SF-1. Introduction

Sheet Flow to Vegetated Filter Strips and **Sheet Flow to Conservation Areas** represent the practice of using adjacent vegetated areas to manage stormwater runoff by slowing runoff velocities and allowing sediment and attached pollutants to settle and be filtered by the vegetation.

Vegetated Filter Strips can be within the limits of disturbance on a development site and are engineered to minimum specifications, constructed, and stabilized with vegetation. However, effort should be made to preserve native vegetation if at all possible for a Vegetated Filter Strip

Conservation Areas are areas that meet minimum criteria in their natural condition, are protected from impacts during construction, and are protected from impacts after construction with an easement or other protective covenant. Conservation Areas can include stream buffers and can be reforested or enhanced with a vegetation management plan designed to support preferred vegetation, but are otherwise left undisturbed.

In both cases, stormwater runoff must enter the Filter Strip or Conservation Areas as sheet flow. Inflow from a pipe or channel can be converted to sheet flow with an engineered level spreader.

Sheet Flow to Vegetated Filter Strips and Conservation Areas can be used to:

- Partially manage the first one-inch of rainfall on-site (in conjunction with upgradient practices) when applying Sheet Flow to Vegetated Filter Strips or Conservation Areas with various Hydrologic Soil Groups (HSGs) (see **Table SF-1** and **Table SF-2**). Runoff reduction for Vegetated Filter Strips in C/D soils can be enhanced by using Soil Amendments (see **Appendix D**)

<u>**Note:** Soil Amendments do not generally apply to Sheet Flow to Conservation Areas since these areas are typically left undisturbed. The exception would be areas that are restored and reforested to act as conservation areas. (see **Section SF- 4.4**)</u>.

- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs) (See **Tables SF-3 and SF-4**)
- Retrofit existing developed areas

Vegetated Filter Strips and Conservation Areas can be incorporated into any green space and/or buffer (stream, screening, or other) requirements on site. **Figure SF-1** illustrates some typical applications for these practices, and **Figures SF-2 and SF-3** are schematics showing design characteristics outlined in this specification. **Table SF-5** is a design checklist to help guide the design process for the practices.

SF-1.1. Planning This Practice

Figure SF-1. Typical applications for Sheet Flow to Vegetated Filter Strip and Conservation Area

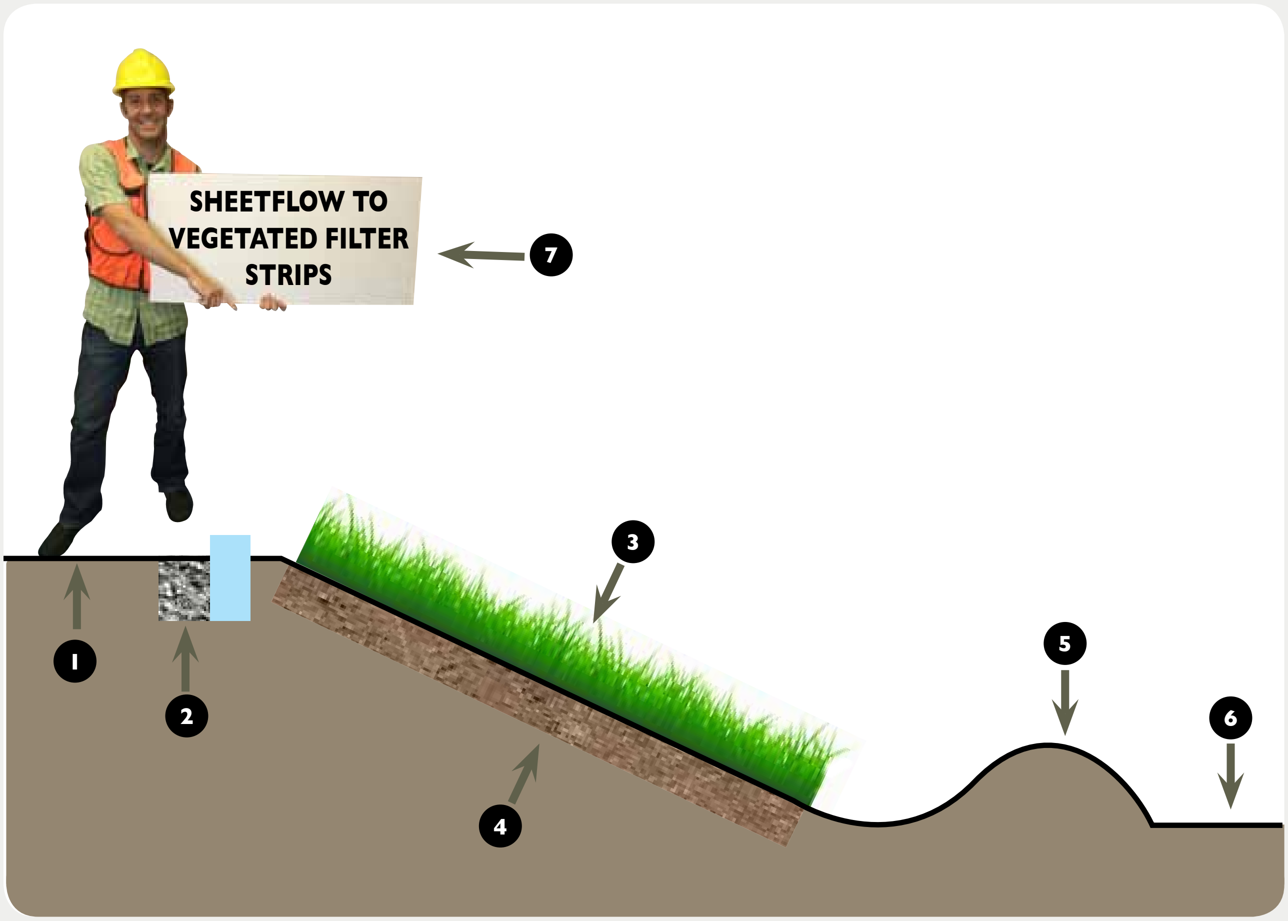
Sheet Flow from small impervious area to Vegetated Filter Strip

