Chapter 9 Biofiltration Treatment Facilities

9.1 Purpose

This Chapter addresses five Best Management Practices (BMPs) that are classified as biofiltration treatment facilities.

Biofilters are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or flat filter strips.

The BMPs discussed in this chapter are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

9.2 Applications

A biofilter can be used as a basic treatment BMP for stormwater runoff from roadways, driveways, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS concentrations, or debris would be present in the runoff, such as high-use sites, a pretreatment system or oil treatment for those components is necessary. Placement of the biofilter in an offline location is preferred to avoid flattening of the vegetation and the erosive effects of high flows.

9.3 Site Suitability

The following factors must be considered for determining site suitability:

- Accessibility for operation and maintenance.
- Suitable growth environment (soil, exposure to sunlight, etc.) for the vegetation.
- Adequate siting for a pre-treatment facility if high petroleum hydrocarbon levels (oil/grease) or high TSS loads could impair treatment capacity or efficiency.

9.4 Best Management Practices

The following five Biofiltration Treatment Facilities BMPs are discussed in this chapter:

BMP T910 – Basic Biofiltration Swale
BMP T920 – Wet Biofiltration Swale
BMP T930 – Continuous Inflow Biofiltration Swale
BMP T940 – Basic Filter Strip & Compost-Amended Filter Strip
BMP T950 – Narrow Area Filter Strip

9.4.1 BMP T910 Basic Biofiltration Swale

9.4.1.1 Description

Biofiltration swales are typically shaped as a trapezoid or a parabola in cross section as shown in Figure 5 - 16 and Figure 5 - 17.

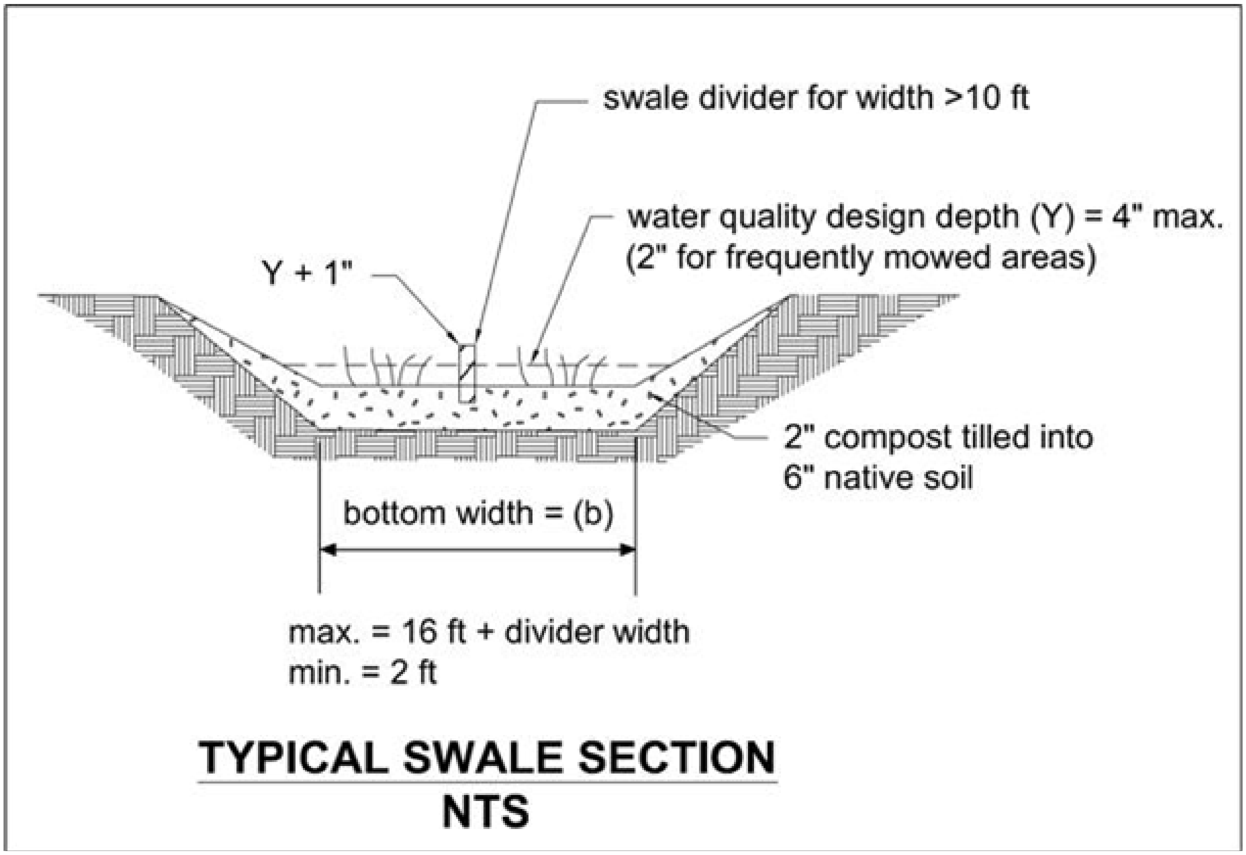


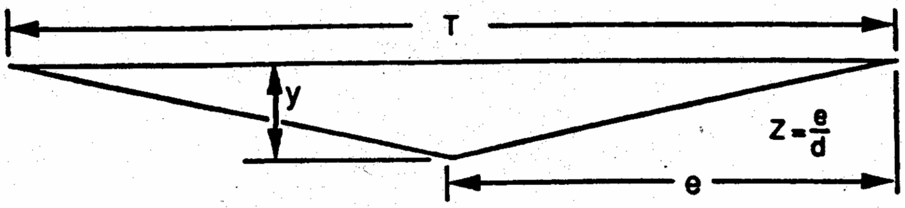
Figure 5 - 16. Typical Swale Section

9.4.1.2 Design Criteria

- Size the swale using sizing criteria specified in Table 5 - 8. Minimum length shall be 100 feet.
- Check the hydraulic capacity/stability using Q_{max}.
- Select a vegetation cover suitable for the site. Refer to Table 5 - 11 through Table 5 - 13.
- Install level spreaders (minimum 1 inch gravel) at the head of all swales, and every 50 feet in swales of ≥4 feet width. Include sediment cleanouts (weir, settling basin, or equivalent) at the head of the biofilter as needed.
- Use energy dissipaters (such as quarry spalls or riprap) as necessary. See Volume 3 for additional information.

