



VEGETATED SWALES

Definition: Vegetated swales are a broad, shallow, trapezoidal or parabolic channel with a dense stand of vegetation covering the side slopes and bottom.

Purpose: Vegetated swales are designed to convey stormwater runoff, reduce the flow velocity, filter runoff, and promote infiltration into the ground; as a result, runoff volumes are smaller, peak discharge rates are lower, and runoff is cleaner.

Components (Depth Zones) and Function:

- Open trapezoidal or parabolic channel sized to store entire WQV. Dry swale infiltrates full WQV and wet swale retains WQV
- Dense vegetation that assists in stormwater filtration and to reduce flow velocities
- Underdrain system for impermeable soils (dry swale only) and wet cells created by check dams (12' – 20')
- Level spreaders every 50 feet, if length exceeds 100 ft

Benefits:

- Help to control peak discharges by reducing runoff velocity, lengthening flow paths, and increasing time of concentration
- Infiltration through the natural substrate helps to reduce total stormwater runoff volume.
- Provide effective pretreatment for downstream BMPs by trapping, filtering and infiltrating particulates and associated pollutants.
- Improve site landscaping

Limitations:

- Cannot be used on steep slopes
- Require a thick vegetative cover for these practices to function properly
- Swales can be subject to channelization, if erosive velocity is exceeded

Design Considerations:

- Maximum drainage area of 10 acres
- Longitudinal slopes must be less than 6%
- Side slopes 3:1 or flatter; 4:1 recommended
- Bottom width of 2 to 8 feet
- Runoff velocities must be non-erosive
- Requires vegetation that can withstand both relatively high velocity flows and wet and dry periods

POLLUTION REDUCTION (%)

35 – 81	TSS (Sediments)
25 – 50	TP (Total Phosphorus)
20 – 35	TN (Total Nitrogen)
35 – 80	Pathogens
30 – 71	Metals
62 – 80	Hydrocarbons
40 – 70	

SITING CONSIDERATIONS

- Parking lots
- Residential
- Commercial/Industrial
- Highway/Road
- B, C and D soil types.
Underdrain is needed where native soils are C and D

FEASIBILITY AND COST

√	Ensure that vegetation is well established
√	Mow grass to 4'-5' high
√	Clean out sediments
High	Land Requirement
Median	Construction Cost
L – H	Maintenance burden
Median	Community Acceptance

A. GENERAL DESCRIPTION

Vegetated swales (also known as bio-swales, enhanced swales, or water quality swales) are vegetated open channels that receive directed flow and convey stormwater. 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.

B. COMPONENTS

Figure 5.1 – 5.3 illustrate vegetated swales. Vegetated swales consist of:

- (1) Open trapezoidal or parabolic channel:** It is typically designed with moderated slopes for ease of maintenance and side inflow by sheet flow
 - Provide substantial water quality improvement
 - Infiltration of full WQV in case of dry swale
 - Retention of WQV in case of wet swale
- (2) Filter bed of permeable, engineered soils**
 - Enhancement of pollutant removal through a high level of organic material
- (3) Underdrain system for impermeable soils (dry swale only)**
 - Collecting and conveying runoff by a perforated pipe and gravel underdrain system to the outlet
- (4) Level spreaders every 50 feet, if length exceeds 100 feet**
 - Convert concentrated, potentially erosive flow to sheet flow
 - Enhance pollutant filtering and runoff infiltration and reduces the potential for erosion