Enhancing runoff reduction with Soil Amendments

Sheet Flow to Conservation Area (stream buffer) along with Reforestation

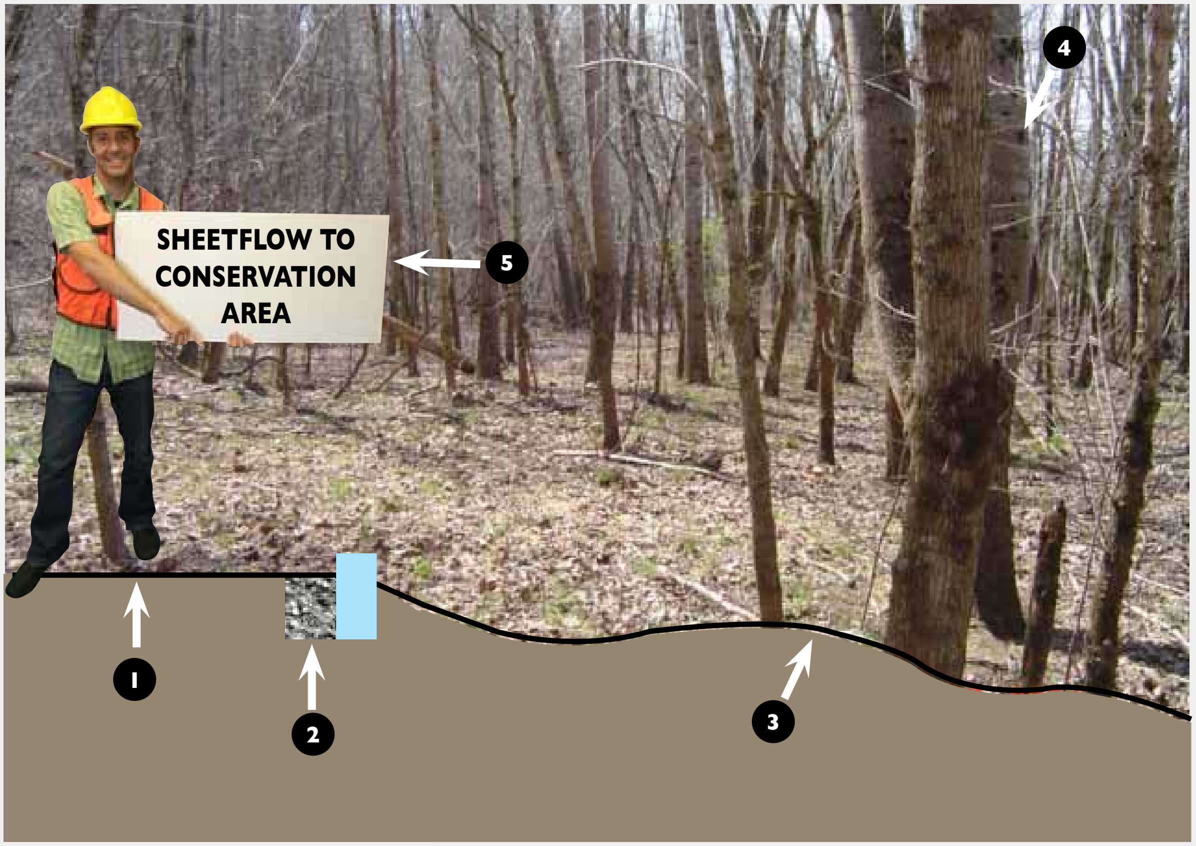
Waterway buffer sign used to mark boundary of Conservation Area

Figure SF-2. Schematic for Sheetflow to Vegetated Filter Strip



1. **Contributing impervious or pervious flow path** – Table SF-1 & Section SF-3.2
2. **Pretreatment gravel diaphragm/level spreader** – Section SF-4.2
3. **Vegetated filter strip (slope, width, vegetation)** – Table SF-1, Sections SF-3.2 & SF-4.4
4. **Soil amendments** – Section SF-4.1 & Appendix D of Manual
5. **Permeable berm** – Section SF-4.2
6. **Transition to natural vegetation or downstream BMP**
7. **Signage** – Section SF-4.5

Figure SF-3. Schematic for Sheetflow to Conservation Area



1. **Contributing impervious or pervious flow path** – Table SF-1 & Section SF-3.2
2. **Pretreatment gravel diaphragm/level spreader** – Section SF-4.2
3. **Conservation area (slope, geometry)** – Table SF-2 & Section SF-3.1
4. **Conservation area (vegetation)** – Section SF-4.4 & Appendix F of Manual
5. **Signage** – Section SF-4.5

SF-1.2. Sheet Flow to Filter Strips and Conservation Areas Design Options & Performance

Table SF-1 describes the basic design options for Sheet Flow to Vegetated Filter Strips and **Table SF-2** provides the same for Sheet Flow to Conservation Areas and the corresponding performance in terms of reducing the volume associated with one-inch of rainfall on the site. **Tables SF-3** and **SF-4** summarize the corresponding pollutant removal performance values for the two practices. Pollutant removal is provided for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table SF-1. Sheet Flow to Vegetated Filter Strips Description & Performance

Hydrologic Soil Group	Description	Applications	Performance[1]
A / B[2]	Standard Design – Geometry Slope and width[3]: 1% to 4% - min 35 ft. width; 4% to 6% - min 50 ft. width; 6% to 8% - min 65 ft. width; First 10 ft. must be ≤ 2% in all cases Inflow Sheet Flow: Pervious areas: max flow length ≤ 150 ft.; Impervious areas: max flow length ≤75 ft.; Concentrated Flow: ELS[4] lip = 13 lin. ft. per 1 cubic foot per second (cfs) Pre-Treatment: GD[4] at top of filter PB[4] at bottom of filter	Treat small areas of impervious cover (e.g., 5,000 sq. ft.); and/or Moderate areas (10,000 sq. ft.) turf-intensive land uses (sports fields, golf courses) close to source	6 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Filter Strip
C / D	Standard Design – Same as A/B soils	Same as A/B Soils	3 ft^3 of volume reduction for every 100 ft^2 of Filter Strip
C / D	Soil Amendments Same as A/B soils Filter Strip soil amendments[5]	Same as A/B Soils	6 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Filter Strip

[1] *Performance achieved toward reducing runoff from a one-inch rainfall.*
[2] *The plan approving authority may require verification of soil types, especially if the soils are disturbed during construction. Restoration of disturbed A/B soils should be verified in order to achieve the A/B HSG performance credit.*
[3] *Vegetated Filter Strips used during construction (Specification 3.25 in WVDEP, 2006) are required to be a minimum of 100 ft. in width to manage sediment loads typical of active construction sites.*
[4] *ELS = Engineered Level Spreader; GD = Gravel Diaphragm; PB = Permeable Berm*
[5] *Refer to Appendix D for Soil Amendment specifications*

Table SF-2. Sheet Flow to Conservation Areas Description & Performance

Hydrologic Soil Group	**Description**	**Applications**	**Performance**[1]
A / B	Standard Design – Geometry • Slope: - 0.5% to 3% - min 35 ft. width; - 3% to 6% - min 50 ft. width; - First 10 ft. must be ≤ 2% in all cases[2] Inflow • Sheet Flow: - Pervious areas: max flow length ≤ 150 ft.; - Impervious areas: max flow length ≤75 ft.; • Concentrated Flow: - ELS[3] lip = 13 lin. ft. per 1 cfs for areas with 90% vegetative cover[4]; - ELS lip = 40 lin. ft. per 1 cfs for forested or re-forested areas length Pre-Treatment: • GD[3] at top of Conservation Area	Adjacent to stream or wetland buffer or forest Conservation Area	9 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Conservation Area
C / D	Standard Design – Same as A/B soils	Same as A/B Soils	4 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Conservation Area

[1] *Performance achieved toward reducing runoff from a one-inch rainfall.*

[2] *For Conservation Areas with a varying slope, a pro-rated length may be computed only if the first 10 ft. is 2% or less.*

[3] *ELS = Engineered Level Spreader; GD = Gravel Diaphragm*

[4] *Vegetative cover is described in* ***Section SF-4.4***

Table SF-3. Total Pollutant Load Reduction Performance Values for Sheet Flow to Vegetated Filter Strips[1]

Hydrologic Soil Group	**Total Suspended Solids (TSS)**	**Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)[2]**
A / B	TSS = 75%	TP = 50% TN = 50%
C / D	TSS = 63%	TP = 25% TN = 25%
C / D w/ Soil Amendments	TSS = 75%	TP = 50% TN = 50%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration (EMC) as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).
[2] There is insufficient monitoring data to assign a nutrient removal rate to Filter Strips at this time. Therefore, Sheet Flow to Filter Strips does not receive any nutrient removal credit, and only moderate TSS removal; therefore, nutrient load reduction is a function of runoff volume reduction only.

