Waukesha County Stormwater Workshop

Vegetated Swale
Tech Standard 1005

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SEH

Vegetated Swale Tech Std. 1005

Brief Overview of Tech Std.

Applications

Questions

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

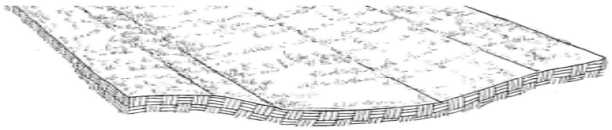
CONSERVATION PRACTICE STANDARD

VEGETATED SWALE

CODE 1005

I. DEFINITION

Vegetated swales are constructed storm water conveyance systems designed to achieve water quality and quantity benefits.



II. PURPOSES

The purposes of this practice are to filter and trap pollutants, improve water quality, attenuate peak flow, and/or promote infiltration while limiting groundwater contamination.

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USGS & WDNR research found excellent TSS and Phosphorus reductions in roadside swales

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III. CONDITIONS WHERE PRACTICE APPLIES

This standard applies to new vegetated swales. Refer to WDNR Guidance[1] for evaluation of existing swale systems. Swales are intended to treat relatively flat drainage areas with contributory areas generally less than 5 acres. Swales are not suitable in areas of steep longitudinal slope or areas with erodible soils without measures to reduce flow velocities and protect against erosion.

Vegetated swales are best suited for use:

A. In low- to medium-density residential areas with 7 units per acre or fewer;

B. In non-residential areas where infiltration of runoff is allowable under ch. NR 151, Wis. Adm. Code;

C. Along roads and drainage easements;

D. In meeting the swale treatment option in chs. NR 151 (subchapter IV, Transportation Facility Performance Standards), Wis. Adm. Code;

E. With other control practices, such as filter strips, wet detention ponds, and bioretention devices.

IV. FEDERAL, STATE, AND LOCAL LAWS

Users of this standard shall be aware of potentially applicable Federal, State, and local laws, rules, regulations, or permit requirements governing vegetated swales. This standard does not contain the text of Federal, State, or local laws.

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[1] *See most current modeling guidance for municipalities at http://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html*

Conservation Practice Standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your local WDNR office or the Standards Oversight council office in Madison, WI at (608) 441-2677.

WDNR
September 2016

- Updated to better address use in infiltration practices
- Intended for NEW swales (does not apply to MS4 modeling of existing swales and WDNR guidance)

Applications

- Meeting Infiltration Standards (incl. MEP)
- Pretreatment
- Water quality

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V. CRITERIA

Vegetated swales may be used independently or as a component of a storm water conveyance/storage system, and in either case shall be designed in accordance with the following:

A. **Site Assessment**

1. To receive credit toward meeting NR 151 performance standards or Total Maximum Daily Load (TMDL) allocations, conduct and document a site assessment in accordance with WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002).
2. For transportation projects (III.D) not required to meet NR 151 performance standards or TMDL allocations, conduct a site assessment of sufficient detail to establish site-specific design factors, including but not limited to soil types and depth to seasonal high groundwater.

B. **Site Layout –** In the site layout, identify vegetated swale location in relation to and in consideration of buildings, water supply wells, karst geology, lot boundaries, site topography, drainage patterns, and existing or proposed public rights-of-way, easements, as well as other environmental and regulatory items of concern. Chapter NR 151 Wis. Adm. Code specifies required minimum separation distances.

1. If a swale accepts runoff from more than one property, locate the swale in a permanent legally-established drainage easement granting access for maintenance, or in a public right-of-way.
2. Do not *hydraulically connect*[2] swales to foundations and do not locate swales where they cause negative impacts to structures.
3. Do not locate swales such that overflow from the swale could cause flooding of existing or proposed buildings, roads, or adjacent properties during storm events (refer to applicable regulatory requirements for drainage design).
4. Identify how and where runoff from each drainage area will enter the swale, either as *sheet flow* from the side of the swale, or from a concentrated source such as a pipe or curb cut. Describe the flow path of runoff from source areas through pre-treatment devices and into swales. Examples include:
   a. Sheet flow from road surface to road shoulder, to *vegetated filter strip* for pre-treatment prior to a vegetated swale.
   b. Upstream pre-treatment device, such as a wet detention pond, discharging through a pipe into a vegetated swale.
5. If swales are located such that the bottom of the swale is at or below the seasonally high groundwater level, set the infiltration rate for that portion of the swale to zero in the model.
6. In site plans, identify which swales are designed in accordance with this Standard.

