

BMP 6.4.8: Vegetated Swale



A Vegetated Swale is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. In steeper slope situations, check dams may be used to further enhance attenuation and infiltration opportunities.

<ul style="list-style-type: none"> ▪ Plant dense, low-growing native vegetation that is water-resistant, drought and salt tolerant, providing substantial pollutant removal capabilities ▪ Longitudinal slopes range from 1 to 6% ▪ Side slopes range from 3:1 to 5:1 ▪ Bottom width of 2 to 8 feet ▪ Check-dams can provide limited detention storage, as well as enhanced volume control through infiltration. Care must be taken to prevent erosion around the dam ▪ Convey the 10-year storm event with a minimum of 6 inches of freeboard ▪ Designed for non-erosive velocities up to the 10-year storm event ▪ Design to aesthetically fit into the landscape, where possible ▪ Significantly slow the rate of runoff conveyance compared to pipes 	<p style="text-align: center;"><u>Potential Applications</u></p> <p style="text-align: center;">Residential: Commercial: Yes Yes Ultra Urban: Limited Industrial: Yes Yes Retrofit: Yes Highway/Road:</p> <hr/> <p style="text-align: center;"><u>Stormwater Functions</u></p> <p style="text-align: center;">Volume Reduction: Low/Med. Recharge: Low/Med. Peak Rate Control: Med./High Water Quality: Med./High</p> <hr/> <p style="text-align: center;"><u>Water Quality Functions</u></p> <p style="text-align: center;">TSS: 50% TP: 50% NO3: 20%</p>
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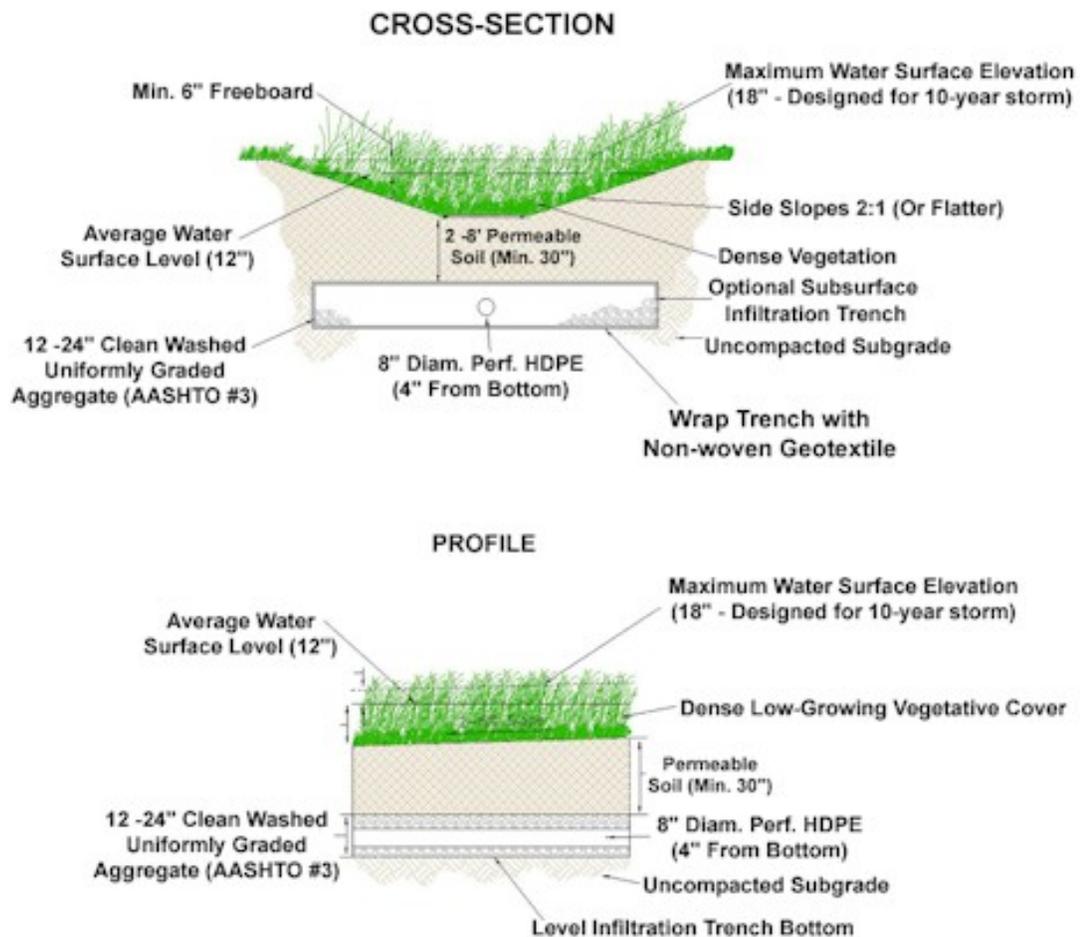
Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed whenever infiltration of runoff is desired, see Appendix C