CHANNEL GEOMETRY

V - Shape

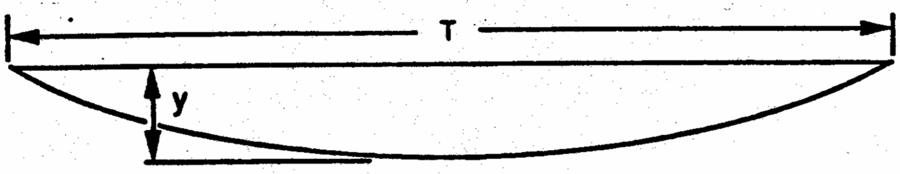


Cross-Sectional Area (A) = Zy^2

Top Width (T) = $2yZ$

Hydraulic Radius (R) = $\frac{Zy}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

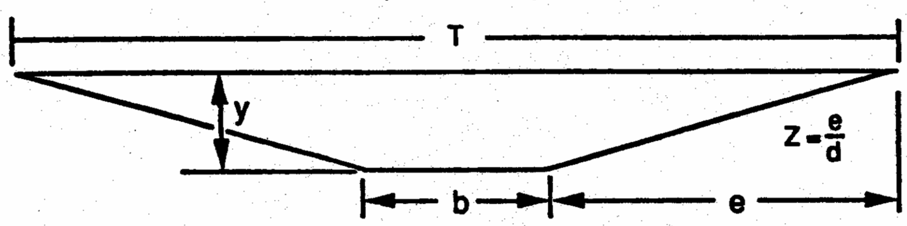


Cross-Sectional Area (A) = $\frac{2}{3}Ty$

Top Width (T) = $\frac{1.5A}{y}$

Hydraulic Radius (R) = $\frac{T^2y}{1.5T^2 + 4y^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $by + Zy^2$

Top Width (T) = $b + 2yz$

Hydraulic Radius (R) = $\frac{by + Zy^2}{b + 2y\sqrt{Z^2 + 1}}$

Source: Livingston, et al, 1984

Figure 5 - 17. Geometric Formulas for Common Swale Shapes

Table 5 - 8: Sizing Criteria

Design Parameter	BMP T910 - Biofiltration Swale	BMP T940 - Filter Strip
Longitudinal Slope	0.015 - 0.025[a]	0.01 - 0.15
Maximum velocity	1 ft / sec @ K[b] multiplied by the WQ design flow rate	0.5 ft / sec @ K multiplied by the WQ design flow rate
Maximum velocity for channel stability[c]	3 ft/sec	---
Maximum water depth[d]	2”- if mowed frequently; 4” if mowed infrequently	1-inch max.
Manning coefficient	(0.2 – 0.3)[e] (0.24 if mowed infrequently)	0.35 (0.45 if compost amended, or mowed to maintain grass height ≤ 4”)
Bed width (bottom)	(2 - 10 ft)[f]	---
Freeboard height	0.5 ft	---
Minimum hydraulic residence time at K multiplied by Water Quality Design Flow Rate	9 minutes (18 minutes for continuous inflow)	9 minutes
Minimum length	100 ft	Sufficient to achieve hydraulic residence time in the filter strip
Maximum sideslope	3 H:1 V 4H:1V preferred	Inlet edge ≥ 1” lower than contributing paved area
Max. tributary drainage flowpath	---	150 feet
Max. longitudinal slope of contributing area	---	0.05 (steeper than 0.05 need upslope flow spreading and energy dissipation)

a. For swales, if the slope is less than 1.5% install an underdrain using a perforated pipe, or equivalent. Amend the soil if necessary to allow effective percolation of water to the underdrain. Install the low-flow drain 6” deep in the soil. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches. Underdrains can be made of 6 inch Schedule 40 PVC perforated pipe or equivalent with 6” of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric (see Figure 5 - 19 and Figure 5 - 20).

b. K=A ratio of the peak 10-minute flow predicted by SBUH to the water quality design flow rate estimated using the WWHM. The value of K for offline systems is 3.5, and for online systems is 2.0 in the City of Tacoma.

c. Maximum flowrate for channel stability shall be the 100-year, 24-hour discharge (Q_{100}) calculated with WWHM using a 15-minute time step. If an hourly time step is used, multiply the Q_{100} by 1.6.

d. Below the design water depth install an erosion control blanket, at least 4” of topsoil, and the selected biofiltration mix. Provide vegetation above the water line.

e. This range of Manning’s n can be used in the equation; $b = Qn/1.49y^{(1.67)} S^{(0.5)} - Zy$ with wider bottom width b, and lower depth y, at the same flow. This provides the designer with the option of varying the bottom width of the swale depending on space limitations. Designing at the higher n within this range at the same flow decreases the hydraulic design depth, thus placing the pollutants in closer contact with the vegetation and the soil.

f. For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet (Figure 5 - 21).

9.4.1.3 Bypass Guidance

Most biofiltration swales are currently designed to be online facilities. However, an offline design is possible. Swales designed in an offline mode should not engage a bypass until the flow rate exceeds a value determined by multiplying Q, the offline water quality design flow rate predicted by the WWHM, by 3.5 for offline systems and 2.0 for online systems. This modified design flow rate is an estimate of the design flow rate determined by using SBUH procedures. Ecology's intent is to maintain recent biofiltration sizing recommendations until more definitive information is collected concerning bioswale performance.

9.4.1.4 Sizing Procedure for Biofiltration Swales

Preliminary Steps

P.1 Determine the water quality design flow rate (Q) in 15-minute time steps using an approved continuous simulation model and modified per Section 9.4.1.3.

P.2 Establish the longitudinal slope of the proposed biofilter.

P.3 Select an appropriate vegetated cover for the site. Refer to Table 5 - 11 through Table 5 - 13.

Design Steps

D.1 Select the type of vegetation and depth of flow (based on frequency of mowing and type of vegetation).

D.2 Select a value of Manning's n (see Table 5 - 8).

D.3 Select swale shape.

D.4 Use Manning's equation and first approximations relating hydraulic radius and dimensions for the selected swale shape to obtain a working value of a biofilter bottom and top width dimension:

$$Q = \frac{1.49 A R^{0.67} s^{0.5}}{n} \qquad (1)$$

Where:

Q = Water quality design flowrate per step P.1 (cfs)
n = Manning's n (dimensionless)
s = Longitudinal slope as a ratio of vertical rise/horizontal run (dimensionless)
A= cross-sectional area (ft^2)
R= hydraulic radius (ft)

Because the depth of flow in most biofiltration swales is shallow relative to the bottom width, channel side slopes can be ignored in the calculation of bottom width. Use the following equation to estimate the swale bottom width for a trapezoidal swale. For other swale shapes, substitute R and A into Equation 1 to solve for b.

$$b \approx \frac{Qn}{1.49y^{1.67}s^{0.5}} - Zy \qquad (2)$$

Where:

b = Bottom width (ft)
Q = Water quality design flowrate per step P.1 (cfs)
n = Manning's n (see Table 5 - 8)
y = Design flow depth (see Table 5 - 8)
s = Longitudinal slope (see Table 5 - 8)
Z = Side slope (for trapezoid select 3)

A minimum 2-foot bottom width is required. If the calculated bottom width is less than 2 feet, increase the width to 2 feet and recalculate the design flow depth y, using equation 3 below.

$$y = \frac{Qn}{1.49s^{0.5}b} \qquad (3)$$

Where Q, n, and s are the same as equation 2, but b = 2 feet.

Next, compute the top width T (ft). For a trapezoid.

$$T = b + 2yZ$$

If b for a swale is greater than 10 ft, either investigate how Q can be reduced, divide the flow by installing a low berm, or arbitrarily set b = 10 ft and continue with the analysis. For other swale shapes refer to Figure 5 - 17.