C. **Modeling Parameters –** Use an *approved model* to quantify infiltration volume and/or pollutant load reduction provided by vegetated swales. The swales used in the models are those that meet the criteria of this standard. When modeling, do not include segments of the swale that do not meet velocity and depth requirements in section V.D. When modeling, do not combine swale segments that have significantly different flow depths, flow velocities, or infiltration rates unless the most conservative values are applied to all segments (steepest slope, narrowest bottom width, lowest infiltration rate, etc.). The modeling parameters are defined below.

1. Average swale length to outlet (feet) is used if the analysis incorporates particulate pollutant reductions due to filtering or settling.
   a. If a swale conveys runoff from an upstream point source to a downstream discharge point with little additional runoff added to the swale between the upstream and downstream points, the 'average swale length to outlet' is defined as the total swale length.

[2] *Words in the standard that are shown in italics are described in Definitions Section IX. The words are italicized the first time they are used in this text.*

   b. If a swale network conveys runoff from a drainage area with multiple defined point source inputs or sheet flow, then the 'average swale length to outlet' is defined as the total of half of each swale segment length in the drainage area served by swales divided by the number of swale segment lengths.

$$SL_{avg} = [(SS_1/2) + (SS_2/2) + \ldots + (SS_n/2)] / n$$

Where:

SL_{avg} = Average Swale Length to Outlet (feet)

SS_n = Swale Segment Length

n = Number of Swale Segment Lengths

2. *Design infiltration rate* (inches/hour) is the dynamic infiltration rate of the swale (one-half of the static infiltration rate to account for flowing water). See Section V.I.4. for equation.
3. Rainfall (inches) data that is used in the analysis shall be appropriate for the site as determined by the *administering authority*.
4. Total swale length (feet) is the total length of all swales in the drainage area developed in accordance with this standard. Exclude culvert lengths from total swale length.
5. Swale densities (feet/acre) are the total swale length divided by the treated drainage area. Calculate swale densities for each drainage area.
6. Swale geometry includes side slopes, longitudinal slopes, and bottom width (V.E.) of the typical swale in the drainage area being analyzed. Swales with significant variations in width, longitudinal slope, bottom width, and/or drainage area along their length should be divided into segments and modeled in series to account for these variations.
7. Swale retardance factor describes the type and height of the grass which is then used to determine the Manning's *n* value used in the equations provided in HEC-15 (September 2005) and as extended by Kirby and others (2005). Vegetated swales typically have a retardance factor represented by Retardance Class C or D.
8. Total Tributary Drainage Area (acres) is the drainage area served by the swale including the area of the swale.
9. Vegetation height (inches) is the typical height of vegetation in the swale. Pollutant reduction varies with the vegetation height, type, and density.

D. **Velocity and Depth** – The maximum velocity of runoff into and through a vegetated swale shall not cause the swale system to become unstable (such as through erosion, sediment resuspension, scour, etc.), and shall allow adequate residence time for infiltration.

1. For the 2-year, 24-hour design storm, do not exceed 1.5 feet per second peak flow velocity, and do not exceed a 12-inch flow depth. For design storms greater than the 2-year, 24-hour, velocities shall be non-erosive for finished grade soil with *established vegetation*.
2. Select Manning's roughness coefficients, "*n*", consistent with the type of vegetation, mowing height, and depth of flow as determined using HEC-15. Attachment 1 illustrates the variation in Manning's *n* values for various flow depths.
3. If allowed by the regulatory authority, install ditch checks as necessary to reduce velocities, extend detention time, or retain a design volume. Refer to WDNR Conservation Practice Standard "Ditch Checks" (1062) for design requirements.
4. Design ditch checks so standing water drains within 24 hours after a rainfall/runoff event. If using wet-tolerant vegetation, standing water must drain within 48 hours of the rainfall/runoff event.

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wale Geometry[3]

Design swales with side slopes no steeper than three horizontal to one vertical (3:1) for trapezoidal or triangular swale cross sections, except for roadways, where a slope as steep as 2.5:1 is allowed because the ratio of contributing drainage area from highways to swale length is typically low. Use flatter side slopes if possible to reduce erosion and increase infiltration.