Description

Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated Swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems, while providing partially treated (pretreatment) and partially distributed stormwater flows to subsequent BMPs. Swales are often heavily vegetated with a dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential. The various pollutant removal mechanisms of a swale include: sedimentary filtering by the swale vegetation (both on side slopes and on bottom), filtering through a subsoil matrix, and/or infiltration into the underlying soils with the full array of infiltration-oriented pollutant removal mechanisms.

A Vegetated Swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (See BMP 6.4.4 Infiltration Trench for further design guidelines).



A major concern when designing Vegetated Swales is to make certain that excessive stormwater flows, slope, and other factors do not combine to produce erosive flows, which exceed the Vegetated Swale capabilities. Use of check dams or turf reinforcement matting (TRM) can enhance swale performance in some situations.

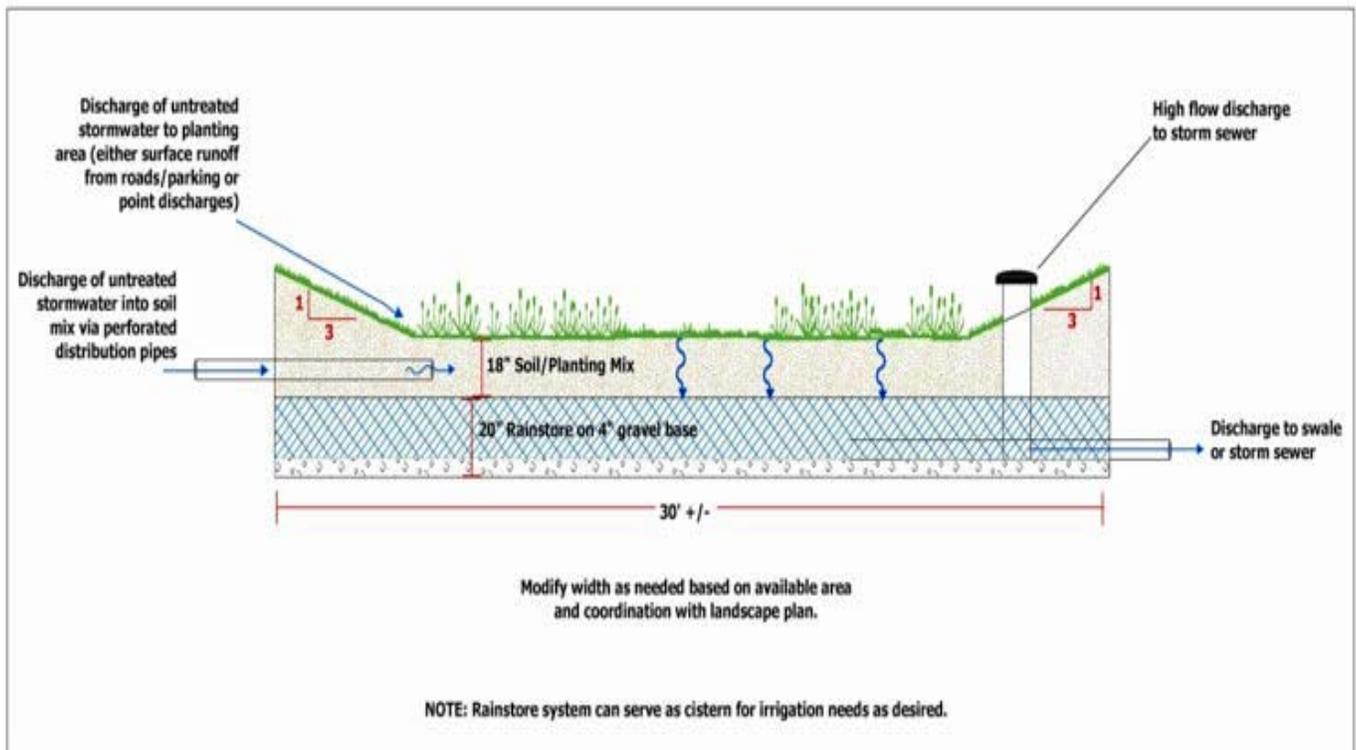
A key feature of vegetated swale design is that swales can be well integrated into the landscape character of the surrounding area. A vegetated swale can often enhance the aesthetic value of a site through the selection of appropriate native vegetation. Swales may also discreetly blend in with landscaping features, especially when adjacent to roads.