Table SF-4. Total Pollutant Load Reduction Performance Values for Sheet Flow to Conservation Areas[1]

Hydrologic Soil Group	**Total Suspended Solids (TSS)**	**Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)[2]**
A / B	TSS = 94%	TP = 75% TN = 75%
C / D	TSS = 75%	TP = 50% TN = 50%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration (EMC) as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al (2008).
[2] There is insufficient monitoring data to assign a nutrient removal rate for Conservation Areas at this time. Therefore, Sheet Flow to Conservation Areas does not receive any EMC-based nutrient removal credit, and only moderate EMC-based TSS removal; therefore, nutrient load reduction is a function of runoff volume reduction only.

SF-1.3. Sheet Flow Design Checklist

Table SF-5. Sheet Flow Design Checklist

CHECKLIST

This checklist will help the designer through the necessary design steps for Sheet Flow to Vegetated Filter Strips and Conservation Areas.

- ☐ Check feasibility for site – **Section SF-3**
- ☐ Determine whether a Vegetated Filter Strip or a Conservation Area is applicable to the site – **Tables SF-1 and SF-2**
- ☐ Complete Design Compliance Spreadsheet to plan and confirm required Filter Strip dimensions and if any additional practices are needed to achieve overall site compliance – Design Compliance Spreadsheet & Chapter 3 of Manual
- ☐ Verify Filter Strip sizing guidance and make sure there is an adequate footprint on the site perimeter for Filter Strips or Conservation Areas – **Sections SF-4.1 & SF-4.2**
- ☐ Check design adaptation appropriate to the site – **Section SF-6**
- ☐ Design Filter Strips in accordance with design criteria and typical details –**Sections SF-2 & SF-4**
- ☐ Provide all necessary plan view, profile, and cross-section details along with elevations, materials specifications, grading and construction sequence and notes

SF-2. Typical Details

These details show typical configurations for Sheet Flow to a Conservation Area (**Figure SF-4**), pretreatment at the edge of a Conservation Area (**Figure SF-5**), and several configurations and options for engineered level spreaders when inflow is comprised, at least in part, of concentrated flow and/or channel flow (**Figure SF-6 through SF-10**). See Section **SF-4.2** for more detail on engineered level spreaders.

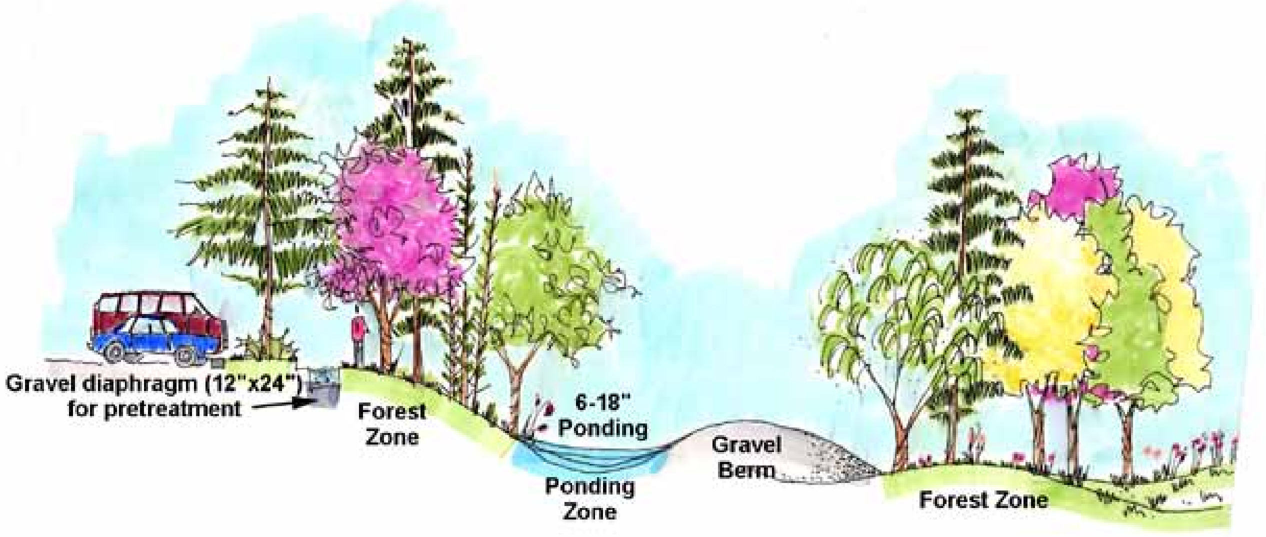


Figure SF-4. Typical Sheet Flow to Conservation Area

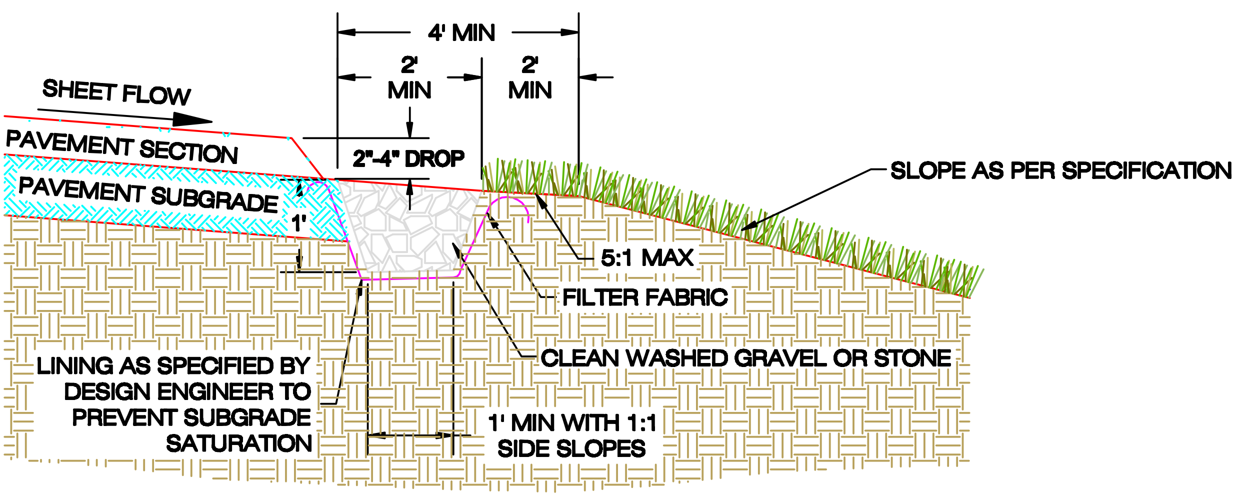


Figure SF-5. Sheet Flow Gravel Diaphragm Pretreatment to Filter Strip or Conservation Area – Typical Section

