	$1 \times 24,000 = 24,000 / 12 = 2,000 \text{ CF}$ $2,000 / .40 = 5,000 \text{ CF}$ <p>D = 3.5 feet; L = 100 feet</p> $5,000 \text{ cu ft} = 3.5D \times 100L \times 15W$

Rooftop Disconnection

Recommended V_Q Credit for Rooftop Disconnection

Disconnection Length	0-14 ft	15-29 ft	30-44 ft	45-59 ft	60-74 ft	>75 ft
V_Q credit for disconnection	0%	20%	40%	60%	80%	100%
V_Q to be managed through infiltration best management practices	100%	80%	60%	40%	20%	0%
Practice storage volume required to manage V_Q not managed through disconnection	42 CF	34 CF	26 CF	18 CF	10 CF	0 CF

Source: Georgia Stormwater Management Manual
Rooftop Disconnection Compensation Storage Volume Requirement
(Per Disconnection)

Post-construction Soil Quality Restoration

To achieve targeted soil organic matter content:

$$CR = D (X) \frac{SBD (SOM\% - FOM\%)}{SBD (SOM\% - FOM\%) - CBD (COM\% - FOM\%)}$$

Where:

CR = Compost application rate (inches)

D = Depth of incorporation (inches)

SBD = Soil bulk density (lb/cubic yard dry weight) *

SOM% = Initial soil organic matter (%)

FOM% = Final target soil organic matter (%)

CBD = Compost bulk density (lb/cubic yard dry weight) #

COM% = Compost organic matter (%)

*To convert soil bulk density in g/cm³ units to lb/yard, multiply by 1697

To convert compost bulk density from lbs/ yard "as is" to lbs./yard dry weight, multiply by solids content

Vegetated Filter Strip

2. Calculate peak flow

$$q = (1.486/n)(A)(R^{0.667})(S^{0.5}) \text{ where:}$$

Where:

q = Design runoff flow rate (cfs)

n = Manning's coefficient (dimensionless, i.e. n = .25)

A = Cross-sectional area (ft²)

R = Hydraulic radius (ft)

S = Longitudinal slope (ft/ft)

3. The design flow depth should be limited to 0.5 inches to maintain sheet flow. For a wide, shallow channel the hydraulic radius is approximately equal to depth (y).
4. Manning's roughness coefficient (n) should be selected on the basis of vegetative species and density. A roughness coefficient of approximately 0.25 to 0.30 is often appropriate for sheet flow through a filter (USDA-SCS, 1984). When design flow has been established the continuity and Manning's equation can be used to calculate width (perpendicular to flow).
5. Length rule of thumbs include:
 - a. Use the same length of vegetated strip as contributing impervious area.
 - b. The width of the strip (perpendicular to flow) should be a minimum of 20 feet. The length of the strip should be a minimum of 50 to 75 feet with an increase of 4 feet for every one percent slope on the strip.

Wet Pond

The area required for a wet pond is generally 1 to 3 percent of its drainage area. Wet ponds should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events. Pond surface area, as a percent of the tributary drainage area and percent of total imperviousness within the drainage area:

Land Use / Description / Management	Total Impervious (%)	Permanent Pool Surface Area (% of Watershed)
Residential		
<2.0 units/acre (>1/2 acre lots)	8 - 28	0.7
2.0 – 6.0 units / acre	28 – 41	0.8
>6.0 units/acre (high density)	41 – 68	1.0
Office park / Institutional / Warehouse	<60	1.6
(Non-retail related business, multi-storied buildings, usually more lawn/landscaping not heavily traveled, no outdoor storage/manufacturing_	60 – 80	1.8
	>80	2.0
Shopping / Manufacturing / Storage	<60	1.8
(Large heavily used outdoor parking areas, material storage or manufacturing operations.)	60 – 80	2.1
	>80	2.4
Parks / Open Space / Woodland / Cemeteries	0 – 12	0.6
Highways / Freeways (includes right of way area)		
Typically grass banks / conveyance	<60	1.4
Mixture of grass and curb/gutter	60 – 90	2.1
Typically curb/gutter conveyance	>90	2.8

The Wisconsin Stormwater Manual: Wet Detention Basins (G3691-4)

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