Variations

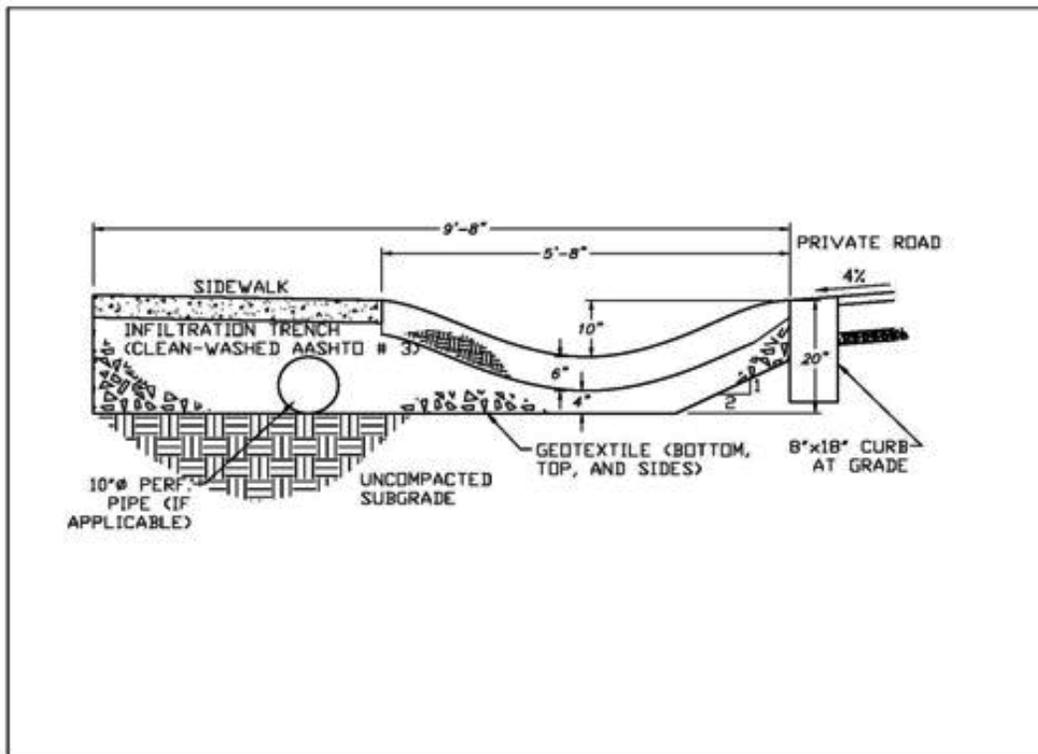
Vegetated Swale with Infiltration Trench

This option includes a 12 to 24 inch aggregate bed or trench, wrapped in a nonwoven geotextile (See BMP 6.4.4 Infiltration Trench for further design guidelines). This addition of an aggregate bed or trench substantially increases volume control and water quality performance although costs also are increased. Soil Testing and Infiltration Protocols in Appendix C should be followed.



Vegetated Swales with Infiltration Trenches are best fitted for milder sloped swales where the addition of the aggregate bed system is recommended to make sure that the maximum allowable ponding time of 72 hours is not exceeded. This aggregate bed system should consist of at least 12 inches of

uniformly graded aggregate. Ideally, the underdrain system shall be designed like an infiltration trench. The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the required storage of the 1-inch storm event.



Grass Swale

Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than swales with longer and denser vegetation. However, they provide far less infiltration and pollutant removal opportunities. Grass swales are to be used only as pretreatment for other structural BMPs. Design of grass swales is often rate-based. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to reduce the rate of flow across a site.