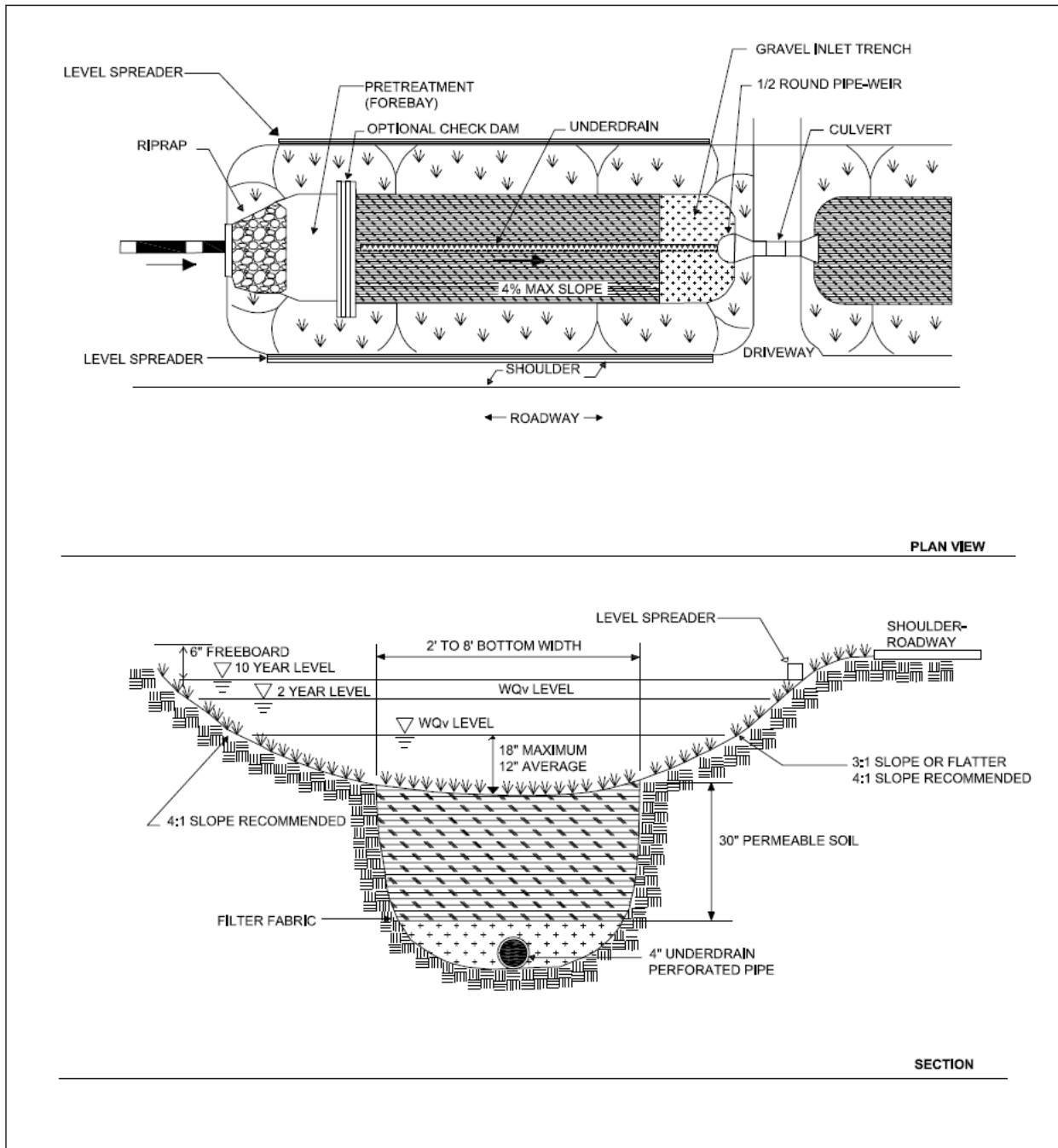


Figure 5.1 Dry Swale

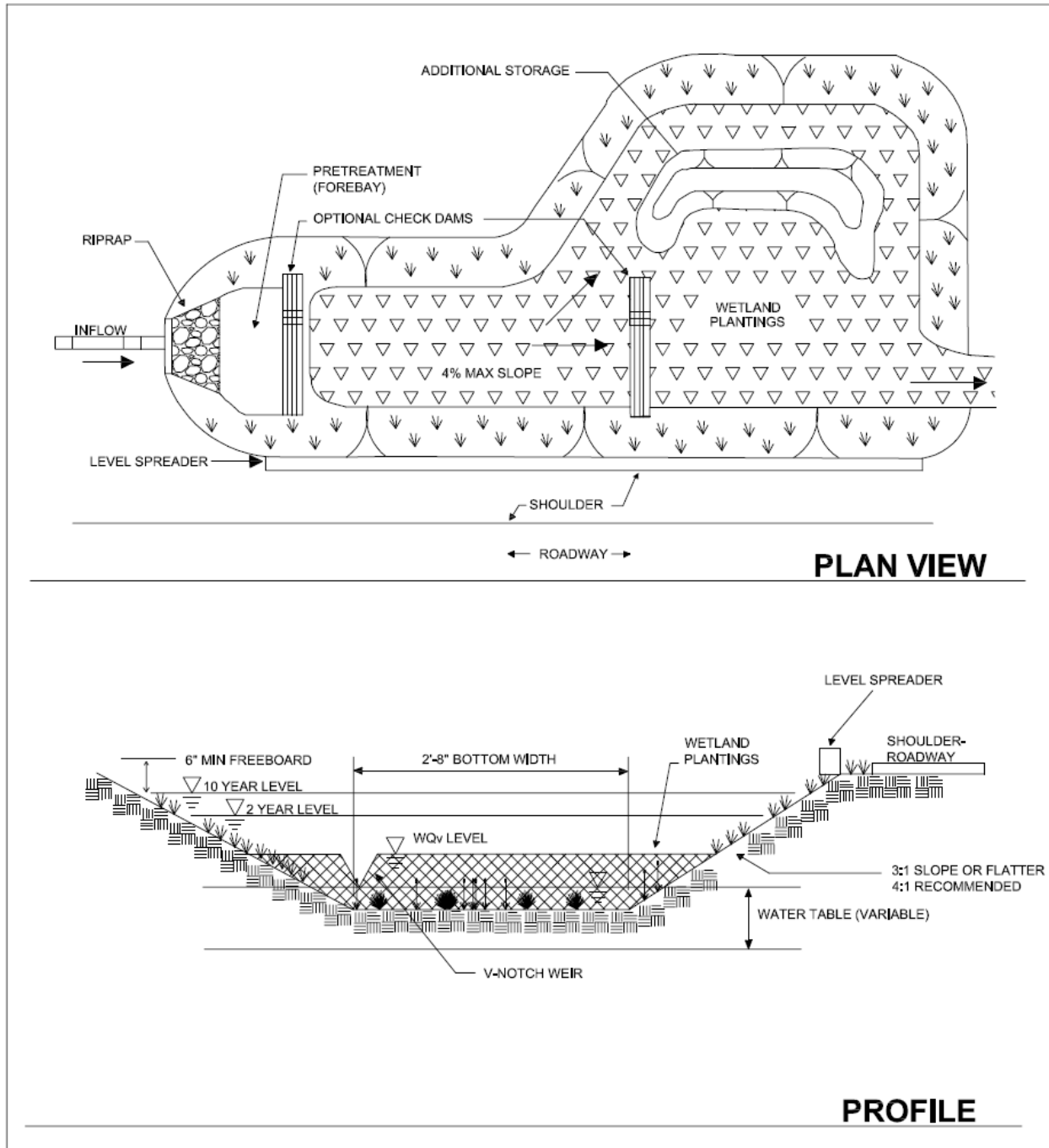