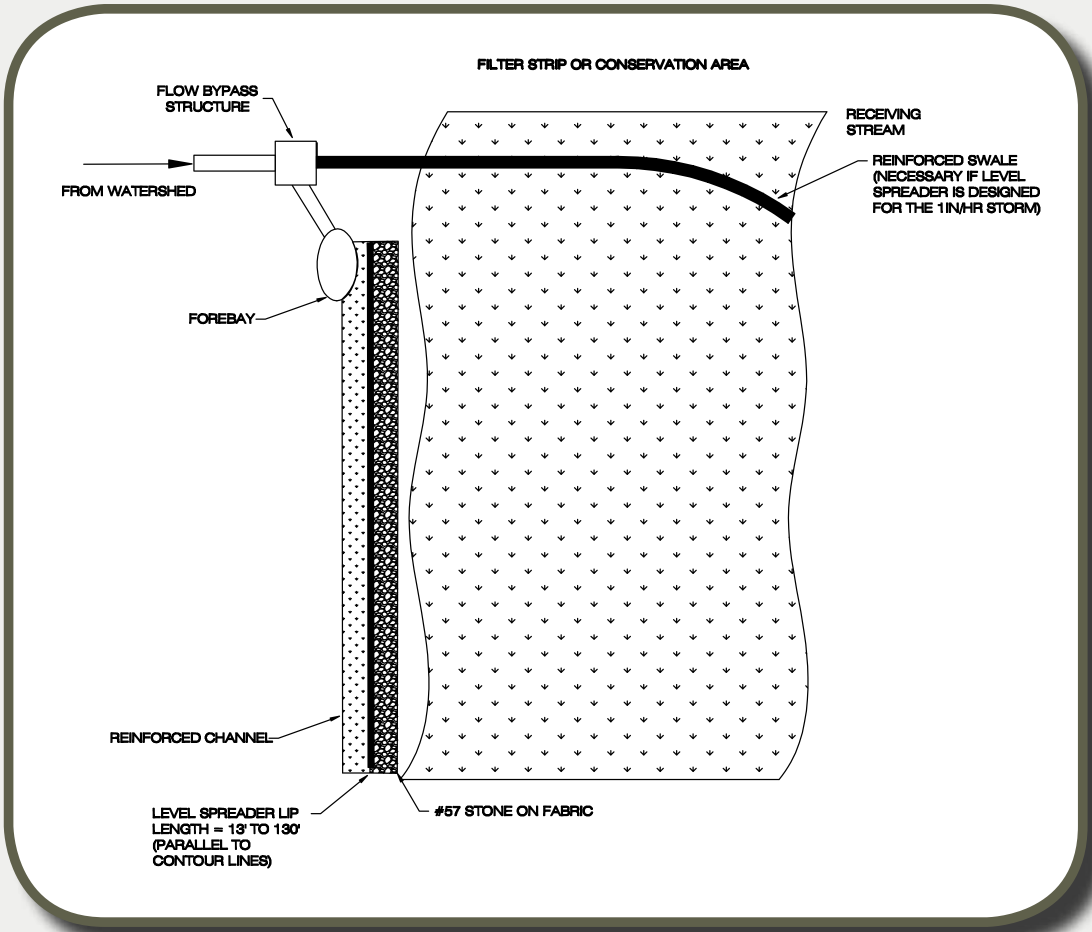


Figure SF-6. Concentrated Flow Engineered Level Spreader (with flow splitter and forebay) to Filter Strip or Conservation Area – Typical Plan View

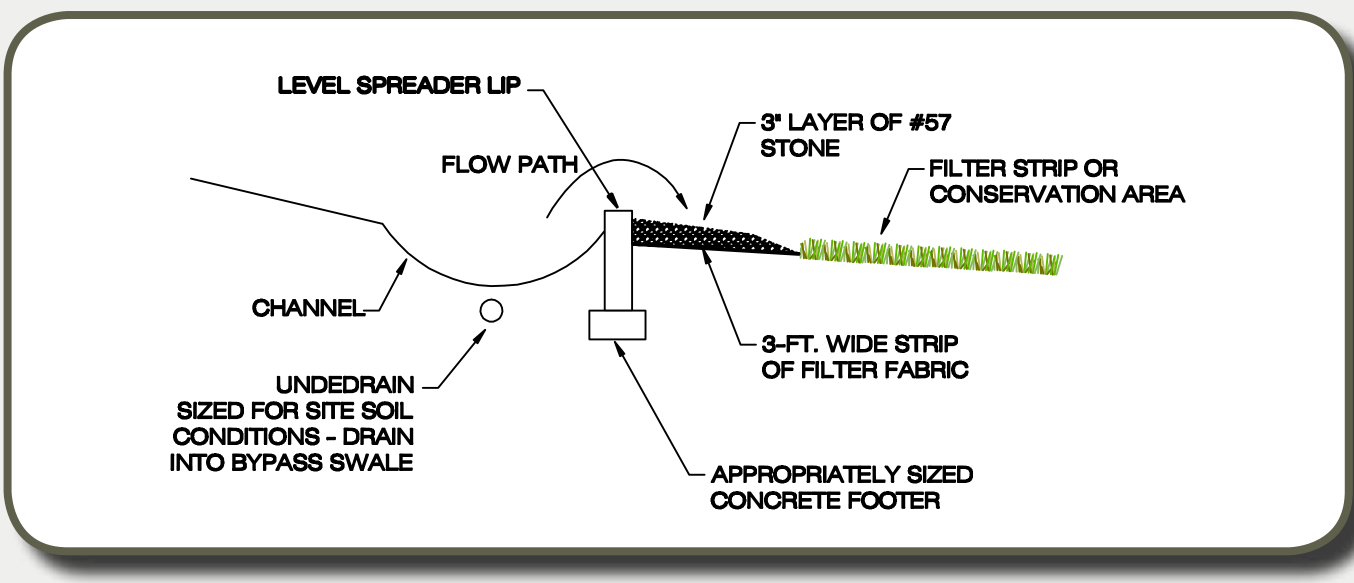


Figure SF-7. Concentrated Flow Engineered Level Spreader to Filter Strip or Conservation Area – Typical Section (Hathaway and Hunt, 2006)

Figure SF-8. Image of Slotted Trench Drain Level Spreader into Conservation Area (Source: CONTECH Construction Products, Inc.)