D.5 Compute A

$A_{trapezoid} = by + Zy^2$

Where:
A = cross-sectional area (ft²)
T = top width of trapezoid or width of a rectangle (ft)
y = depth of flow (ft)
b= bottom width of trapezoid (ft)
Z= side slope

D.6 Compute the flow velocity at design flow rate:

V= (Q/A)

A = cross-sectional area (ft^2)

Q = water quality design flow rate per step P.1 (cfs)

If V >1.0 ft/sec (or V>0.5 ft/sec for a filter strip), repeat steps D-1 to D-6 until the condition is met. A velocity greater than 1.0 ft/sec was found to flatten grasses, thus reducing filtration. A velocity lower than this maximum value will allow a 9-minute hydraulic residence time criterion in a shorter biofilter. If the value of V suggests that a longer biofilter will be needed than space permits, investigate how Q can be reduced (e.g., use of low impact development BMP's), or increase y and/or T (up to the allowable maximum values) and repeat the analysis.

D.7 Compute the swale length (L, ft)

L = Vt (60 sec/min)

Where: t = hydraulic residence time (min)
V = flow velocity

Use t = 9 minutes for this calculation (use t = 18 minutes for a continuous inflow biofiltration swale). If a biofilter length is greater than the space permits, follow the advice in step 6.

If a length less than 100 feet results from this analysis, increase it to 100 feet, the minimum allowed. In this case, it may be possible to save some space in width and still meet all criteria. This possibility can be checked by computing V in the 100 ft biofilter for t = 9 minutes, recalculating A (if V < 1.0 ft/sec) and recalculating T.

D.8 If there are space constraints, the local government and the project proponent should consider the following solutions (listed in order of preference):

1. Divide the site drainage to flow to multiple biofilters.
2. Use infiltration or other low impact development techniques (Volume 6) to provide lower discharge rates to the biofilter (only if the Site Suitability Criteria in Section 7.3 of this volume are met).
3. Increase vegetation height and design depth of flow (note: the design must ensure that vegetation remains standing during design flow).
4. Reduce the developed surface area to gain space for biofiltration.
5. Increase the longitudinal slope.
6. Increase the side slopes.
7. Nest the biofilter within or around another BMP.

Stability Check Steps

The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height. A check is not required for biofiltration swales that are located offline from the primary conveyance/detention system. Maintain the same units as in the biofiltration capacity analysis.

The maximum permissible velocity for erosion prevention (Vmax) is 3 feet per second.

S.1 Perform the stability check for the 100-year, return frequency flow using 15-minute time steps using WWHM. The designer can use the WWHM 100-yr. hourly peak flows times an adjustment factor of 1.6 to approximate peak flows in 15-minute time steps.

S.2 Estimate the vegetation coverage ("good" or "fair") and height on the first occasion that the biofilter will receive flow, or whenever the coverage and height will be least. Avoid flow introduction during the vegetation establishment period by timing planting.

S.3 Estimate the degree of retardance from Table 5 - 9. When uncertain, be conservative by selecting a relatively low degree of retardance.

Table 5 - 9: Stability Check Steps (SC) Guide for Selecting Degree of Retardance[a]

Coverage	Average Grass Height (inches)	Degree of Retardance
Good	≤ 2	E. Very Low
	2-6	D. Low
	6-10	C. Moderate
	11-24	B. High
	≥ 30	A. Very High
Fair	≤ 2	E. Very Low
	2-6	D. Low
	6-10	D. Low
	11-24	C. Moderate
	≥ 30	B. High

a. See Chow (1959), In addition, Chow recommended selection of retardance C for a grass-legume mixture 6-8 inches high and D for a mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach

S.4 Select a trial Manning's n for the high flow condition. The minimum value for poor vegetation cover and low height (possibly, knocked from the vertical by high flow) is 0.033. A good initial choice under these conditions is 0.04.

S.5 Refer to Figure 5 - 18 to obtain a first approximation for VR.

S.6 Compute hydraulic radius, R, from VR in Figure 5 - 18 and a V_{max} in Table 5 - 10.

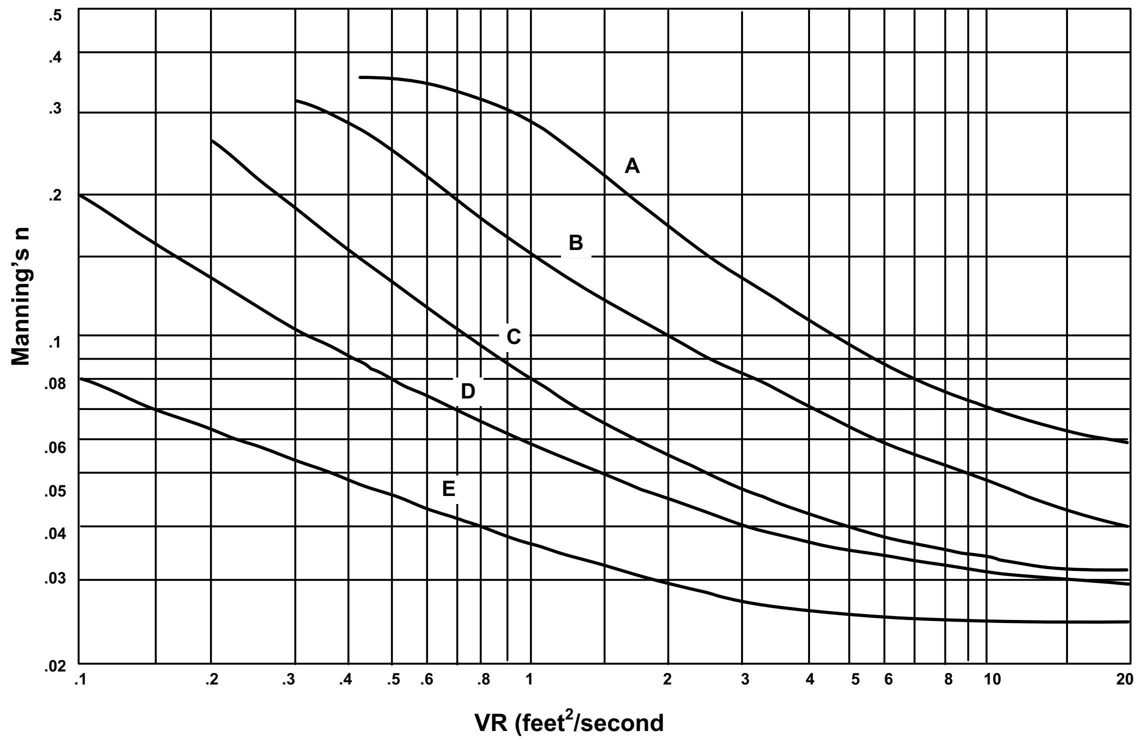


Figure 5 - 18. The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E)

Table 5 - 10: Guide to Selecting Maximum Permissible Swale Velocities for Stability[a]

Cover	Slope (percent)	Max Velocity - ft/sec (m/sec)	
		Erosion-Resistant Soils	Easily Eroded Soils
Kentucky bluegrass Tall fescue	0-5	6 (1.8)	5 (1.5)
Kentucky bluegrass Ryegrasses Western wheatgrass	5-10	5 (1.5)	4 (1.2)
Grass-legume mixture	0-5	5 (1.5)	4 (1.2)
	5-10	4 (1.2)	3 (0.9)
Red fescue	0-5	3 (0.9)	2.5 (0.8)
Redtop	5-10	Not recommended	Not recommended

a.Adapted from Chow (1959), Livingston et al (1984), and Goldman et al (1986)

S.7 Use Manning's equation to solve for the actual VR.