Design the bottom width of swales with trapezoidal cross section to be no more than 8 feet wide to minimize channelization. If widths greater than 8 feet are needed, use a triangular cross-section with shallow side slopes (as flat as 20:1) with appropriate erosion control matting (refer to WDNR Conservation Practice Standard "Channel erosion mat" (1053)), or length-wise dividers so that the maximum bottom width of any given cell is 8 feet.

Design the longitudinal slope of the swale to be between 0.5% and 4%. Slopes less than 1% with infiltration rates below 0.13 inches/hour must be planted with wet-tolerant vegetation. Ditch checks may be used to mitigate for steeper slopes (refer to WDNR Conservation Practice Standard "Ditch Checks" (1062) for design requirements).

egetation

Plant swales with native vegetation or turf grass.

Provide site-specific planting information with project plans and specifications for establishment of *dense vegetation*.

Use a companion or cover crop if needed to establish native vegetation. Care should be taken with proper selection of companion or cover crop since many seed mixes are already formulated to address this issue.

Select vegetation that is tolerant of road salt and wetness, depending on swale location.

Install a planting medium that can support the selected vegetation.

To maintain typical swale vegetation, design swales to drain and to have no standing water within 24 hours after a rainfall/runoff event. If sump pump discharges to a swale are expected, use wet-tolerant vegetation. If wet-tolerant vegetation is established, standing water must drain within 48 hours of the rainfall/runoff event.

onstruction

Prepare a construction erosion and sediment control plan.

Where swales are proposed in filled areas, specify in the plans that fill used in the swale area is a soil type consistent with the infiltration rate assumed in the modeling.

If possible, construct swales off-line. Bring swales on-line after the vegetation is established and the contributing watersheds are fully stabilized. The swale shall be brought on-line when the area draining to the basin has achieved 90% *build out* of all lots in any of the first 3 years or 75% build out in any subsequent year. By 5 years from the start of construction in the drainage area, all vegetated swales shall be brought on-line.

Where swales cannot be constructed off-line, such as in the case of a road ditch or construction conveyance channel that is intended to serve as an infiltration practice post-construction, follow one of these approaches:

a. Construct and stabilize the swale as early in the construction process as possible to allow the vegetation to become established before receiving large quantities of runoff. Install and maintain effective erosion and sediment controls to prevent swales from receiving construction site sediment, which is difficult to remove from an established swale without destroying the vegetation (refer to WDNR Conservation Practice Standards "Channel Erosion Mat" (1053) and "Seeding for Construction Site Erosion Control" (1059) for further guidance).

standard does not set forth criteria for the analysis of site hydrology, system hydraulic analysis for large flows, or channel ility. See References, Section X.

b. If grading plan provides sufficient elevation, temporarily leave swales one foot above finished grade to protect the infiltration capacity. Excavate to final grade once the site is stabilized. Protect and vegetate the swale as specified in V.G.4.c. below.

c. Construct the swales as part of the overall grading plan, but do not finish the swales until the rest of the construction is completed and the contributing watershed has been stabilized by following these steps:

i. Stabilize adjacent construction areas. After the tributary areas are stabilized, remove any sediment that entered the swale during construction.

ii. Stabilize the swale following compaction mitigation or addition of necessary soil amendments.

iii. If the swale infiltration capacity has been reduced due to silt or clay sediment, excavate the top 1 foot of soil and replace with *engineered soils* or appropriate native soils that provide infiltration characteristics to meet the modeling requirements.

iv. Refer to WDNR Conservation Practice Standards "Channel Erosion Mat" (1053), "Mulching for Construction Sites" (1058), and "Seeding for Construction Site Erosion Control" (1059).

5. During construction there may be a delay between the initial road construction and installation of utilities outside of the swales. To address compaction and sediment deposition from utility installation, follow one of these approaches:

a. Complete swale construction immediately following road completion, and then protect the swales as aggressively as possible during utility installation, using construction fencing, biologs, etc.

b. Stabilize the swales following road construction using topsoil, temporary seeding, and erosion control matting (refer to WDNR Conservation Practice Standards "Channel Erosion Mat" (1053) and "Seeding for Construction Site Erosion Control" (1059) for further guidance). Following utility installation, complete the swale stabilization. This may entail sediment removal, compaction mitigation, soil amendments, installing erosion control matting a second time, and seeding with the permanent seed mix.

c. Avoid placing utility easements within the swale boundary.