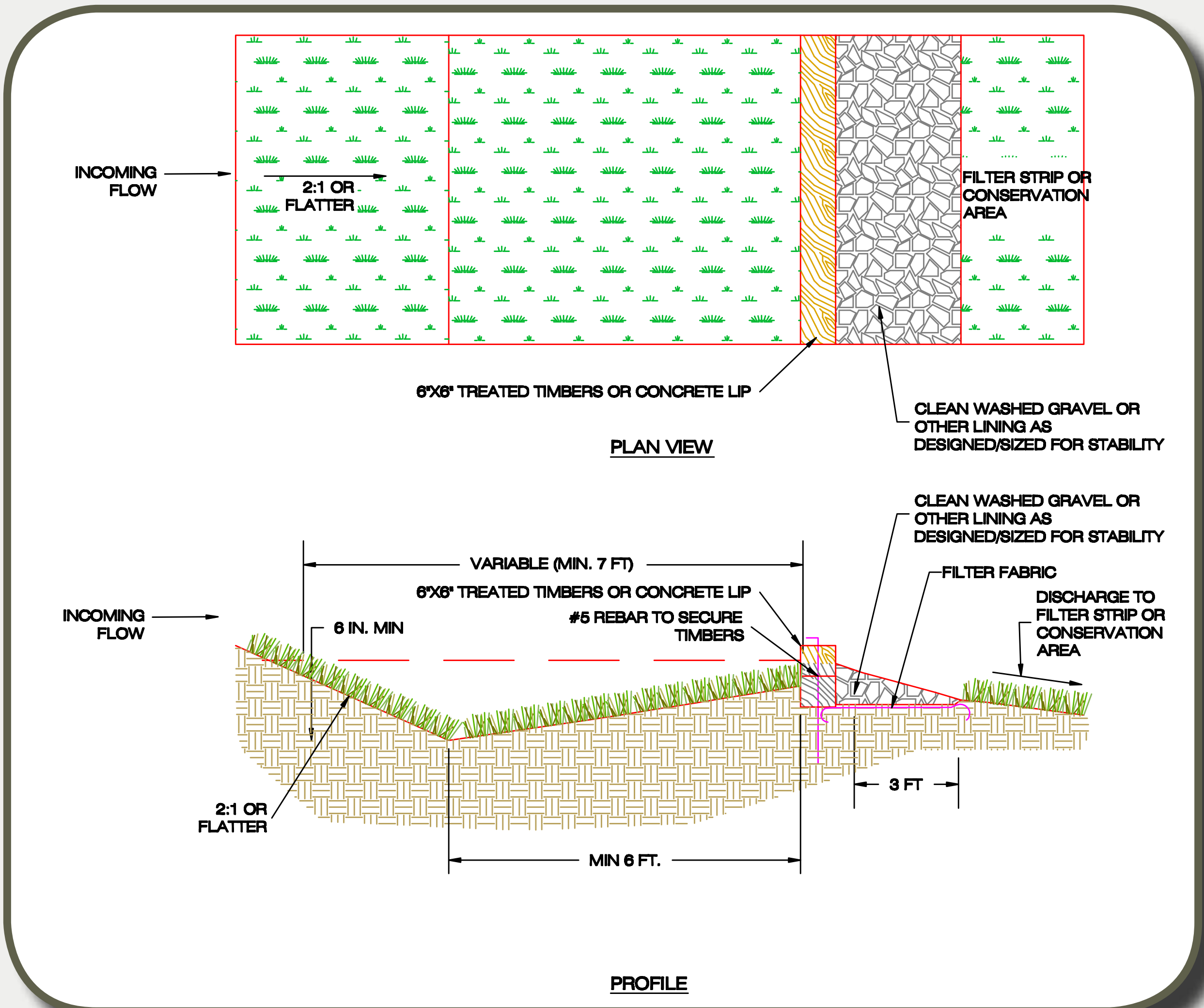


Figure SF-9. Channel Flow Level Spreader to Filter Strip or Conservation Area – Plan View and Section View

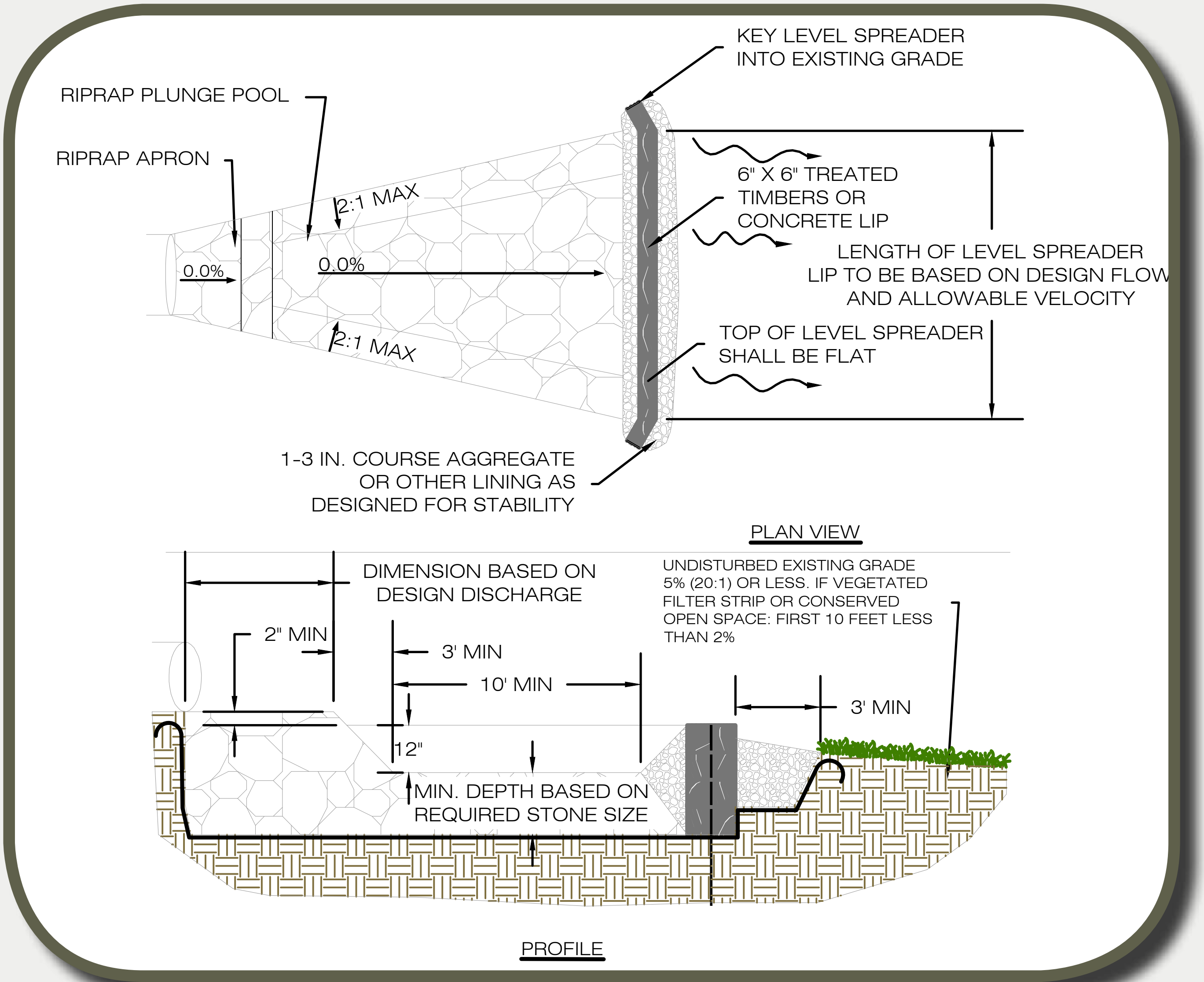


Figure SF-10. Concentrated (Pipe) Inflow Level Spreader to Filter Strip or Conservation Area – Plan and Section (Source: Henrico, Co, VA)

SF-3. Feasibility Criteria and Design Considerations

Vegetated Filter Strips and Conservation Areas can be applied on most sites where adequate space for pervious vegetated areas is available. Highly permeable soils are advantageous and are credited with more runoff reduction; similarly, relatively mild slopes will also improve performance. In cases of tight or moderate soils (HSG C & D soils), Soil Amendments can be added to improve the performance of Vegetated Filter Strips.