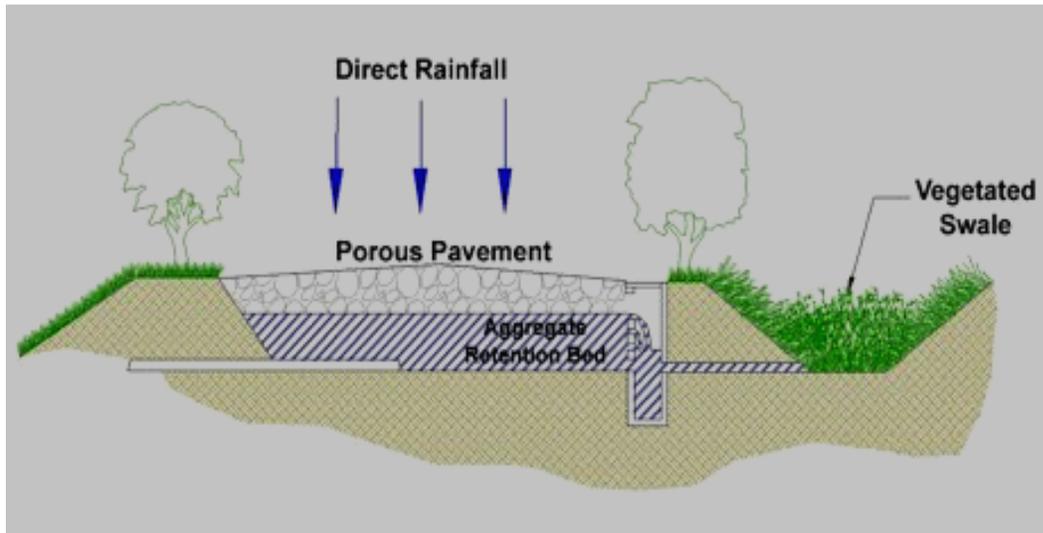
Wet Swales

Wet swales are essentially linear wetland cells. Their design often incorporates shallow, permanent pools or marshy conditions that can sustain wetland vegetation, which in turn provides potentially high pollutant removal. A high water table or poorly drained soils are a prerequisite for wet swales. The drawback with wet swales, at least in



residential or commercial settings, is that they may promote mosquito breeding in the shallow standing water (follow additional guidance under Constructed Wetland for reducing mosquito population). Infiltration is minimal if water remains for extended periods.

Applications



- **Parking**
- **Commercial and light industrial facilities**
- **Roads and highways**
- **Residential developments**
- **Pretreatment for volume-based BMPs**
- **Alternative to curb/gutter and storm sewer**

Design Considerations

1. Vegetated Swales are sized to temporarily store and infiltrate the 1-inch storm event, while providing conveyance for up to the 10-year storm with freeboard; flows for up to the 10-year storm are to be accommodated without causing erosion. Swales should maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout. Six inches of freeboard is recommended for the 10-year storm. Residence times between 5 and 9 minutes are acceptable for swales without check-dams. The maximum ponding time is 48 hours, though 24 hours is more desirable (minimum of 30 minutes). Studies have shown that the maximum amount of swale filtering occurs for water depths below 6 inches. It is critical that swale vegetation not be submerged, as it could cause the vegetation to bend over with the flow. This would naturally lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

2. Longitudinal slopes between 1% and 3% are generally recommended for swales. If the topography necessitates steeper slopes, check dams or TRM's are options to reduce the energy gradient and erosion potential.
3. Check dams are recommended for vegetated swales with longitudinal slopes greater than 3%. They are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity, and promote additional filtering and settling of nutrients and other pollutants. In effect, check-dams create a series of small, temporary pools along the length of the swale, which shall drain down within a maximum of 72 hours. Swales with check-dams are much more effective at mitigating runoff quantity and quality than those without. The frequency and design of check-dams in a swale will depend on the swale length and slope, as well as the desired amount of storage/treatment volume. Care must be taken to avoid erosion around the ends of the check dams.



Check-dams shall be constructed to a height of 6 to 12 in and be regularly spaced. The following materials have been employed for check-dams: natural wood, concrete, stone, and earth. Earthen check-dams however, are typically not recommended due to their potential to erode. A weep hole(s) may be added to a check-dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep hole(s) is not subject to clogging. In the case of a stone check-dam, a better approach might be to allow low flows (2-year storm) to drain through the stone, while allowing higher flows (10-year storm) drain through a weir in the center of the dam. Flows through a stone check-dam are a function of stone size, flow depth, flow width, and flow path length through the dam. The following equation can be used to estimate the flow through a stone check dam up to 6 feet long:

$$q = h^{1.5} / (L/D + 2.5 + L^2)^{0.5}$$

where:

- q = flow rate exiting check dam (cfs/ft)
- h = flow depth (ft)
- L = length of flow (ft)
- D = average stone diameter (ft) (more uniform gradations are preferred)

For low flows, check-dam geometry and swale width are actually more influential on flow than stone size. The average flow length through a check-dam as a function of flow depth can be determined by the following equation:

$$L = (ss) \times (2d - h)$$

where:

ss = check dam side slope (maximum 2:1)

d = height of dam (ft)

h = flow depth (ft)

When swale flows overwhelm the flow-through capacity of a stone check-dam, the top of the dam shall act as a standard weir (use standard weir equation). (Though a principal spillway, 6 inches below the height of the dam, may also be required depending on flow conditions.) If the check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

4. The effectiveness of a vegetated swale is directly related to the contributing land use, the size of the drainage area, the soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. Use of natural low points in the topography may be suited for swale location, as are natural drainage courses although infiltration capability may also be reduced in these situations. The topography of a site should allow for the design of a swale with sufficiently mild slope and flow capacity. Swales are impractical in areas of extreme (very flat or steep) slopes. Of course, adequate space is needed for vegetated swales. Swales are ideal as an alternative to curbs and gutters along parking lots and along small roads in gently sloping terrain.

Siting of vegetated swales should take into account the location and function of other site features (buffers, undisturbed natural areas, etc.). Siting should also attempt to aesthetically fit the swale into the landscape as much as possible. Sharp bends in swales should be avoided.

Implementing vegetated swales is challenging when development density exceeds four dwelling units per acre, in which case the number of driveway culverts often increases to the point where swales essentially become broken-pipe systems.

Where possible, construct swales in areas of uncompacted cut. Avoid constructing side slopes in fill material. Fill slopes can be prone to erosion and/or structural damage by burrowing animals.

5. Soil Testing is required when infiltration is planned (see Appendix C).
6. Guidelines for Infiltration Systems should be met as necessary (see Appendix C).
7. Swales are typically most effective, when treating an area of 1 to 2 acres although vegetated swales can be used to treat and convey runoff from an area of 5 to 10 acres in size. Swales serving greater than 10-acre drainage areas will provide a lesser degree water quality treatment, unless special provisions are made to manage the increased flows.
8. Runoff can be directed into Vegetated Swales either as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is

included (see #6). If flow is to be directed into a swale via curb cuts, provide a 2 to 3 inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately.

9. Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially roadway runoff. However, when swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the heavier sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Pretreatment options include a vegetated filter strip, a sediment forebay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a 6-inch drop where parking lot sheet flow is directed into a swale.
10. The soil base for a vegetated swale must provide stability and adequate support for proposed vegetation. When the existing site soil is deemed unsuitable (clayey, rocky, coarse sands, etc.) to support dense vegetation, replacing with approximately 12 inches of loamy or sandy soils is recommended. In general, alkaline soils should be used to further reduce and retain metals. Swale soils should also be well-drained. If the infiltration capacity is compromised during construction, the first several feet should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth.
11. Swales are most efficient when their cross-sections are parabolic or trapezoidal in nature. Swale side slopes are best within a range of 3:1 to 5:1 and should not be greater than 2:1 for ease of maintenance and side inflow from sheet flow.
12. To ensure the filtration capacity and proper performance of swales, the bottom widths typically range from 2 to 8 feet. Wider channels are feasible only when obstructions such as berms or walls are employed to prohibit braiding or uncontrolled sub-channel formation. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.
13. Ideal swale vegetation should consist of a dense and diverse selection of close-growing, water-resistant plants whose growing season preferably corresponds to the wet season. For swales that are not part of a regularly irrigated landscaped area, drought tolerant vegetation should be considered as well. Vegetation should be selected at an early stage in the design process, with well-defined pollution control goals in mind. Selected vegetation must be able to thrive at the specific site and therefore should be chosen carefully (See Appendix B). Use of native plant species is strongly advised, as is avoidance of invasive plant species. Swale vegetation must also be salt tolerant, if winter road maintenance activities are expected to contribute salt/chlorides.