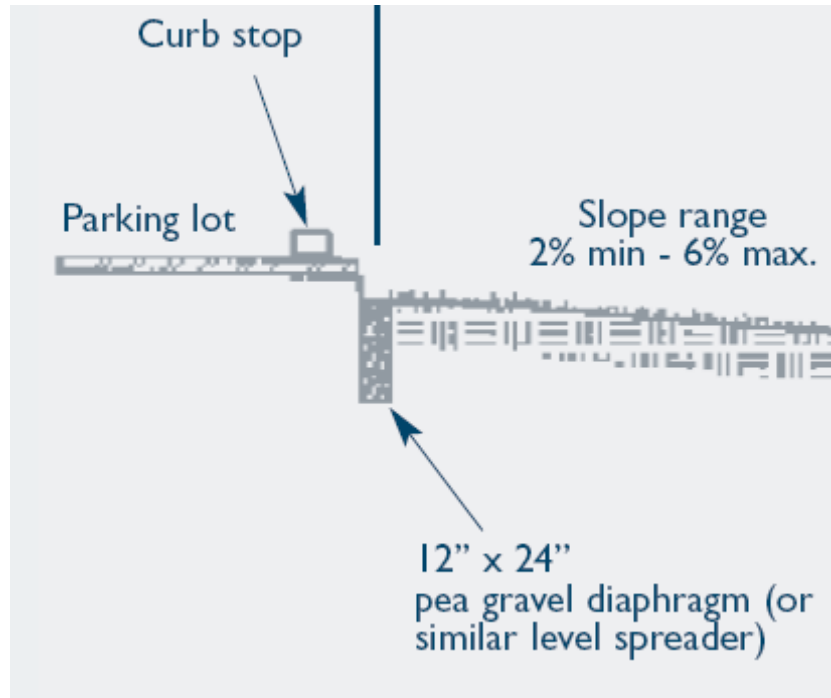
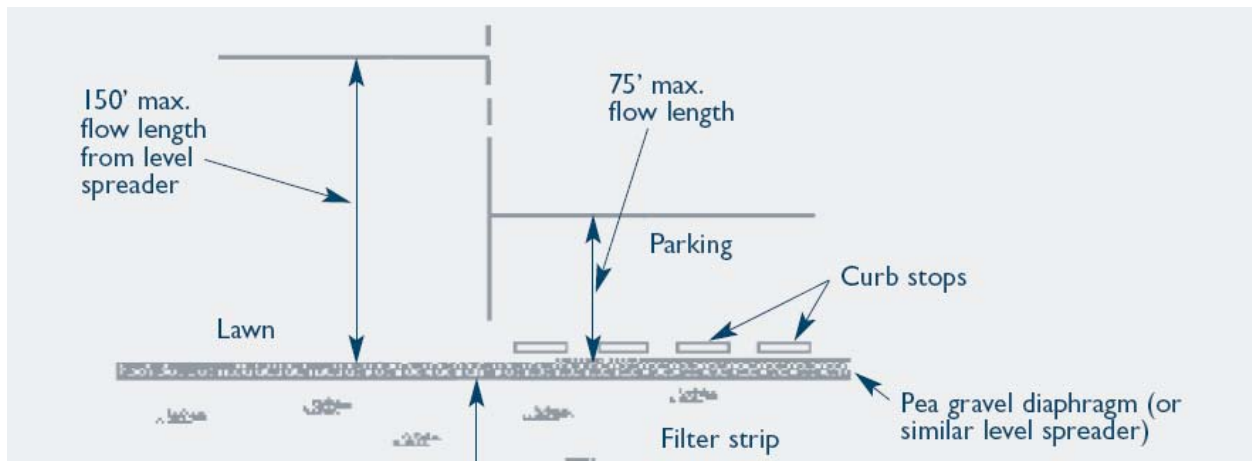