Vegetated Filter Strips are also extremely applicable to linear developments such as roads and highways.

SF-3.1. Conservation Areas

The most common design applications of Conservation Areas are on sites that are hydrologically connected to a protected stream buffer, wetland buffer, floodplain, forest Conservation Area, or other protected lands. Conservation Areas are an ideal component of the "outer zone" of stream buffers which normally receives runoff as sheet flow. Care should be taken to locate all energy dissipaters or flow spreading devices outside of the protected area.

Designers may apply a runoff reduction credit to any impervious or managed turf cover that is hydrologically connected and effectively treated by a protected Conservation Area that meets the following eligibility criteria:

- The goal of establishing Conservation Area is to protect a vegetated area contiguous to a receiving system, such as a stream or natural channel, for treating stormwater runoff. Establishing isolated Conservation Area pockets on a development site may not achieve this goal unless they effectively serve to "buffer" the receiving stream from surface runoff to the receiving system. Therefore, a locality may choose to establish goals for minimum acreage to be conserved (in terms of total acreage or percentage of the total project site), and the physical location (adjacent to a stream, or other criteria) in order for the cumulative Conservation Area to qualify for the runoff reduction credit.
- No major disturbance may occur within the Conservation Area during or after construction (i.e., no clearing or grading is allowed except temporary disturbances associated with incidental utility construction, restoration operations, or management of nuisance vegetation). The Conservation Area shall not be stripped of topsoil. Some light grading may be needed at the boundary using tracked vehicles to prevent compaction.
- The limits of disturbance should be clearly shown on all construction drawings and protected by acceptable signage and erosion control measures.
- A long term vegetation management plan must be prepared to maintain the Conservation Area in a natural vegetative condition. Generally, Conservation Area management plans do not encourage or even allow any active management. However, a specific plan should be developed to manage the unintended consequences of passive recreation, control invasive species, provide for tree and understory maintenance, etc. Managed turf is not considered an acceptable form of vegetative management, and only the passive recreation areas of dedicated parkland are eligible for the practice (e.g., the actively used portions of ball fields and golf courses are not eligible), although Conservation Areas can be ideal treatment practices at the edges of turf-intensive land uses.
- The Conservation Area must be protected by a perpetual easement or deed restriction that assigns the responsible party to ensure that no future development, disturbance, or clearing may occur within the area.
- The practice does not apply to jurisdictional wetlands that are sensitive to increased inputs of stormwater runoff (e.g., bogs and fens).

SF-3.2. Key Feasibility Criteria for Filter Strips and Conservation Areas

Available Space. Space requirements for Vegetated Filter Strips vary according to the ground slope and ranges from 35 feet to 65 feet in width (parallel to the flow). Vegetated Filter Strips applied as a runoff reduction practice are smaller in width than those utilized on active construction sites (**Specification 3.25** in WVDEP, 2006). The larger width is required on active construction sites due to the significantly higher anticipated sediment loading. After the development site has been stabilized and the construction has been terminated, the width of the Filter Strip can be reduced to the designated width.

The width of Conservation Areas is similarly dependent on slope and varies from 35 feet to 50 feet or more. The maximum allowable slope, and therefore maximum width, on a Conservation Area is less than that of Filter Strips because the vegetation in Conservation Areas will generally consist of more woody vegetation and not have the thick ground cover to protect the soil from eroding.

The length of Filter Strips or Conservation Areas (perpendicular to the flow) is typically equal to that of the contributing drainage area when runoff enters as sheet flow. When runoff enters as concentrated flow, level spreaders will determine the minimum design length. The length of most Conservation Area applications will be based on the property boundary, stream segment, or other physical feature.

Filter Strips and Conservation Areas are generally applied in two types of situations:

1. The interior of the site where the Filter Strip is applied between the targeted drainage area and the storm drainage conveyance infrastructure (pipe or channel); and
2. The perimeter of the site where vegetated Filter Strips or Conservation Areas manage the runoff as it leaves the site or drains to an offsite conveyance system.

Typical commercial, industrial, or business land uses may not have adequate space for Filter Strips on the interior. Parking islands, landscape areas, and other small pockets of open space are typically better suited for other BMPs, such as bioretention. On the other hand, large institutional campus style developments and large scale residential developments may have numerous opportunities to apply both Filter Strips and Conservation Areas within the proposed infrastructure on the interior of the site. Designers should focus attention on the soil types and slopes when conducting the initial site assessment for the Watershed Protection Elements (see Chapter 2). Three of the Watershed Protection Elements (preserve ecologically sensitive areas; protect trees and other vegetation; and protect native soils) offer opportunities to identify favorable locations for Vegetated Filter Strips and Conservation Areas, both of which can provide very inexpensive and effective runoff reduction and pollutant removal credits.

Designers Should Consider These Practices During Initial Site Assessment

Designers should focus attention on opportunities to implement Vegetated Filter Strips and Conservation Areas when conducting the initial site assessment. This includes permeable soils and flat slopes. Both variants provide very inexpensive and effective runoff reduction and pollutant removal credits.

Site Topography. Filter Strips and Conservation Areas are applicable on sites with rolling or moderate topography. The grade of a proposed Vegetated Filter Strip can be constructed as needed to accommodate the Filter Strip or the overall site design, from 1% to 8% (with the Filter Strip designed accordingly). A minimum of 1% is recommended for any constructed Filter Strips in order to ensure positive drainage, while a Filter Strip designated on natural grade can be as low as 0.5% if allowed by the local plan approving authority. In either case, the first 10 feet must be 2% or less to adequately slow down the runoff as it enters the Filter Strip.

Conservation Areas, on the other hand, are not graded (and actually protected from any impacts during construction), and the designated width of the Conservation Area is determined by the existing grade, ranging from 0.5% to approximately 6% (average slope). Similar to Filter Strips, the first 10 feet must be 2% or less to ensure low velocities. If necessary due to site topography, this 10-foot zone can be constructed as a transition zone upgradient from the Conservation Area in order to achieve the necessary (relatively flat) slope. This is the one exception to Conservation Areas not being graded or disturbed during construction.

Water Table and Bedrock. Filter Strips and Conservation Areas are not constrained by groundwater or bedrock provided these conditions do not impact the growth and health of vegetation.

Soils. Vegetated Filter Strips are appropriate for all soil types, except fill soils. The runoff reduction rate and corresponding pollutant removal, however, are dependent on the underlying HSGs (see **Tables SF-1** through **SF-4** above) and whether soils receive compost amendments.

Soil Amendments on Fill Soils Do Not Achieve the Same Credit

Soil amendments can be applied to fill soils to improve the abstraction and vegetative cover, but will not achieve the runoff reduction credit of C/D soils with soil amendments. Amended fill soils can be credited with the runoff reduction and pollutant removal credit of C/D soils without soil amendments.