Table 6.8.1

Commonly used vegetation in swale (New Jersey BMP Manual, 2004)		
Common Name	Scientific Name	Notes
Alkali Saltgrass	<i>Puccinellia distans</i>	Cool, good for wet, saline swales
Fowl Bluegrass	<i>Poa palustris</i>	Cool, good for wet swales
Canada Bluejoint	<i>Calamagrostis canadensis</i>	Cool, good for wet swales
Creeping Bentgrass	<i>Agrostis palustris</i>	Cool, good for wet swales, salt tolerant
Red Fescue	<i>Festuca rubra</i>	Cool, not for wet swales
Redtop	<i>Agrostis gigantea</i>	Cool, good for wet swales
Rough Bluegrass	<i>Poa trivialis</i>	Cool, good for wet, shady swales
Switchgrass	<i>Panicum virgatum</i>	Warm, good for wet swales, some salt tolerance
Wildrye	<i>Elymus virginicus/rigarius</i>	Cool, good for wet, shady swales

Notes: These grasses are sod forming and can withstand frequent inundation, and are ideal for the swale or grass channel environment. A few are also salt tolerant. Cool refers to cool season grasses that grow during the colder temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot, mid summer months.

By landscaping with trees along side slopes, swales can be easily and aesthetically integrated into the overall site design without unnecessary loss of usable space. An important consideration however, is that tree plantings allow enough light to pass and sustain a dense ground cover. When the trees have reached maturity, they should provide enough shade to markedly reduce high temperatures in swale runoff.

14. Check the temporary and permanent stability of the swale using the standards outlined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual. Swales should convey either 2.75 cfs/acre or the calculated peak discharge from a 10-year storm event. The permissible velocity design method may be used for design of channel linings for bed slopes <0.10 ft/ft; use of the maximum permissible shear stress is acceptable for all bed slopes. Flow capacity, velocity, and design depth in swales are generally calculated by Manning’s equation.

Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, compost blankets, or curled wood blankets. Most vendors will provide information about the Manning’s ‘n’ value and will specify the maximum permissible velocity or allowable shear stress for the lining material.

The post-vegetation establishment capacity of the swale should also be confirmed. Permanent turf reinforcement may supersede temporary reinforcement on sites where not exceeding the maximum permissible velocity is problematic. If driveways or roads cross a swale, culvert capacity may supersede Manning’s equation for determination of design flow depth. In these cases, the culvert should be checked to establish that the backwater elevation would not exceed the banks of the swale. If the culverts are to discharge to a minimum tailwater condition, the exit velocity for the culvert should be evaluated for design conditions. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures should be implemented. The following tables list the maximum permissible shear stresses (for various channel liners) and velocities (for channels lined with vegetation) from the Pennsylvania Erosion and Sediment Pollution Control Program Manual.

Maximum Permissible Shear Stresses for Various Channel Liners

Lining Category	Lining Type	lb/ft ²
Unlined - Erodible Soils*	Silts, Fine - Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Erosion Resistant Soils**	Clay loam	0.25
	Silty Clay loam	0.18
	Sandy Clay Loam	0.10
	Loam	0.07
	Silt Loam	0.12
	Sandy Loam	0.02
	Gravelly, Stony, Channery Loam	0.05
	Stony or Channery Silt Loam	0.07
Temporary Liners	Jute	0.45
	Straw with Net	1.45
	Coir - Double Net	2.25
	Coconut Fiber - Double Net	2.25
	Curled Wood Mat	1.55
	Curled Wood - Double Net	1.75
	Curled Wood - Hi Velocity	2.00
	Synthetic Mat	2.00
Vegetative Liners	Class B	2.10
	Class C	1.00
	Class D	0.60
Riprap***	R-1	0.25
	R-2	0.50
	R-3	1.00
	R-4	2.00
	R-5	3.00
	R-6	4.00
	R-7	5.00
	R-8	8.00

- * Soils having an erodibility "K" factor greater than 0.37
- ** Soils having an erodibility "K" factor less than or equal to 0.37
- *** Permissible shear stresses based on rock at 165 lb/cuft. Adjust velocities for other rock weights used. See Table 12.

Manufacturer's shear stress values based on independent tests may be used.

xture	<5	5	4
Reed Canarygrass	5-10	4	3
Serecea Lespedeza	<5	3.5	2.5
Weeping Lovegrass			
Redtop			
Red Fescue			
Annuals	<5	3.5	2.5
Temporary cover only			
Sudangrass			

¹ Cohesive (clayey) fine grain soils and coarse grain soils with a plasticity index OF 10 TO 40 (CL, CH, SC and GC). Soils with K values less than 0.37.

² Soils with K values greater than 0.37.

³ Use velocities exceeding 5 ft/sec only where good cover and proper maintenance can be obtained.