Figure 5.2 Wet Swale



Plan View



Profile

Figure 5.3 Example of Level Spreader (for Swales Receiving Directly Connected Runoff)

C. VARIATIONS AND APPLICATIONS

A vegetated swale is an infiltration and filtration method that is typically used to provide pre-treatment before stormwater runoff is discharged to treatment systems. There are three types of vegetated swales:

Dry swales - The dry swale (or bio-swale) consists of an open channel that has been modified to enhance its water quality treatment capability by adding a filtering medium consisting of a soil bed with an underdrain system (CRC, 1996). The dry swale system is sized to accept the entire WQv and allow it to be filtered through the treatment medium and/or infiltrate through the bottom of the swale. The dry swale system is designed to drain down between storm events within about one day. Since this system is dry most of the time, it is the preferred system for residential applications. The water quality treatment mechanisms are similar to bioretention practices, except that the pollutant uptake is likely to be more limited since only a grass cover crop is available for nutrient uptake. Figure 5-1 illustrates the design components of the dry swale with filter media (MDE, 2000).

Wet swale - The wet swale is a vegetated channel, also called a wetland channel that acts as a shallow wetland system that retains the WQv. The channel supports wetland vegetation in shallow marshy conditions. Usually impermeable or poorly drained soils are necessary to support the sufficient retention of water. Wet swales remove pollutants through sediment settling and biological removal. A wet swale does not require an underdrain. Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and institutional areas of low to moderate density where the impervious cover in the contributing drainage area is relatively low. They can also be used along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area. Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing water, which may create nuisance odor or mosquito problems. Figure 5-2 illustrates the design components of the wet swale.

**Dry swale****Wet swale****Figure 5.4** Examples of vegetated swale

D. POLLUTION REDUCTION CAPABILITIES AND MECHANISMS

Volume Control Capabilities

Vegetated swales can provide effective control under light to moderate runoff conditions, but their ability to control large storms is limited. Vegetated swales are typically shallow, vegetated, man-made conveyance channels designed such that the bottom elevation is above the water table to facilitate the infiltration of runoff to the soil. The vegetation covering the side slopes and channel bottom provide a filtration surface as the runoff is collected and slowly conveyed to a downstream discharge location. Swales provide additional treatment of the stormwater runoff as water moves through a subsoil matrix and infiltrates into the underlying soils. The vegetation also serves to reduce flow velocities. Swales can be either dry or wet; dry swales are more desirable where standing water is not wanted, such as residential areas; wet swales can be used where standing water does not create a nuisance and where the groundwater is close enough to the surface to maintain a shallow permanent pool between storm events. An advantage of wet swales is the ability to include wetland vegetation to assist in pollutant removal (U.S. EPA 1999b).