S.8 Compare the actual VR from step S.7 and first approximation from step S.5. If they do not agree within 5 percent, repeat steps S.4 to S.8 until acceptable agreement is reached. If n<0.033 is needed to get agreement, set n = 0.033, repeat step S.7, and then proceed to step S.9.

S.9 Compute the actual V for the final design conditions:

S.10 Check to be sure $V < V_{max}$.

S.11 Compute the required swale cross-sectional area, A, for stability.

S.12 Compare the A, computed in step S.11 of the stability analysis, with the A from the biofiltration capacity analysis (step D.5).

If less area is required for stability than is provided for capacity, the capacity design is acceptable. If not, use A from step S.11 of the stability analysis and recalculate channel dimensions.

S.13 Calculate the depth of flow at the stability check design flow rate condition for the final dimensions and use A from step S.11.

S.14 Compare the depth from step S.13 to the depth used in the biofiltration capacity design (Step D.1). Use the larger of the two and add 0.5 ft. of freeboard to obtain the total depth (y_t) of the swale. Calculate the top width for the full depth using the appropriate equation.

S.15 Recalculate the hydraulic radius: (use b from Step D.4 calculated previously for biofiltration capacity, or Step S.12, as appropriate, and y_t = total depth from Step S.14)

S.16 Make a final check for capacity based on the stability check design storm (this check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance). Use Equation 1, a Manning's n selected in step D.2, and the calculated channel dimensions, including freeboard, to compute the flow capacity of the channel under these conditions. Use R from step S-14, above, and $A = b(y_t) + Z(y_t)^2$ using b from Step D.4, D.15, or S.12 as appropriate.

If the flow capacity is less than the stability check design storm flow rate, increase the channel cross-sectional area as needed for this conveyance. Specify the new channel dimensions.

Completion Step

Review all of the criteria and guidelines for biofilter planning, design, installation, and operation above and specify all of the appropriate features for the application.