Contributing Drainage Area. The contributing drainage area to Vegetated Filter Strips and Conservation Areas is limited by the longest flow path length and not the total acreage (since the total acreage of a linear drainage area is irrelevant when the Filter Strip is applied to the entire length or border). As a rule, flow tends to concentrate after 75 feet of flow length for impervious surfaces, and 150 feet for pervious surfaces (Claytor, 1996). When flow concentrates, it moves too rapidly to be effectively treated by a Filter Strip, unless an engineered level spreader or energy dissipater is used. A perimeter level spreader (such as a gravel diaphragm – **Figure SF-5**) will serve to ensure an even distribution of runoff into the Filter Strip.

When the existing flow at a site is concentrated, a Grass Swale (see **Specification 4.2.5**) and level spreader should be used to disperse the flow into the Filter Strip or Conservation Area.

In cases of Conservation Areas that also serve as stream buffers, the contributing drainage areas can be substantial since the stream or buffer is at the bottom of the contributing drainage area. The runoff will often be conveyed to the Conservation Area by a storm drain or armored channel to protect the slopes from being eroded. Special design considerations must be made to distribute the flow across as wide an area as possible. A level spreader, such as those depicted in **Figures SF-6 through SF-10** must be designed using the design flow of the pipe or drainage system. One alternative is to transition the flow from the pipe or channel with traditional outlet protection and then turn the flow perpendicular to the buffer width into a vegetated channel at a 0% to 0.5% grade, allowing the entire downstream edge of the channel to serve as a level spreader (**Figure SF-6 and SF-9**; also refer to **Specification 3.19** in WVDEP, 2006).

Hotspot Land Uses. Vegetated Filter Strips should not receive hotspot runoff, since the runoff may stress vegetation and/or infiltrated runoff could cause groundwater contamination.

For a list of potential stormwater hotspots, please consult Chapter 6 of the Manual.

Turf-Intensive Land Uses. Both Conservation Areas and Vegetated Filter Strips are appropriate to treat managed turf and the actively-used areas of sports fields, golf courses, parkland, and other turf-intensive land uses (these areas should also be managed by a nutrient management plan that applies to the Vegetated Filter Strip.)

Floodplains. Conservation Areas are acceptable in floodplains. Vegetated Filter Strips should generally be outside of the floodplain and/or buffer areas.

4.2.1. Sheet Flow to Vegetated Filter Strips and Conservation Areas (SF)

SF-4. Design Criteria

The design of Vegetated Filter Strips (and the screening of Conservation Areas) is relatively straightforward in terms of the geometry (dimensions and slope) of the contributing drainage area and the pervious area designated to receive runoff. The additional design elements of improving the performance of marginal soils with Soil Amendments, enhancing the vegetation, and establishing sheet flow with level spreaders are discussed below.

SF-4.1. Soil Amendments

Compost Soil Amendments will enhance the runoff reduction capability of a vegetated Filter Strip when located on Hydrologic Soil Groups (HSG) C and/or D soils, and where necessary, disturbed HSG B soils subject to the following design requirements:

- Approved compost material shall meet the material specifications provided in **Appendix D.**
- The soils in the area of the vegetated Filter Strip should be tested in accordance with **Appendix D** to ascertain pre-construction soil properties at proposed amendment areas (soils verified to be HSG B soils do not necessarily need amendments - the local plan approving authority may require field tests to verify the HSG of the soil in order to approve the use of the runoff reduction credit without amendments). Testing will also confirm or characterize any potential drainage problems and determine what, if any, further soil amendments may be needed.
- The compost amendments should extend over the full length and width of the Filter Strip.
- The amount of approved compost material and the depth to which it must be incorporated is provided in **Table SF-6** (and discussed further in **Appendix D**).
- The amended area will be raked to achieve the most level slope possible without using heavy construction equipment, and it will be stabilized rapidly with perennial grass and/or herbaceous species.
- If slopes exceed 3%, a protective biodegradable fabric or matting (e.g., **Specification 3.13** in WVDEP, 2006) should be installed to stabilize the site prior to runoff discharge.
- Compost amendments should not be incorporated until the gravel diaphragm and/or engineered level spreader are installed (see Section SF-7.2).
- The local plan approval authority may require compost amendments on disturbed HSG B soils in order to receive credit as a vegetated Filter Strip unless the designer can provide verification of the adequacy of the disturbed soil type, texture, and profile to function as a Filter Strip.

Table SF-6. Short-Cut Method to Determine Compost and Incorporation Depths

	Contributing Impervious Cover (IC) to Soil Amendment (SA) Area Ratio [1]			
	IC/SA = 0 [2]	**IC/SA = 0.5**	**IC/SA = 0.75**	**IC/SA = 1.0** [3]
Compost (in) [4]	4	6	8	10
Incorporation Depth (in)	8	12	16	18 to 24
Incorporation Method	Rototiller	Tiller	Subsoiler	Subsoiler

Notes:

[1] IC = contributing impervious cover (sq. ft.) and SA = surface area of compost amendment (sq. ft.)

[2] For amendment of compacted lawns that do not receive off-site runoff

[3] In general, IC/SA ratios greater than 1 should be avoided

[4] Average depth of compost added

Once the area and depth of the soil amendments are known, the designer can estimate the total amount of compost needed, using an estimator developed by TCC (1997):

$$C = A * D * 0.0031$$

Where: C = compost needed (cu. yds.)
A = area of soil amended (sq. ft.)
D = depth of compost added (in.)
0.0031 = unit conversion factor

SF-4.2. Pretreatment: Diaphragms, Berms and Level Spreaders

Gravel Diaphragms: A pea gravel diaphragm at the top of the slope is required for both Conservation Areas and Vegetated Filter Strips that receive sheet flow. The pea gravel diaphragm is created by excavating a two-foot wide and one-foot deep trench that runs on the same contour at the top of the Filter Strip. The diaphragm serves two purposes. First, it acts as an energy dissipating pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the Filter Strip. Refer to **Figure SF-5**.

- The flow should travel over the impervious area and to the practice as sheet flow and then drop 2 to 4 inches onto the gravel diaphragm. The drop helps to prevent runoff from running laterally along the pavement edge, where grit and debris tend to build up (thus allowing by-pass of the Filter Strip).
- A layer of filter fabric should be placed between the gravel and the underlying soil trench.
- If the contributing drainage area is steep (6% slope or greater), larger stone (clean bank-run gravel that meets AASHTO #57 grade – blend of # 5, 6, & 7) should be used in the diaphragm.
- If the contributing drainage area is solely turf (e.g., sports field), then the gravel diaphragm may be eliminated.

Engineered Level Spreaders. The design of engineered level spreaders should conform to the following design criteria based on recommendations of Hathaway and Hunt (2006), or a locally approved standard that meets the intent of these criteria, in order to ensure non-erosive sheet flow into the vegetated buffer area. **Figures SF-6, SF-7, SF-8 and SF-9** represent level spreader configurations. **Figure SF-6** includes a bypass structure that diverts the design storm to the level spreader, and bypasses the larger storm events around the Conservation Area or Vegetated Filter Strip through an improved channel.