Pollutant Removal Capabilities

Both dry and wet swales demonstrate good pollutant removal, with dry swales providing significantly better performance for metals and nitrate. In addition, they effectively remove petroleum hydrocarbons based on the performance reported for grass channels. However, swales are less effective for dissolved metals and nutrients because effectiveness for bacteria is variable. Their pollutant removal effectiveness is very dependent on vegetation type and height. Native prairie grasses are preferred over conventional turf grass. The effectiveness of vegetated swales can be enhanced by adding check dams which maximize the retention time within the swale, decrease flow velocities and promote particulate settling.

Table 5.1 Pollutant removal efficiency of vegetated swales

Parameter	Removal Efficiency (%)
Total Suspended Solids	35 – 81
Total Phosphorus	25 – 50
Total Nitrogen	20 – 35
Pathogens	35 – 80
Heavy Metals	30 – 71
Hydrocarbons	62 – 80
Runoff Peak Flow	40 – 70

Pollutant Removal Mechanisms

Pollutants are removed in swales by the filtering action of grass, deposition in low velocity areas, or by infiltration into the subsoil. The primary pollutant removal mechanism is through sedimentation of suspended materials. Therefore, TSS and adsorbed metals are most effectively removed through a grass swale. Removal efficiencies reported in the literature vary, but generally fall into the low to medium range, with some swale systems recording no water quality effects at all.

Seasonal differences in dry/wet swale performance have been reported; pollutant removal efficiencies for many constituents can be markedly different during the growing and dormant periods (Driscoll and Mangarella, 1990). In seasonal climates, fall and winter temperatures force vegetation into dormancy, thereby reducing uptake of runoff pollutants and removing an important mechanism for flow rate reduction. Furthermore, decomposition of accumulated organic matter can lead to production of nutrients in a soluble form, making them free to be transported downstream. Freezing temperatures greatly reduce infiltration in dry swales, removing an important pollutant removal mechanism.

E. PLANNING AND DESIGN CRITERIA

Design and Site Considerations

- Vegetated swale should be sited such that the topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and cross-sectional area to maintain nonerosive velocities.
- Channels must be sited so that the longitudinal slope is less than 4%. *Drop structures*, which disrupt flow by producing a pool of water behind them and a short drop in the surface gradient for water flowing over the structure, may be used to reduce the velocity of water in areas with greater slopes. Drop structures include check dams.
- The water quality swale should have a contributing drainage area of five acres or less to prevent problems with distributing flow evenly across the swale.
- Wet swales may be used where the water table is very high (at or near the surface of the soil) or where the water balance in poorly drained soils will support wetland vegetation.
- Both wet and dry water quality swales are designed to treat for water quality, but also to pass larger storms. Runoff enters the channel through a pretreatment forebay. In addition, distributed flow can enter along the sides of the channel after passing through a flow spreader such as a pea gravel diaphragm, level 2 x 12 timbers, or other level spreader along the bank of the channel.
- Dry water quality swale: consists of an open channel with a filter bed of permeable soils overlaying an underdrain system. Water flows into the channel where it is filtered through the permeable bed. After being filtered, the runoff is conveyed through a perforated pipe and underdrain system to the outlet. A schematic is found in Figure 5-1.
- Wet water quality swale: consists of an open channel excavated to the water table or to poorly drained soils. Check dams divide the channel into cells. A schematic is found in Figure 5-2.
- Swales can incorporate raised inlets (4 to 6 inches) to allow for the retention of initial runoff volume.
- Channel slopes of 1% to 2% and no greater than 4% are recommended. If steeper slopes are necessary, 6 to 12 inch drop structures (see #1 above) can be used to limit runoff energy. Energy dissipators must be installed below drop structures and drop structures must be no closer than 50 feet. The depth of the water at the downstream end of the swale must not exceed 18 inches.
- Both dry and wet water quality swales must have a bottom channel width of 2 to 8 feet. Wider channels may be installed if designed with berms, walls, or a multi-level cross-section that prevent the channel from meandering and eroding.