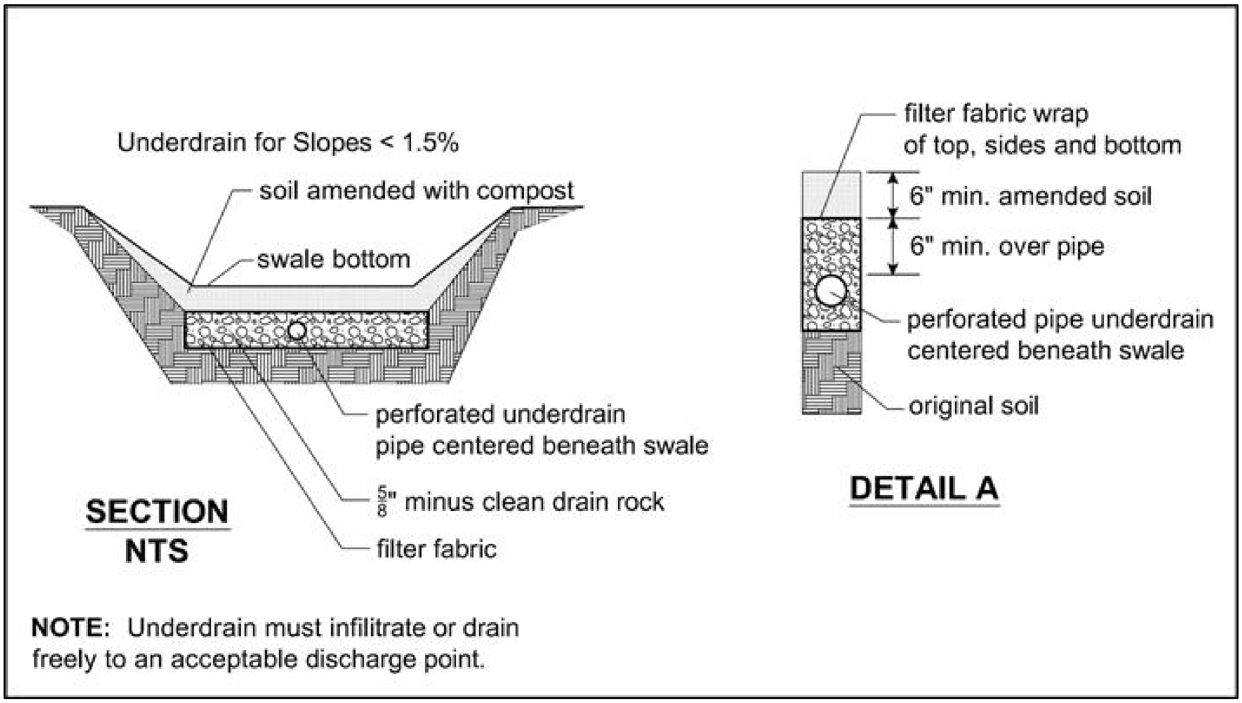


Figure 5 - 19. Biofiltration Swale Underdrain Detail

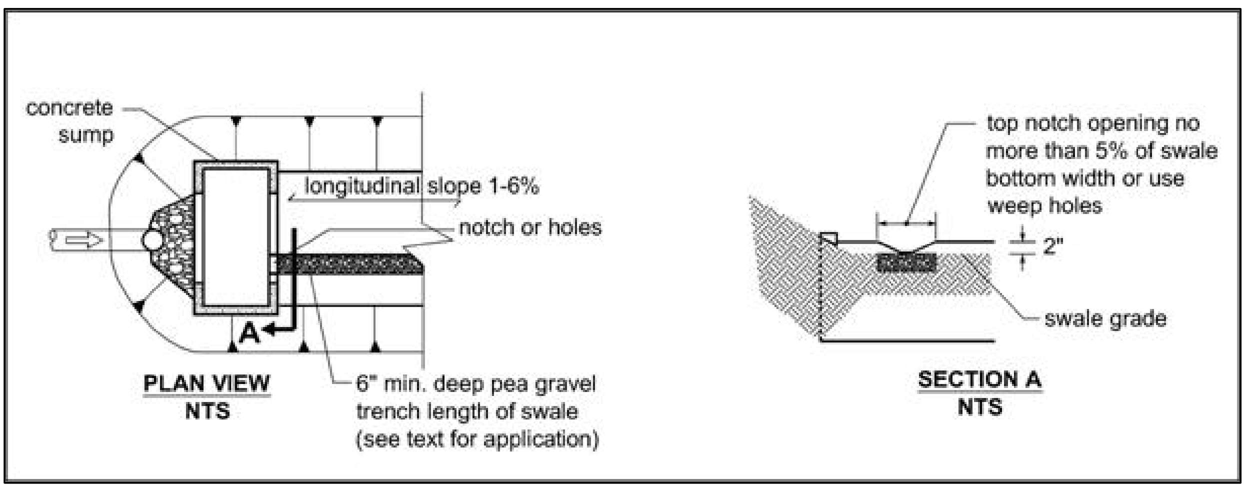
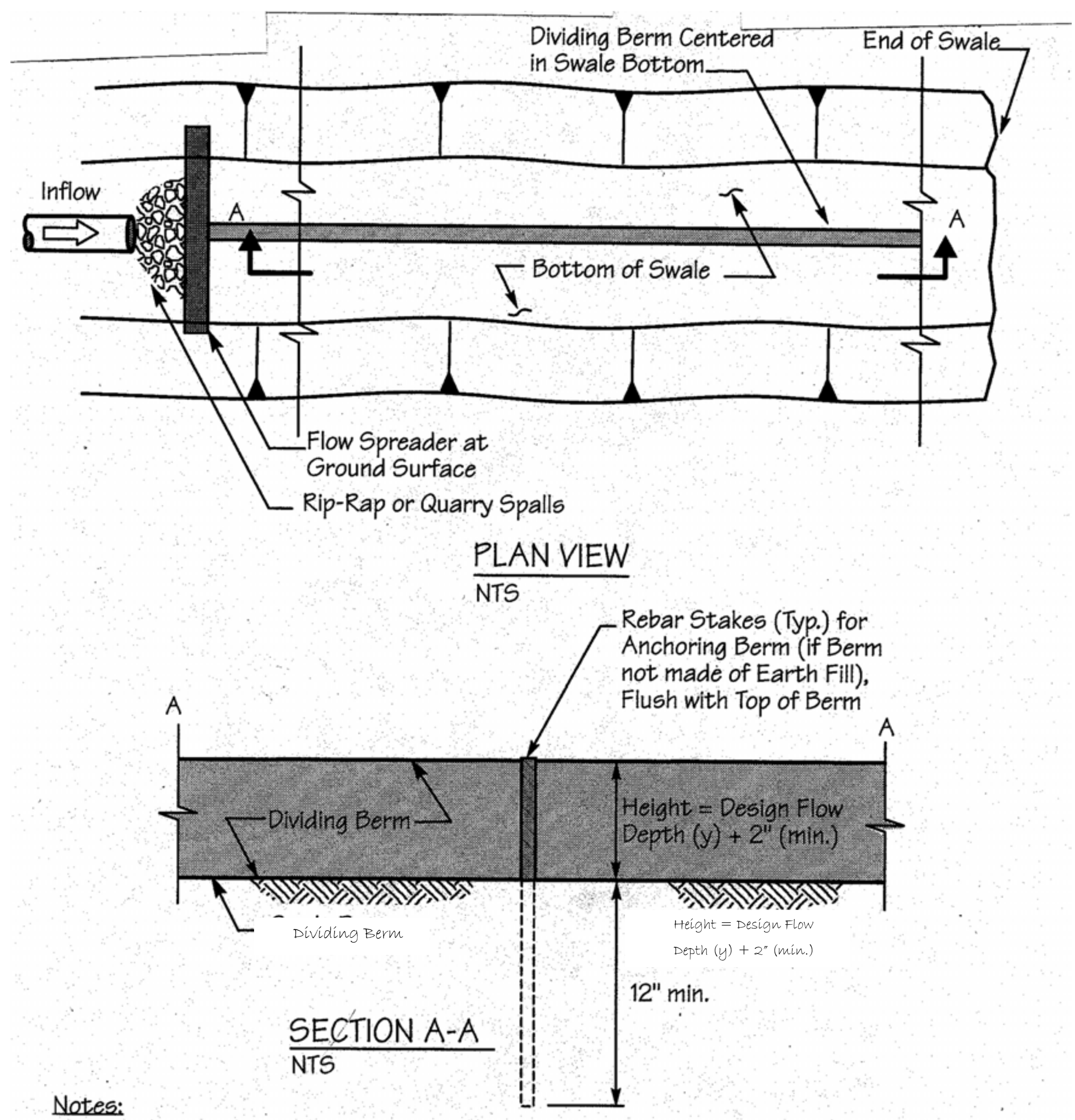


Figure 5 - 20. Biofiltration Swale Low-Flow Drain Detail



Notes:

1. Berm may be Made of Compacted Earthfill (seeded with grass), Timber, Concrete Plastic, or Similar Weather - Resistant Non - Erodible Material.
2. Rebar Stakes or Similar Berm Anchoring Materials Needed if Berm Made of Timber, Plastic, or Concrete Curbing - Stake Placement Required at Both Ends of Each Individual Member (at a minimum).

Figure 5 - 21. Swale Dividing Berm

9.4.1.5 Soil Criteria

- Use the following list as a guide for choosing appropriate soils for the biofiltration swale. Use at least 8-inches of the following top soil mix:
  - Sandy loam 60-90 %
  - Clay 0-10 %
  - Composted organic matter,10-30 %
    (excluding animal waste, toxics)
- Use compost amended soil where practicable.
- Till to at least 8-inch depth.
- For longitudinal slopes of < 2 percent use more sand to obtain more infiltration.
- If groundwater contamination is a concern, seal the bed with clay or a geomembrane liner.

9.4.1.6 Vegetation Criteria

- See Table 5 - 11 through Table 5 - 13 for recommended grasses, wetland plants, and groundcovers.
- Select fine, turf-forming, water-resistant grasses where vegetative growth and moisture will be adequate for growth.
- Irrigate if moisture is insufficient during dry weather season.
- Use sod with low clay content and where needed to initiate adequate vegetative growth. Preferably sod should be laid to a minimum of one-foot vertical depth above the swale bottom.
- Consider sun/shade conditions for adequate vegetative growth and avoid prolonged shading of any portion not planted with shade tolerant vegetation.
- Stabilize soil areas upslope of the biofilter to prevent erosion.
- Fertilizing a biofilter shall not be allowed.

9.4.1.7 Construction Criteria

- Do not put swale into operation until exposed soil in contributing drainage area is stabilized.
- Keep erosion and sediment control measures in place until swale vegetation is established.
- Avoid compaction during construction.
- Grade biofilters to attain uniform longitudinal and lateral slopes.

9.4.1.8 Maintenance Criteria

Per Minimum Requirement #10, an operation and maintenance plan shall be prepared for all stormwater management facilities. See Volume 1, Appendix C, Maintenance Checklist #9 for specific maintenance requirements for biofiltration swales. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during maintenance operation must be disposed of in a City approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed of in accordance with state and local waste regulations.

Facilities shall be constructed such that the facility can be easily inspected by one person. This may require construction of additional inspection ports or access manholes to allow inspection acces to be opened by one person.

Table 5 - 11: Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas[a]

Mix 1		Mix 2	
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	redtop

a.All percentages are by weight, based on Briargreen, Inc.