6. To address swale compaction, use one of the following options:

a. Avoid swale compaction during and after construction. Keep vehicles and equipment with ground pressure equal to or greater than 5 pounds per square inch (PSI) out of swales at all times.

b. Mitigate swale compaction by one or more of the following methods:

i. Use a chisel plow or rotary tillage device, to incorporate four inches of compost per WDNR Specification "S100 Compost," to a depth of 12 inches below the surface. Keep vehicles and equipment with ground pressure equal to or greater than 5 PSI out of swales after mitigation is completed. Refer to Section V.I. to determine appropriate infiltration rate.

ii. After topsoil placement, *subsoil* (deep till) the bottom of the swale to a depth of 20 inches below the surface to loosen the soil and mix soil layers. See definition of "subsoil" for more detail. Keep vehicles and equipment with ground pressure equal to or greater than 5 PSI out of swales after mitigation is completed. Refer to Section V.I. to determine appropriate infiltration rate.

c. If swale compaction is not avoided or mitigated as described in items V.G.6.a or V.G.6.b, refer to Sections V.I.3 and V.I.4 (also see example in Attachment 6) to determine the appropriate infiltration rate.

H. **Pre-treatment –** As with other infiltration devices, vegetated swales require pre-treatment of storm water to remove sediment from source areas listed in s. NR 151.124(7) Wis. Adm. Code. Pre-treatment is intended to prevent clogging of the infiltration system and protect groundwater. For vegetated swales,

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many contaminants are mitigated in the soil column, and vegetation prevents clogging. Therefore, the pre-treatment options below are intended to protect swale vegetation, mainly to allow for settling of larger particles that could smother vegetation.

The area of any pre-treatment practice does not count toward the *effective infiltration area*. For vegetated swales, pre-treatment can be accomplished through the use of the following practices (see Attachment 2 for pre-treatment diagrams):

1. *Vegetated Filter Strip* – Vegetated filter strips can pre-treat sheet flow. Use level spreaders, grading, and shaping to convert concentrated flow to sheet flow before reaching filter strips. Design vegetated filter strips for a maximum flow depth of ½ inch, and a slope not steeper than 3:1, except for roadways, where a slope as steep as 2.5:1 is allowed because the ratio of contributing drainage area from highways to swale length is typically low. Use flatter side slopes if possible to reduce erosion and increase infiltration. Determine if the filter strips satisfy the following pre-treatment requirements:
   a. Ten or more feet of filter strip flow length is sufficient for pre-treatment of sheet flow runoff into swales.
   b. If there is less than five feet of filter strip flow length, the filter strip does not count toward pre-treatment, and an alternate pre-treatment method must be used.
   c. For filter strip flow length five feet or greater, but less than ten feet, use the procedure in Attachment 3 to account for the deficient filter strip flow length.
   d. Filter strips are not an adequate pre-treatment measure when receiving runoff from more than 100 feet of flow from impervious and/or non-vegetated areas.
2. Vegetated Swale – Vegetated swales can pre-treat concentrated flow from point sources such as pipes and curb cuts. When calculating the effective infiltration area, subtract the pre-treatment swale area (multiply 80 feet of swale length by the swale wetted perimeter (see Attachment 4)) from the total infiltration area.[4]
3. *Sedimentation Device* – Sedimentation devices can accept sheet flow and/or concentrated flow for pre-treatment. Design the sedimentation device to capture at least a 100-micron particle size, which equates to approximately 10% *NURP* total suspended solids reduction.
4. Other Device – To the extent technically and economically feasible, minimize the level of pollutants infiltrating to groundwater though use of pre-treatment devices for the pollutants of concern.

Infiltration – To meet the infiltration performance standards of s. NR 151.124 Wis. Adm. Code, a swale must meet the following:

1. Effective Infiltration Area – Use the following equation to calculate the area that can be counted toward requirements in s. NR 151.124 Wis. Adm. Code :

$$A = P * L$$

Where:

A = effective infiltration area in square feet

P = wetted perimeter (at one-inch flow depth) in feet

L = length of vegetated swale in feet

See Attachment 4 for calculation methodology. Pre-treatment areas do not count toward the effective infiltration area. Vegetated swales receiving runoff from source areas identified in s. NR 151.124(7) Wis. Adm. Code cannot be counted toward the effective infiltration area unless the water is effectively pre-treated prior to entering the swale.