- Cross-sections of dry and wet swales are to be parabolic or trapezoidal with moderate slopes of no greater than 3:1. More gentle slopes of 4:1 are recommended.
- Minimum width should be determined using Manning’s equation, with an n of 0.2 to 0.24.
- Maximum length of the swale shall be 100 feet unless level spreaders are used. Level spreaders shall be placed at least every 50 feet. Maximum length without a level spreader is 80 feet.
- The maximum ponding depth of the WQ_v must be no greater than 18 inches at the downstream end of the swale. The average ponding depth should be 12 inches.
- The maximum velocity should be no more than 0.9 feet per second.
- Dry swale channels are sized to store and infiltrate the entire water quality volume (WQ_v) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours, though a 24-hour ponding time is more desirable. Refer to PTP-01 for orifice sizing.
- The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated pipe (AASHTO Schedule 40) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 0.5 inches/hour (maximum 0.75 inches/hour) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.

Table 5.2 Infiltration Rates of Common Soil Types

Common Soil Type	Infiltration Rates (inches/hour)
Coarse Sand	¾ to 2
Fine Sand	½ to 1
Fine Sandy Loam	⅓ to ¾
Silt Loam	¼ to ⁴/₁₀
Clay Loam	¹/₁₀ to ¼

(Source: NRCS, USDA www.soil.usda.gov)

- The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.
- Wet swale channels are sized to retain the entire water quality volume (WQ_v) with less than 18 inches of ponding at the maximum depth point.
- Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.
- Inlets to enhanced swales must be provided with energy dissipators such as riprap.
- Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. The pretreatment volume should be equal to 0.1 inches per impervious acre. This storage is usually obtained by providing check dams at pipe inlets and/or driveway crossings.
- Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a flow spreader at the upstream end of the control.

- A flow spreader and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.
- *Dry water quality swale* underdrain system must discharge to the storm drainage infrastructure or a stable outfall.
- *Wet water quality swales* must have outlet protection at any outlet so that scour and downstream erosion do not occur.
- Water quality swales must be designed to safely pass flows that exceed the design storm flows.
- Maintenance access must be provided for all swales.
- Landscaping must specify grass species and/or wetland plants that will thrive under the hydric and soils conditions at the particular site.

F. CONSTRUCTION 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.

Swale Soil

It 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.

Swale Sand

It shall be ASTM C-33 fine aggregate concrete sand (0.02 in to 0.04 in).

Check dams

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.

G. OPERATION AND MAINTENANCE REQUIREMENTS

Common 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 a sanitary sewer at 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.

Table 5.3 Recommended maintenance activities for vegetated swales

Inspection Activities	Suggested Schedule
Inspect after seeding and after first major storm for any damage to vegetation, side slopes and bottom	Post construction
Inspect for signs of erosion, unhealthy or damaged vegetation, denuded areas, channelization of flow, debris and litter, and areas of sediment accumulation. Perform inspections at the beginning and end of the wet season. Additional inspections after periods of heavy rainfall are desirable	Semi-annually
Inspect level spreader for clogging (if applicable), grass along side slopes for erosion and formation of rills or gullies, and sand/soil bed for erosion problems. Inspect pea gravel diaphragm for clogging. Inspect sediment forebays and/or pretreatment areas for debris and sediment accumulation	Annually
Maintenance Activities	Suggested Schedule
Mow grass to maintain a height of 3–4 inches, for safety, aesthetic, or other purposes, if needed. Litter should always be removed prior to mowing. Grass clippings, if captured, should not be dumped in the swale. Irrigate swale during dry season (April through October) or when necessary to maintain the vegetation. Repair damaged areas (e.g., erosion rills or gullies) and re-establish vegetation where needed. Remove invasive species manually. The use of fertilizers, herbicides and pesticides should occur only when absolutely necessary, and then in minimal amounts	As needed (frequent, seasonally)
Remove litter, branches, rocks blockages, and other debris and dispose of properly. Clear accumulated debris and sediment from the inlet flow spreader (if applicable) and pea gravel diaphragm	Semi-annually
Inspect pea gravel diaphragm for clogging and correct the problem. Plant an alternative grass species if the original grass cover has not been successfully established. Reseed and apply mulch to damaged areas	Annually (if needed)
Remove all accumulated sediment that may obstruct flow through the swale. Sediment accumulating near culverts and in channels should be removed when it builds up to 3 in. at any spot, or covers vegetation, or once it has accumulated to 10% of the original design volume. Replace the grass areas damaged in the process. Remove all accumulated sediment in the sediment forebay and pretreatment areas. Repair areas of erosion around swale and underdrain outlets. Reestablish soil stabilization measures (e.g., rip-rap stone, turf grasses) as needed. Rototill or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. Re-establish swale vegetation after rototill activities.	As needed (infrequent)