Table 5 - 12: Groundcovers & Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	*Arctostaphylos uva-ursi*
Epimedium	*Epimedium grandiflorum*
creeping forget-me-not	*Omphalodes verna*
--	*Euonymus lanceolata*
yellow-root	*Xanthorhiza simplissima*
--	*Genista*
white lawn clover	*Trifolium repens*
white sweet clover*	*Melilotus alba*
-------	*Rubus calycinoides*
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)
tufted fescue	*Festuca amethystina*
buffalo grass	*Buchloe dactyloides*
red fescue*	*Festuca rubra*
tall fescue grass*	*Festuca arundinacea*
blue oatgrass	*Helictotrichon sempervirens*
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)

*** Good choices for swales with significant periods of flow, such as those downstream of a detention facility.**

Table 5 - 13: Recommended Plants for Wet Biofiltration Swale

Common Name	Scientific Name	Spacing (on center)
Shortawn foxtail	*Alopecurus aequalis*	seed
Water foxtail	*Alopecurus geniculatus*	seed
Spike rush	*Eleocharis spp.*	4 inches
Slough sedge*	*Carex obnupta*	6 inches or seed
Sawbeak sedge	*Carex stipata*	6 inches
Sedge	*Carex* spp.	6 inches
Western mannagrass	*Glyceria occidentalis*	seed
Velvetgrass	*Holcus mollis*	seed
Slender rush	*Juncus tenuis*	6 inches
Water parsley*	*Oenanthe sarmentosa*	6 inches
Hardstem bulrush	*Scirpus acutus*	6 inches
Small-fruited bulrush	*Scirpus microcarpus*	12 inches

*** Good choices for swales with significant periods of flow, such as those downstream of a detention facility. Cattail (Typha latifolia) is not appropriate for most wet swales because of its very dense and clumping growth habit which prevents water from filtering through the clump.**

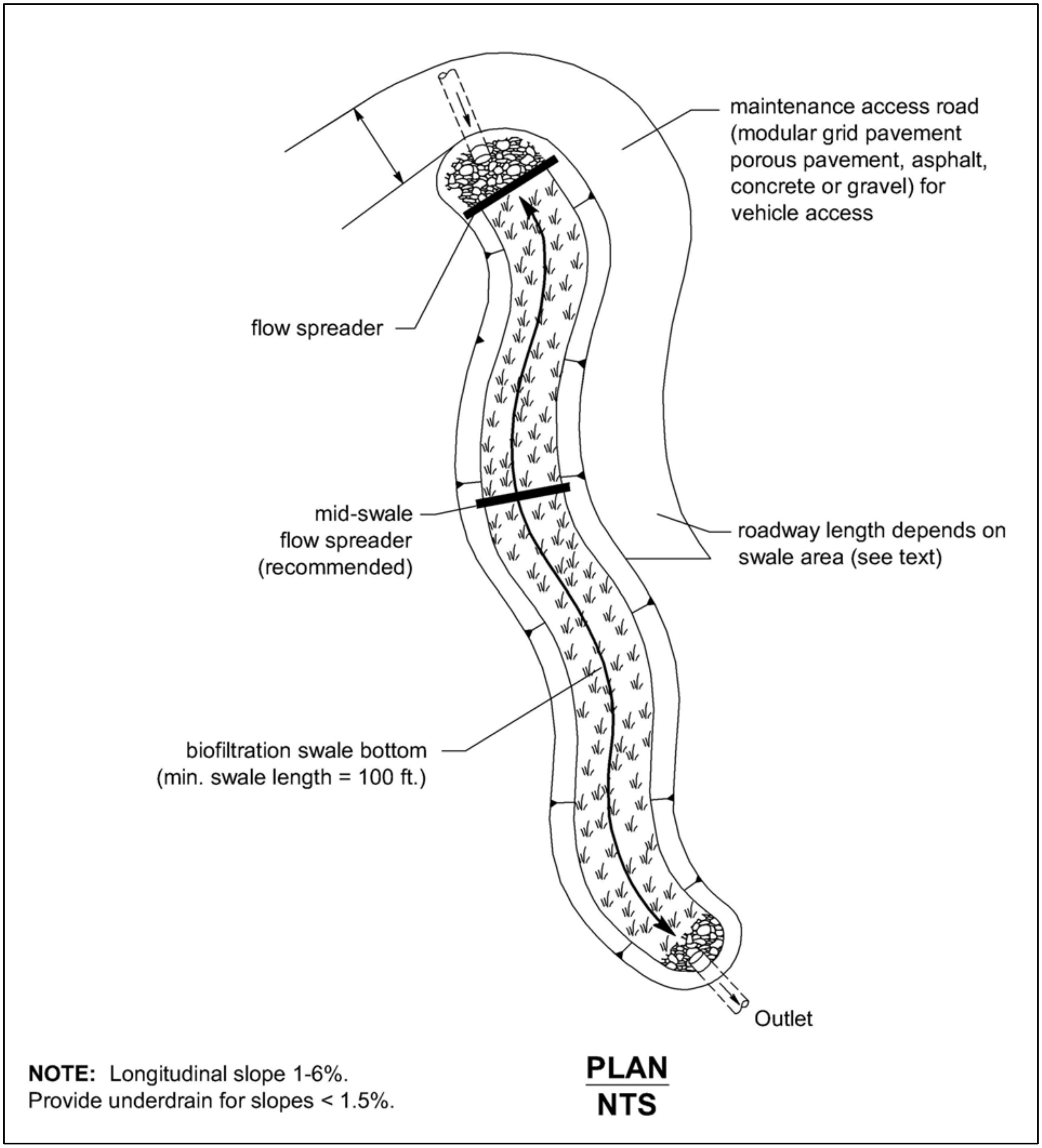


Figure 5 - 22. Biofiltration Swale Access Features

9.4.2 BMP T920 Wet Biofiltration Swale

9.4.2.1 Description

A *wet biofiltration swale* is a variation of a basic biofiltration swale for use where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. Where saturation exceeds about 2 weeks, typical grasses will die. Thus, vegetation specifically adapted to saturated soil conditions is needed. Different vegetation in turn requires modification of several of the design parameters for the basic biofiltration swale.

9.4.2.2 Performance Objectives

To provide basic water quality treatment.

9.4.2.3 Applications/Limitations

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because one or more of the following conditions exist:

- The swale is located on glacial till soils and is downstream of a detention pond providing flow control.
- Saturated soil conditions are likely because of seeps or base flows on the site.
- Longitudinal slopes shall be less than 2 percent.

9.4.2.4 Design Criteria

Use the same sizing and criteria as for basic biofiltration swales except for the following:

1. Adjust for extended wet season flow.
    - If the swale will be downstream of a detention pond or vault providing flow control, multiply the treatment area (bottom width times length) of the swale by 2, and readjust the swale length, if desired. Maintain a 5:1 length to width ratio.
2. Swale geometry.
    - The bottom width may be increased to 25 feet maximum, but a length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed.

      The minimum swale length is 100 feet.
    - If longitudinal slopes are greater than 2 percent, the wet swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of retaining walls, log check dams, or short riprap sections. **No underdrain or low-flow drain is required**.
3. High-flow bypass
    - A high-flow bypass (i.e., an offline design) is required for flows greater than the offline water quality design flow that has been increased by 3.5. The bypass may be an open channel parallel to the wet biofiltration swale.
4. Water Depth and Base Flow
    - Design water depth shall be 4 inches for all wetland vegetation selections.
    - No underdrains or low-flow drains are required.
5. Flow Velocity, Energy Dissipation, and Flow Spreading

- No flow spreader is required.

6. Access
    - Access is only required to the inflow and outflow of the swale. Access along the swale is not required.
    - Wheel strips may not be used for access.
7. Planting Requirements
    - A list of acceptable plants and recommended spacing is shown in Table 5 - 13.
    - A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting of rootstock or nursery stock is required. Poor coverage is considered to be more than 30 percent bare area through the upper 2/3 of the swale after four weeks.
8. Maintenance Considerations
    - See Volume 1, Appendix C, Checklist #10 for specific maintenance requirements for wet biofiltration swales.