[4] The 80-foot length of swale is based on a Stokes' law calculation using approximately 1 foot flow depth, 1.5 feet per second flow velocity, and 100-micron particle size, and applies for each drainage area of 5 acres or smaller.

2. Infiltration Volume – Use an approved model to quantify the volume of water infiltrated and the resulting pollutant reduction to surface water.
3. Static Infiltration Rate – The design infiltration rate is a function of the static infiltration rate. Use one of these approaches to determine the static infiltration rate:
   a. Use WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002) to determine static infiltration rate; except that if conducting site-specific infiltration tests at design bottom elevation of the swale, the WDNR modified (2-hour) double-ring infiltrometer test[5] may be used.
   b. If sod grown in muck soils is used for vegetated swales, use a static infiltration rate of no more than 0.05 inches per hour.
   c. If imported topsoil is used, use the infiltration rate commiserate with the textural class of the topsoil and use the WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002).
   d. If incidental soil compaction of a swale will not be addressed as described in V.G.6.a or V.G.6.b, determine the static infiltration rate as specified in V.I.3.a. and apply the appropriate multiplier from Table 1 below (see example in Attachment 6):

Table 1. Static Infiltration Rate Multiplier for Incidental Soil Compaction

Compacted Soil Type		Multiplier
Sand	Coarse Sand or Coarser	0.9
	Loamy Coarse Sand	
	Sand	
	Loamy Sand	
Loam	Sandy Loam	0.4
	Loam	
	Silt Loam	
	Sandy Clay Loam	
Clay	Clay Loam	0.2
	Silty Clay Loam	
	Sandy Clay	
	Silty Clay	
	Clay	

[5] For more detail regarding the WDNR modified (2-hour) double-ring infiltrometer test procedure, see "Process to Assess and Model Grass Swales" (WDNR 2010) http://dnr.wi.gov/topic/stormwater/documents/GrassSwales080424.pdf

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sign Infiltration Rate – Use the following equation to calculate the design infiltration rate for ales:

$$K_{swale} = ½ * K_{static}$$

ere:

K_{swale} = design infiltration rate in inches per hour

K_{static} = static infiltration rate in inches per hour determined in accordance with WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002)

½ = safety factor to account for the dynamic nature of a swale through which water is moving, compared to the static nature of an infiltration test in which water is ponded

DERATIONS

ng considerations are intended to enhance the use of this practice, or to address special cases rise in the implementation of the practice.

s should be designed to have hydraulic capacities that meet applicable local government or state requirements for conveying runoff from large storms, and they should also be designed as part *jor storm water management system* as defined in this standard.

mber and length of swales is dictated by the topography and amounts of runoff from the uting area. For a given depth of flow, the width of a swale depends on the rate and velocity of rough the swale.

shment of deep-rooted vegetation will enhance infiltration.

lrains may be added to swales with less than 1% slope to reduce the duration of standing water. et-tolerant vegetation if the drawdown time exceeds 24 hours. If using underdrains, refer to Conservation Practice Standard "Bioretention for Infiltration" (1004) for guidance. Model areas derdrains separately to determine appropriate surface water pollutant removal credit.

performance may change over time due to site-specific conditions, such as vegetation teristics, maintenance, sediment deposition, compaction, etc. Follow the most recent WDNR ce that specifically addresses evaluation of existing swales.

ct soil tests to determine the amount of fertilizer needed to establish or maintain dense tion.

tion hoes, light equipment with turf-type tires, marsh equipment, or wide-track loaders that have pressure equal to or less than 5 PSI should be used to construct swales and minimize ction. Heavier equipment may require compaction mitigation.

education is recommended to inform local residents of the swales' purpose and to discourage g of leaves or parking within swales or on the edge of swales.

ted swales are not suitable for treating chlorides. Chloride de-icer use within source areas y to a swale can be reduced or eliminated by using alternative de-icers or clean sand.

ect groundwater, if site information indicates compliance with a preventative action limit (in ance with ch. NR 140 Wis. Adm. Code) is not achievable, a vegetated swale may not be installed be modified to prevent infiltration to the maximum extent practicable.

S AND SPECIFICATIONS

specifications shall be prepared in accordance with the criteria of this standard and shall describe ments for applying the practice to achieve its intended use. Plans shall specify the materials, n processes, locations, size and elevations of all components of the practice to allow for of construction upon completion.