15. Manning’s roughness coefficient, or ‘n’ value, varies with type of vegetative cover and design flow depth. Two common methods are based on design depth (see adjacent graph) and based on vegetative cover (as defined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual). Either of these can be used in design.

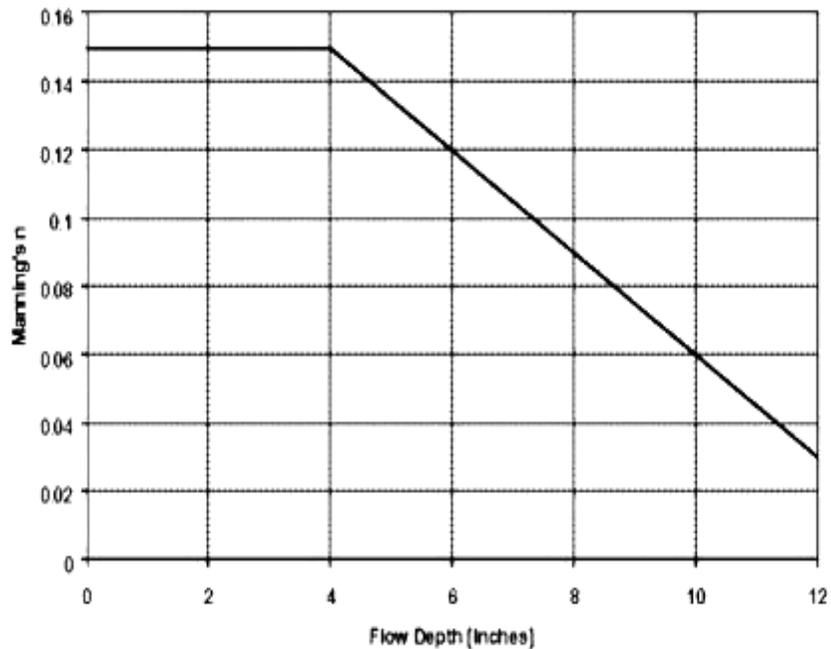


Figure D9.1 Manning’s n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

- 16. If swales are designed according to the guidelines discussed in this section, significant levels of pollutant reduction can be expected through filtration and infiltration. In a particular swale reach, runoff should be well filtered by the time it flows over a check-dam. Thus, the stabilizing stone apron on the downhill side of the check-dam may be designed as an extension of an infiltration trench. In this way, only filtered runoff will enter a subsurface infiltration trench, thereby reducing the threat of groundwater contamination by metals.
- 17. Culverts are typically used in a vegetated swale at driveway or road crossings. By oversizing culverts and their flow capacity, cold weather concerns (e.g. clogging with snow) are lessened.
- 18. Where grades limit swale slope and culvert size, trench drains may be used to cross driveways.
- 19. Swales should discharge to another structural BMP (bioretention, infiltration basin, constructed wetlands, etc.), existing stormwater infrastructure, or a stable outfall.

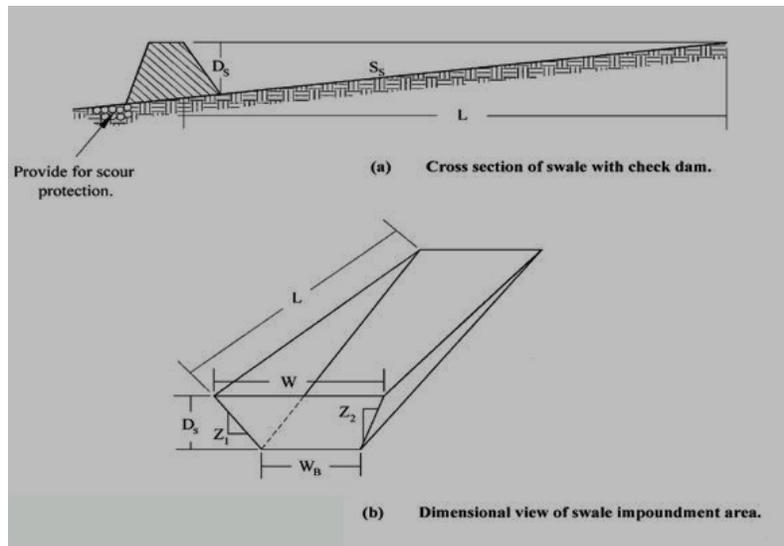
Detailed Stormwater Functions

Infiltration Area (if needed)

Volume Reduction Calculations

The volume retained behind each check-dam can be approximated from the following equation:

$$\text{Storage Volume} = 0.5 \times \text{Length of Swale Impoundment Area Per Check Dam} \times \text{Depth of Check Dam} \times (\text{Top Width of Check Dam} + \text{Bottom Width of Check Dam}) / 2$$



Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin vegetated swale construction only when the upgradient temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection’s *Erosion and Sediment Pollution Control Program Manual*, March 2000 or latest edition.)
2. Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.
3. Construct check dams, if required.
4. Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

5. Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.
6. Once all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving upland stormwater flow.
7. Follow maintenance guidelines, as discussed below.