9.4.3 BMP T930 Continuous Inflow Biofiltration Swale

9.4.3.1 Description

In situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head, a different design approach–the continuous inflow biofiltration swale–is needed. The basic swale design is modified by increasing swale length to achieve an equivalent average residence time.

9.4.3.2 Applications

A continuous inflow biofiltration swale is to be used when inflows are not concentrated, such as locations along the shoulder of a road without curbs. This design may also be used where frequent, small point flows enter a swale, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts. In general, no inlet port shall carry more than about 10 percent of the flow.

A continuous inflow swale is not appropriate for a situation in which significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point of confluence to the discharge point in order to provide adequate treatment for the increased flows.

9.4.3.3 Design Criteria

Same as specified for basic biofiltration swale except for the following:

- The design flow for continuous inflow swales must include runoff from the pervious side slopes draining to the swale along the entire swale length. Therefore, they must be online facilities.
- If only a single design flow is used, the flow rate at the outlet should be used. The goal is to achieve an average residence time through the swale of 9 minutes as calculated using the online water quality design flow rate multiplied by the ratio, K (see footnotes in Table 5 - 8). Assuming an even distribution of inflow into the side of the swale double the hydraulic residence time to a minimum of 18 minutes.
- Interior side slopes above the water quality design treatment elevation shall be planted in grass. A typical lawn seed mix or the biofiltration seed mixes are acceptable. Landscape plants or groundcovers other than grass may not be used anywhere between the runoff inflow elevation and the bottom of the swale.

9.4.4 BMP T940 Basic and Compost-Amended Filter Strip

9.4.4.1 Description

A basic filter strip is flat with no side slopes (Figure 5 - 23). Untreated stormwater is distributed as sheet flow across the inlet width of a biofilter strip.

9.4.4.2 Applications/Limitations

The basic filter strip is typically used online and adjacent and parallel to a paved area such as parking lots, driveways, and roadways. Where a filter strip area is compost-amended to a minimum of 10% organic content in accordance with BMP L613; with hydroseeded grass maintained at 95% density and a 4-inch length by mowing and periodic re-seeding (possible landscaping with herbaceous shrubs), the filter strip serves as an Enhanced Treatment option.

9.4.4.3 Design Criteria for Filter strips

- Use the Design Criteria specified in Table 5 - 8.
- Filter strips shall only receive sheet flow.
- Use curb cuts ≥ 12-inch wide and 1-inch above the filter strip inlet.

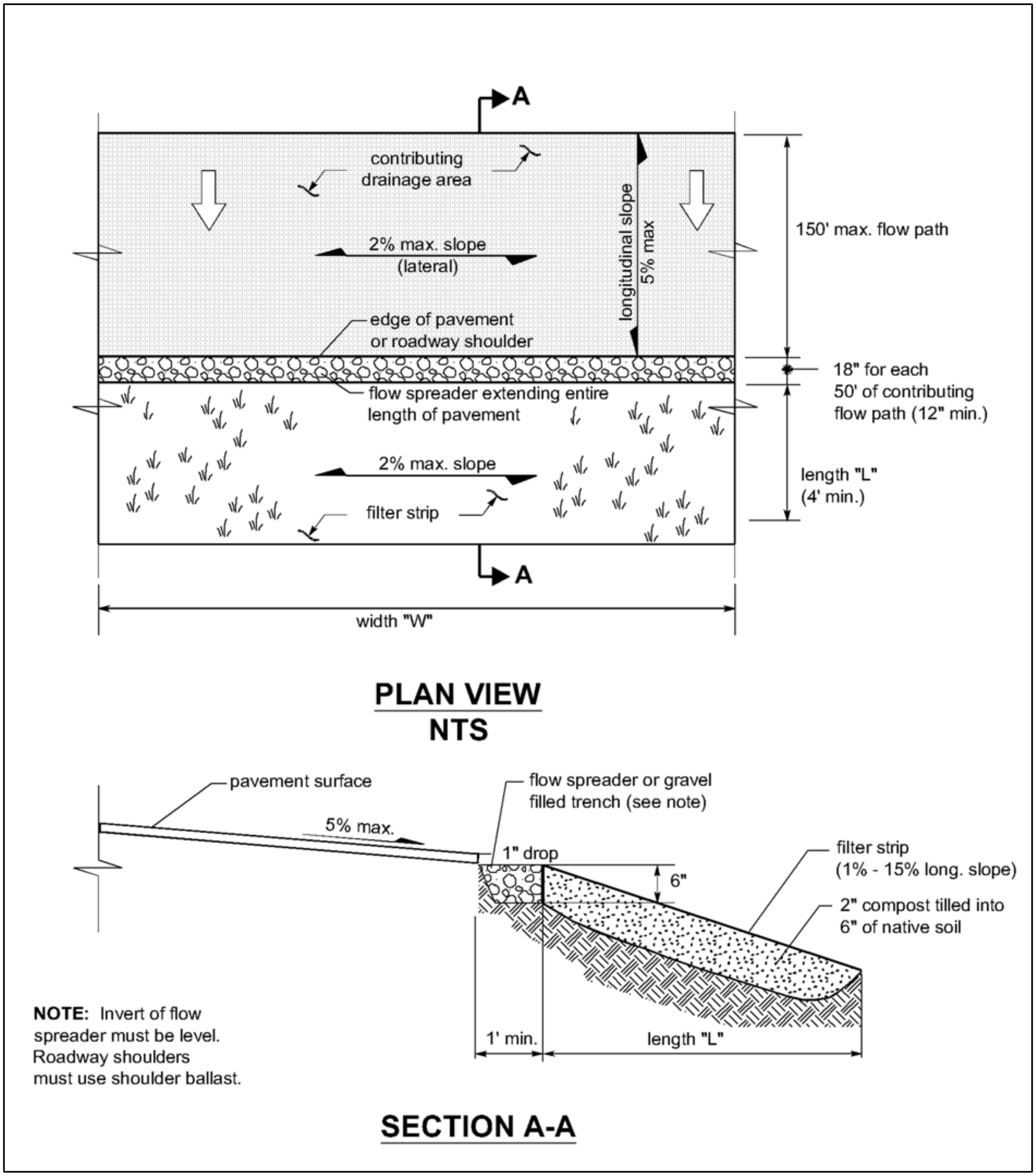


Figure 5 - 23. Typical Filter Strip

9.4.4.4 Sizing Procedure

1. Calculate the design flow depth using Manning's equation as follows:

   $KQ = (1.49A\,R^{0.67}\,s^{0.5})/n$

   Substituting for AR:

$KQ = (1.49Ty^{1.67} s^{0.5})/n$

Where:

$Ty = A_{rectangle, ft}^2$
y = $R_{rectangle}$, design depth of flow, ft. (1 inch maximum)
Q = peak Water Quality design flow rate based on WWHM or an approved continuous simulation model, ft^3/sec
K = A ratio of the peak 10-minute flow predicted by SBUH to the water quality design flow rate estimated using the WWHM. The value of K for offline systems is 3.5 and for online systems is 2.0.[1]
n = Manning's roughness coefficient
s = Longitudinal slope of filter strip parallel to direction of flow
T = Width of filter strip perpendicular to the direction of flow, ft.
A = Filter strip inlet cross-sectional flow area (rectangular), ft^2
R = hydraulic radius, ft.