VIII. OPERATION AND MAINTENANCE

Prepare a site-specific annual inspection and maintenance plan for the swales that addresses the following:

A. Identify the responsible party.

B. Limit off-street parking or other activities that may cause rutting or soil compaction in swales and repair as needed.

C. Inspect swales annually to detect and remedy nuisance conditions such as standing water, weeds, woody growth, and trash dumping. Limit the use of pesticides and fertilizer if swale is used for water quality control.

D. State the proper vegetation type and design height for dense vegetation in the maintenance plan, and maintain the specified height when mowing or cutting.

E. Remove sediment when infiltration rates are impeded, sediment accumulation is visible, or if standing water exists for 48 hours after a rainfall/runoff event. Avoid compaction of the soil in the swale during the sediment removal process. After sediment removal, repair any damaged or eroded areas by filling with topsoil that meets appropriate infiltration requirements. If compaction occurs, restore the swale infiltration capacity by mitigating for compaction as described in V.G.6.b. Mitigation practices can include subsoiling or chisel plowing as described in V.G.6.b. Reseed as needed to reestablish vegetation.

F. Implement erosion control measures if erosion during construction or maintenance becomes severe enough to prevent establishment of vegetation. Refer to WDNR Conservation Practice Standards "Channel Erosion Mat" (1053), "Mulching for Construction Sites" (1058), and "Seeding for Construction Site Erosion Control" (1059) for further guidance.

IX. DEFINITIONS

Administering Authority (V.C.3.): State and/or local units of government with stormwater management regulatory authority.

Approved Model (V.C.): A computer model with an infiltration component that adequately accounts for the hydraulic nature of swales and that has been approved by the applicable regulatory authority. Examples include SLAMM, P-8, and RECARGA.

Build Out (V.G.2): Build out means that the lot has been fully developed and stabilized from erosion.

Dense Vegetation (V.F.2.): A stand of 3 to 12-inch high grassy vegetation that uniformly covers at least 90% of a representative 1 square yard plot.

Design Infiltration Rate (V.C.2.): A velocity, based on soil structure and texture, at which precipitation or runoff enters and moves into or through soil. The design rate is used to size an infiltration device or system. Rates are selected to be minimal rates for the different types of soils. Selection of minimal rates will provide a robust design and maximize the longevity of the device.

Effective Infiltration Area (V.H.): The area of the infiltration system that is used to infiltrate runoff. Does not include the area used for pre-treatment.

Engineered Soil (V.G.4.c.iii.): A prescribed mixture of soil meeting the most recent version of WDNR Conservation Practice Standard "Bioretention for Infiltration" (1004) or most recent guidance regarding engineered soil.

Established Vegetation (V.D.1): A uniform perennial vegetative cover of at least 70% density.

Hydraulically Connected (V.B.2.): Two entities are considered to be hydraulically connected if a surface or subsurface link exists between them such that water is transmitted from one entity to the other.

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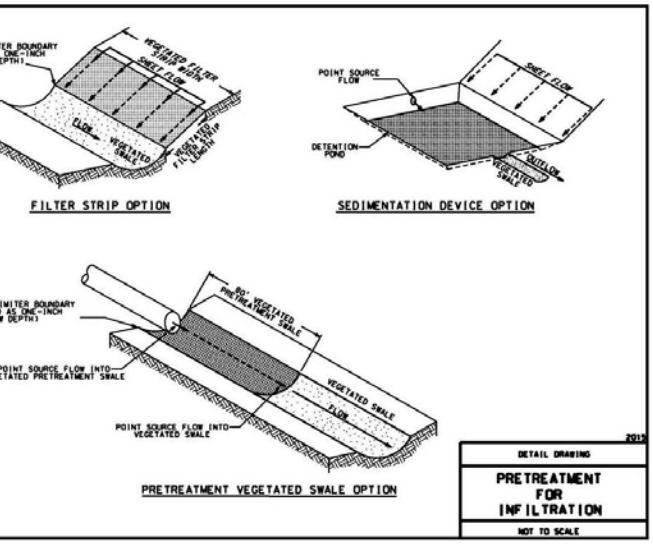
Attachment 2:

Pre-Treatment Options for Swales

Vegetated Swale (1005)