Sample Inspection and Maintenance Provisions

- Important maintenance procedures:
- The drainage area of the grassed swale will be carefully managed to reduce the sediment load to the grassed swale.
- After the first-time fertilization to establish the grass in the swale, fertilizer will not be applied to the grassed swale.

The grassed swale will be inspected once a quarter. Records of inspection and maintenance will be kept in a known set location and will be available upon request. Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately

Table 5.4 Sample Inspection and Maintenance Agreement for vegetated swales

BMP element:	Potential problems	How to remediate the problems
The entire length of the swale	Trash/debris is present.	Remove the trash/debris.
	Areas of bare soil and/or erosive gullies have formed.	Regrade the soil if necessary to remove the gully, and then re-sod (or plant with other appropriate species) and water until established. Provide lime and a one-time fertilizer application.
	Sediment covers the grass at the bottom of the swale.	Remove sediment and dispose in an area that will not impact streams or BMPs. Re-sod if necessary.
	Vegetation is too short or too long.	Maintain vegetation at a height of approximately six inches.
The receiving water	Erosion or other signs of damage have occurred at the outlet.	Contact the LA Division of Water Quality.

H. CONSTRUCTION AND MAINTENANCE COSTS

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.

Table 5.5 Comparison of the cost of a typical vegetated swale with the cost of traditional conveyance elements.

Structure:	Swale
Construction Cost (per linear foot)	\$4.50 - \$8.50 (from seed) \$15 - \$20 (from sod)
Annual O&M cost (per linear foot)	\$0.75
Total Annual Cost (per linear foot)	\$1 (from seed) \$2 (from sod)
Lifetime (years)	50

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.

I. DESIGN PROCEDURE**Step 1. Compute the Water Quality Volume.**

Calculate the Water Quality Volume (WQ_v), which is the volume that must be stored in the swale.

$$WQ_v = P \times R_v \times A / 12$$

Where:

WQ_v = water quality treatment volume, ac-ft

P = rainfall for the 85th percentile storm event (1.1 in)

R_v = runoff coefficient (see below)

A = site area, acres

$$R_v = 0.015 + 0.0092I$$

Where:

I = site impervious cover, % (for example, 50% equals 50)

Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale system (dry or wet swale).

See the *Site and Design considerations*, above.

Step 3. Determine pretreatment volume.

The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage.

The forebay storage volume (F_v) counts toward the total WQ_v requirement and may be subtracted from the WQ_v for subsequent calculations.

$$F_v = 0.1 \text{ inches} \times A_I \text{ acres} \times .0833$$

Where:

F_v = Forebay volume (ac-ft)

A_I = Impervious area of drainage basin, acres

0.0833 = conversion factor of acre inches to acre feet

Often, it is more manageable to work with forebay volumes in cubic feet rather than acre feet, because they are small volumes. To convert F_v in acre feet to cubic feet, multiply F_v by 43560 square feet.

Step 4. Determine swale dimensions.

Size bottom width, depth, length, and slope necessary to store WQ_v with less than 18 inches of ponding at the downstream end.

Channel slope cannot exceed 4% (1% to 2% recommended). For more steeply sloped areas, swale must be “stepped” with check dams or similar structures to maintain slope.

Bottom width should range from 2 to 8 feet

Length to width ratio of 5:1 is suggested.

Ensure that side slopes are no greater than 3:1 (4:1 recommended)
See *Site and Design Considerations*, above.

Step 5. Compute number of check dams or similar structures required to detain WQ_v .

Step 6. Calculate drawdown time in the swale.

Dry Swale: Planting soil, 30 inches, should pass a maximum rate of 1.5 feet/day and must completely filter WQ_v in 48 hours.

Wet Swale: Must hold WQ_v .

Step 7. Check 2-year velocity erosion potential and provide 6 inches of freeboard above 10-year storm.

Step 8. Design low flow orifice at downstream headwalls and checkdams.

Design orifice to pass WQ_v in six hours.