Rearranging for y:

$y = [KQn/1.49Ts^{0.5}]^{0.6}$
y must not exceed 1 inch

2. Calculate the design flow velocity V, ft./sec., through the filter strip:

   V = KQ/Ty
   V must not exceed 0.5 ft./sec

3. Calculate required length, ft., of the filter strip at the minimum hydraulic residence time, t, of 9 minutes:

   L = tV = 540 V

9.4.4.5 Maintenance

Per Minimum Requirement #10, an operation and maintenance plan shall be prepared for all stormwater management facilities. See Volume 1, Appendix C, Maintenance Checklist #11 for specific maintenance requirements for filter strips. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during maintenance operation must be disposed of in a City approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed of in accordance with state and local waste regulations.

Facilities shall be constructed such that the facility can be easily inspected by one person. This may require construction of additional inspection ports or access manholes to allow inspection acces to be opened by one person.

1. As in swale design, an adjustment factor of K accounts for the differential between the Water Quality design flow rate calculated using WWHM and the SBUH design flow.

9.4.5 BMP T950 Narrow Area Filter Strip

9.4.5.1 Description

This section describes a filter strip design[1] for impervious areas with flowpaths of 30 feet or less that can drain along their widest dimension to grassy areas.

9.4.5.2 Applications/Limitations

A narrow area filter strip could be used at roadways with limited right-of-way, or for narrow parking strips. If space is available to use the basic filter strip design, that design should be used in preference to the narrow filter strip.

9.4.5.3 Design Criteria

Design criteria for narrow area filter strips are the same as specified for basic filter strips. The sizing of a narrow area filter strip is based on the length of flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flowpath).

1. Determine the length of the flowpath from the upstream to the downstream edge of the impervious area draining sheet flow to the strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer than the width of the impervious area.
2. Calculate the longitudinal slope of the filter strip (along the direction of unconcentrated flow), averaged over the total width of the filter strip.
    - The minimum slope size is 2 percent. If the slope is less than 2 percent, use 2 percent for sizing purposes.
    - The maximum allowable filter strip slope is 20 percent. If the slope exceeds 20 percent, the filter strip must be stepped so that the treatment areas between drop sections do not have a longitudinal slope greater than 20 percent. Provide erosion protection at the base and flow spreaders for the drop sections. Vertical drops along the slope must not exceed 12 inches in height. If this is not possible, a different treatment facility must be selected.
3. Select the appropriate filter strip length for the flowpath length and filter strip longitudinal slope (Steps 1 and 2 above) from the graph in Figure 5 - 24. Design the filter strip to provide this minimum length *L* along the entire stretch of pavement draining into it.

   To use the graph, find the length of the flowpath on one of the curves (interpolate between curves as necessary). Move along the curve to the point where the design longitudinal slope of the filter strip (x-axis) is directly below. Read the filter strip length on the y-axis which corresponds to the intersection point.

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1. This narrow area filter strip design method is included here because technical limitations exist in the basic design method which results in filter strips that are proportionately longer as the contributing drainage becomes narrower (a result that is counter-intuitive). Research by several parties is underway to evaluate filter strip design parameters. This research may lead to more stringent design requirements that would supersede the design criteria presented here

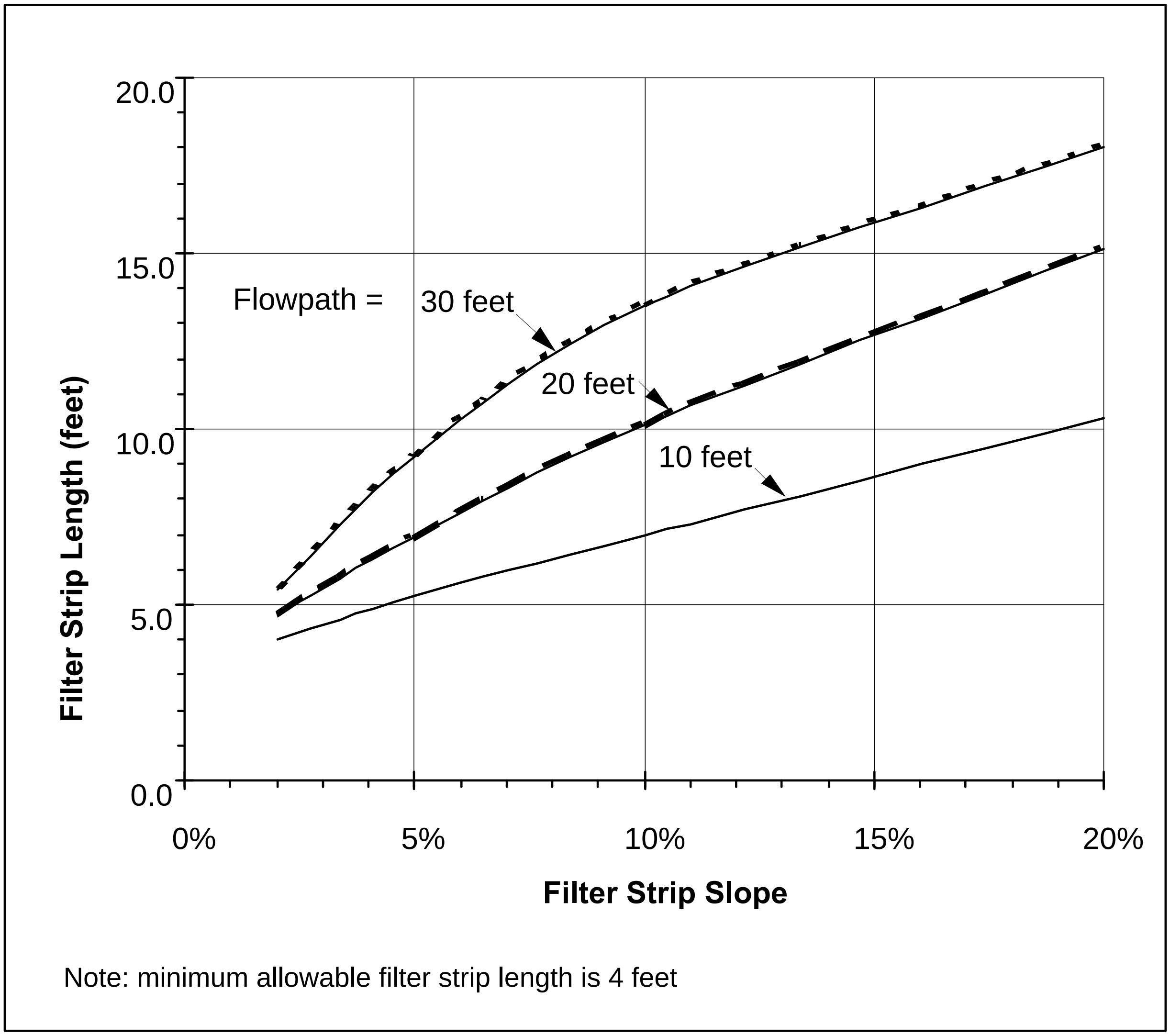

Figure 5 - 24. Filter Strip Lengths for Narrow Right-of-Way