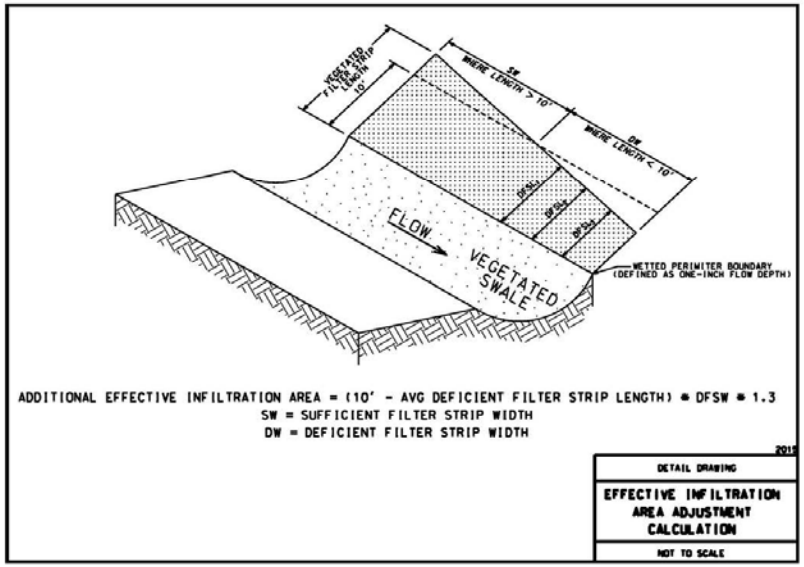
80-ft length of vegetated pretreatment swale is based on a Stokes' Law calculation using
ely 1 foot flow depth, 1.5 feet per second flow velocity, and 100-micron particle size, and applies
ainage area of 5 acres or smaller.

Attachment 3:

Deficient Filter Strip Length

Vegetated Swale (1005)

Use this method to address pre-treatment in situations where there is insufficient filter strip flow length (greater than five feet and less than ten feet).



The Additional Effective Infiltration Area (AEIA) required to compensate for using filter strips less than 10 feet (and at least 5 feet) in length can be calculated using the figure above for reference and the following steps:

1. Determine the deficient filter strip width (DFSW) in feet. This is the cumulative width of filter strip where the filter strip flow path length is less than 10 feet (but at least 5 feet).
2. Determine the average filter strip length (DFSL) in feet in the DFSW. Use a minimum of three distances within any deficient segment of filter strip. One measurement must include the shortest filter strip flow path length in the DFSW.
3. Calculate the Additional Effective Infiltration Area (AEIA) required to compensate for the deficient filter strip. Use the equation:

AEIA = (10 feet – Avg. DFSL) * DFSW * 1.3

The AEIA is the area of swale or other infiltration area that does not count toward the site's effective infiltration area. A maximum of 80 feet of swale length would not be considered "effective infiltration area" for each drainage area (up to five acres) served by swales. Filter strips are not an adequate pre-treatment measure when receiving runoff from more than 100 feet of flow from impervious and/or non-vegetated areas.

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Attachment 4:

Calculation of Effective Infiltration Area

Vegetated Swale (1005)

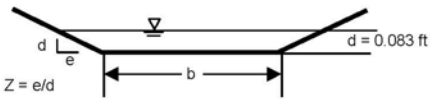
tive infiltration area as outlined in ch. NR 151 Wis. Adm. Code is defined as the area of the
system that is used to infiltrate runoff and does not include the area used for site access, berms,
atment. The area of infiltration is calculated for a swale based on the wetted perimeter of the
owever, the swale is rarely flowing at capacity under the numerous smaller rainfall events that
an average year, so the wetted perimeter at the design capacity of the swale (typically a 2-year or
torm) is not appropriate. The effective infiltration area is determined as follows:

ive Infiltration Area (ft^2) = Wetted Perimeter (ft) * Length of Vegetated Infiltration Swale (ft)

urpose of ch. NR 151 Wis. Adm. Code, the wetted perimeter will be calculated at a 1-inch (0.083
th of flow. The 1-inch depth of flow is intended to simulate the water quality volume. Wetted
can be calculated as outlined below.