Note: If a vegetated swale is used for runoff conveyance during construction, it should be regraded and reseeded immediately after construction and stabilization has occurred. Any damaged areas should be fully restored to ensure future functionality of the swale.

Maintenance Issues

Compared to other stormwater management measures, the required upkeep of vegetated swales is relatively low. In general, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a dense vegetative cover. Experience has proven that proper maintenance activities ensure the functionality of vegetated swales for many years. The following schedule of inspection and maintenance activities is recommended:

Maintenance activities to be done annually and within 48 hours after every major storm event (> 1 inch rainfall depth):

- Inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when > 3 inches at any spot or covering vegetation)
- Inspect vegetation on side slopes for erosion and formation of rills or gullies, correct as needed
- Inspect for pools of standing water; dewater and discharge to an approved location and restore to design grade
- Mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation; dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting
- Inspect for litter; remove prior to mowing
- Inspect for uniformity in cross-section and longitudinal slope, correct as needed
- Inspect swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage, correct as needed

Maintenance activities to be done as needed:

- Plant alternative grass species in the event of unsuccessful establishment

- Reseed bare areas; install appropriate erosion control measures when native soil is exposed or erosion channels are forming
- Rototill and replant swale if draw down time is more than 48 hours
- Inspect and correct check dams when signs of altered water flow (channelization, obstructions, erosion, etc.) are identified
- Water during dry periods, fertilize, and apply pesticide **only when absolutely necessary**

Most of the above maintenance activities are reasonably within the ability of individual homeowners. More intensive swales (i.e. more substantial vegetation, check dams, etc.) may warrant more intensive maintenance duties and should be vested with a responsible agency. A legally binding and enforceable maintenance agreement between the facility owner and the local review authority might be warranted to ensure sustained maintenance execution. Winter conditions also necessitate additional maintenance concerns, which include the following:

- Inspect swale immediately after the spring melt, remove residuals (e.g. sand) and replace damaged vegetation without disturbing remaining vegetation.
- If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of deicing agents.
- Use nontoxic, organic deicing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.
- Use salt-tolerant vegetation in swales.

Cost Issues

As with all other BMPs, the cost of installing and maintaining Vegetated Swales varies widely with design variability, local labor/material rates, real estate value, and contingencies. In general, Vegetated Swales are considered relatively low cost control measures. Moreover, experience has shown that Vegetated Swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers. The following table compares the cost of a typical vegetated swale (15 ft top width) with the cost of traditional conveyance elements.

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Total Annual Cost (per linear foot)	\$1 (from seed) (from sod)	\$2	No data
Lifetime (years)	50		20

It is important to note that the costs listed above are strictly estimates and shall be used for design purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding (if required). The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) reported that actual costs, which do include these activities, may range from \$8.50 to \$50.00 per linear foot depending on swale depth and bottom width. When all pertinent construction activities are considered, it is still likely that the cost of vegetated swale installation is less than that of traditional conveyance elements. When annual operation and maintenance costs are considered however, swales may prove the more expensive option, though they typically have a much longer lifespan.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Swale Soil** shall be USCS class ML (Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity), SM (Silty sands, poorly graded sand-silt mixtures), SW (Well-graded sands, gravelly sands, little or no fines) or SC (Clayey sands, poorly graded sand-clay mixtures). The first three of these designations are preferred for swales in cold climates. In general, soil with a higher percent organic content is preferred.
2. **Swale Sand** shall be ASTM C-33 fine aggregate concrete sand (0.02 in to 0.04 in).
3. **Check dams** constructed of natural wood shall be 6 in to 12 in diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable, as they can rot over time: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen **check dam** shall be constructed of sand, gravel, and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone **check dam** shall be constructed of R-4 rip rap, or equivalent.
4. Develop a native **planting mix**. (see Appendix B)
5. If infiltration trench is proposed, see BMP 6.4.4 Infiltration Trench for specifications.

References

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