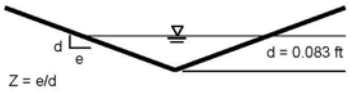
dal Channel Cross section:

Perimeter, p
$2d\,(Z^2+1)^{1/2}$



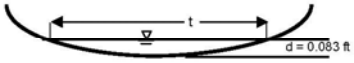
ar Channel Cross section:

Perimeter, p
$(Z^2+1)^{1/2}$



c Channel Cross section

erimeter, p	Top Width of flow, t	Cross-sectional Area of flow, a
$d^2) / (3\,t)$	t = a / (0.67 d)	a = 2/3 (t d)



Attachment 6:

Example

Infiltration Rates for Compacted Soils

Vegetated Swale (1005)

If an infiltration rate is needed for modeling a proposed vegetated swale in which incidental soil compaction will not be avoided or mitigated in accordance with V.G.6.a or V.G.6.b, follow the steps below:

1. Follow WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002) [7] to obtain an infiltration rate.

   Example: for Sandy Loam, $K_{std1002}$ *= 0.5 in/hr*

2. Select a multiplier from the table below corresponding to compacted soil type.

   Example: for Sandy Loam, ***M*** *= 0.4*

Compacted Soil Type		Multiplier
Sand	Coarse Sand or Coarser	0.9
	Loamy Coarse Sand	
	Sand	
	Loamy Sand	
Loam	Sandy Loam	0.4
	Loam	
	Silt Loam	
	Sandy Clay Loam	
Clay	Clay Loam	0.2
	Silty Clay Loam	
	Sandy Clay	
	Silty Clay	
	Clay	

3. Apply the multiplier from step 2 to the infiltration rate obtained in step 1. This is the static infiltration rate adjusted for incidental compaction.

   Example: $K_{static} = M * K_{std1002}$

   $K_{static} = 0.4 * 0.5$ *in/hr*

4. Follow V.I.4 to account for infiltration of flowing water (divide the adjusted infiltration rate from step 3 by two). This is the design/dynamic infiltration rate to use in post-construction storm water modeling and calculations.

   Example: $K_{swale} = ½ * K_{static}$

   $K_{swale} = ½ * (0.4 * 0.5$ *in/hr)*

   $K_{swale} = 0.1$ *in/hr*

[7] *If conducting site-specific infiltration tests at design bottom elevation of the swale, the WDNR modified (2-hour) double-ring infiltrometer test may be used.*

Vegetated Swale Tech Std. 1005

Attachment 7:

Technical Note for Infiltration in Compacted Soils

Vegetated Swale (1005)

The table below documents the approach used for developing multipliers for unmitigated incidental compaction in swales. This approach is intended to serve as a placeholder until the WDNR Conservation Practice Standard "Site Evaluation for Infiltration" is revised to address infiltration rates in compacted soils.

Soil Type[8]		Infiltration Rate, inches/hour		Ratio	Compaction Multiplier[9]
		Table 2 Site Evaluation for Infiltration 1002[10]	Pitt Compaction Measurements[11](*) or Extrapolation		
Sand	Coarse Sand or Coarser	3.6	3.26	0.91	0.9
	Loamy Coarse Sand	3.6	3.26	0.91	
	Sand	3.6	3.26*	0.91	
	Loamy Sand	1.63	1.467	0.90	
Loam	Sandy Loam	0.5	0.22*	0.44	0.4
	Loam	0.24	0.11	0.46	
	Silt Loam	0.13	0.014*	0.11	
	Sandy Clay Loam	0.11	0.0242	0.22	
Clay	Clay Loam	0.03	0.0066*	0.22	0.2
	Silty Clay Loam	0.04[12]	0.01	0.23	
	Sandy Clay	0.04	0.01	0.25	
	Silty Clay	0.07	0.002	0.03	
	Clay	0.07	<0.002*	0.03	

[8] *Use sandy loam infiltration rates for fine sand, loamy fine sand, very fine sand, and loamy fine sand soil textures.*

[9] *Multipliers were developed from a ratio of the compacted soil infiltration rates from the Pitt, R. et al 2003 research and WDNR Conservation Practice Standards "Site Evaluation for Infiltration" (1002) Table 2 infiltration rates, then simplified into three categories.*

[10] *Infiltration rates represent the lowest value for each textural class presented in Table 2 of Rawls, 1998.*

[11] *Compacted soils data from Table 8 (Standard Compaction) of Pitt, R. et al 2003.*

[12] *Infiltration rate in Conservation Practice Standards "Site Evaluation for Infiltration" (1002) Table 2 is an average based on Rawls, 1982 and Clapp & Hornberger, 1978.*

Vegetated Swales Tech Std 1005

Questions?