An alternative approach is a modified **Specification 3.17** from WVDEP (2006) outlet protection design depicted in **Figure SF-8** where pipe or channels discharge at the landward edge of a floodplain or stream buffer. The entire flow is directed through a stilling basin energy dissipater and then a level spreader such that the entire design storm for the conveyance system (typically a 10-year frequency storm) is discharged as sheet flow through the buffer. Also refer to Henrico County's Environmental Program Manual, Chapter 9, Minimum Design Standard 9.01 "Energy Dissipater" at: http://www.co.henrico.va.us/works/environmental-manual.html.

Key design elements of the engineered level spreader, as provided in **Figures SF-6 through SF-9**, include the following:

- High flow bypass provides safe passage for larger design storms through the Filter Strip. The bypass channel should accommodate all peak flows greater than the water quality design flow.
- A forebay should have a maximum depth of 3 feet and gradually transition to a depth of 1 foot at the level spreader lip (**Figure SF-6**). The forebay is sized such that the surface area is 0.2% of the contributing impervious area (a forebay is not necessary if the concentrated flow is from the outlet of an extended detention basin or similar practice).
- The length of the level spreader should be determined by the type of filter area and the design flow:
  - o 13 feet of level spreader length per every 1 cfs of inflow for discharges to a Vegetated Filter Strip or Conservation Area consisting of native grasses or thick ground cover;
  - o 40 feet of level spreader length per every 1 cfs of inflow when the spreader discharges to a Conservation Area

consisting of forested or reforested buffer (Hathaway and Hunt, 2006).

- o Where the Conservation Area is a mix of grass and forest (or re-forested), establish the level spreader length by computing a weighted average of the lengths required for each vegetation type.
- o The minimum level spreader length is 13 feet and the maximum is 130 feet.
- o For the purposes of determining the Level Spreader length, the peak discharge shall be determined using the Modified Curve Number Method, described in **Appendix E**.

- The level spreader lip should be concrete, wood or other non-erodible material with a well-anchored footer.
- The ends of the level spreader section should be tied back into the slope to avoid scouring around the ends of the level spreader; otherwise, short-circuiting of the facility could create erosion.
- The width of the level spreader channel on the up-stream side of the level lip should be three times the diameter of the inflow pipe, and the depth should be 9 inches or one-half the culvert diameter, whichever is greater.
- The level spreader should be placed 3 to 6 inches above the downstream natural grade elevation to avoid turf buildup. In order to prevent grade drops that re-concentrate the flows, a 3-foot long section of AASHTO # 3 stone, underlain by filter fabric, should be installed just below the spreader to transition from the level spreader to natural grade.
- Vegetated receiving areas down-gradient from the level spreader must be able to withstand the force of the flow coming over the lip of the device. It may be necessary to stabilize this area with temporary or permanent rolled erosion control products (**Specification 3.13** in WVDEP, 2006) in accordance with the calculated velocity (on-line system peak, or diverted off-line peak) and material specifications, along with seeding and stabilization in conformance with the West Virginia Erosion and Sediment Control Manual.

Permeable Berm: Vegetated Filter Strips should be designed with a permeable berm at the toe of the Filter Strip to create a shallow ponding area. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm or through a gravel lens in the berm with a perforated pipe. During larger storms, runoff may overtop the berm (Cappiella et al., 2006). The permeable berm should have the following properties:

- A wide and shallow trench, 6 to 12 inches deep, should be excavated at the upstream toe of the berm, parallel with the contours.
- Media for the berm should consist of 40% excavated soil, 40% sand, and 20% pea gravel.
- The 6 to 12 inch high berm should be located downgradient of the excavated depression and should have gentle side slopes to promote easy mowing (Cappiella et al., 2006).
- Stone may be needed to armor the top of berm to handle extreme storm events.
- A permeable berm is not needed when Vegetated Filter Strips are used as pretreatment to another stormwater practice.

SF-4.3. Conveyance and Overflow

Vegetated Filter Strips and Conservation Areas are generally considered on-line practices (refer to **Chapter 3** for definition of on-line and off-line practices). The limitations on the contributing drainage area for sheet flow applications will minimize the need for large storm conveyance and overflow provisions. However, in cases where inflow is from a pipe or channel and must be converted to sheet flow, the Filter Strip or Conservation Area can be taken off-line by using a diversion structure in conjunction with the level spreader. The goal is to prevent the conveyance system design storm discharge (usually the 10-year storm peak rate) from scouring a channel or rill through the practice. **Figure SF-6** plan view shows a diversion structure in conjunction with a level spreader.

SF-4.4. Vegetation

Conservation Areas. No grading or clearing of native vegetation is allowed within the Conservation Area unless it is in compliance with an invasive species management plan or a vegetation enhancement plan. In general, an operation and management plan for maintaining a healthy vegetative cover should be developed for the property and approved by the plan approving authority as conditions of the easements and runoff reduction credits.

Reforested Conservation Areas. At some sites, the proposed stream buffer or Conservation Area may be in turf or meadow cover, or overrun with invasive plants and vines. In these situations, a landscape architect or horticulturalist should prepare a reforestation or restoration plan. The entire area can be planted with native trees and shrubs or planted to achieve a gradual transition from turf to meadow to shrub and forest. Trees and shrubs with deep rooting capabilities are recommended for planting to maximize soil infiltration capacity. Over-plant with seedlings for fast establishment and to account for mortality. Plant larger stock at desired spacing intervals (25 to 40 feet for large trees) using random spacing (Cappiella et al., 2006). Plant ground cover or a herbaceous layer to ensure rapid vegetative cover of the surface area.

Vegetated Filter Strips. Vegetated Filter Strips should be planted at such a density to achieve a 90% grass/herbaceous cover after the second growing season. Filter Strips should be seeded, not sodded. Seeding establishes deeper roots, and sod may have muck soil that is not conducive to infiltration (Wisconsin DNR, 2007). The Filter Strip vegetation may consist of turf grasses, meadow grasses, other herbaceous plants, shrubs, and trees, as long as the primary goal of at least 90% coverage with grasses and/or other herbaceous plants is achieved. Designers should choose vegetation that stabilizes the soil and is salt tolerant. Vegetation at the toe of the filter, where temporary ponding may occur behind the permeable berm, should be able to withstand both wet and dry periods. The planting areas can be divided into zones to account for differences in inundation and slope.

SF-4.5. Signage

Signage is a valuable maintenance tool since landscaping contractors may not be aware of the designation of pervious areas specifically designed Filter Strips. There are numerous examples of pretreatment swales and vegetated Filter Strips being managed with pesticides and fertilizers along with the rest of the managed turf on a site, which may be prevented by installing signage at the site.

Signage indicating the designation of Conservation Areas is mandatory to ensure that current and future owners are aware of the designation (in addition to all the appropriate legal documentation that is conveyed with the property) and the accompanying operation and management plan.

4.2.1. Sheet Flow to Vegetated Filter Strips and Conservation Areas (SF)

SF-5. Materials Specifications

Recommended material specifications for Vegetated Filter Strips and Conservation Areas are shown in **Table SF-7**.

Table SF-7. Vegetated Filter Strip and Conservation Area Materials Specifications

Material	Specification	Quantity
Gravel Diaphragm	Pea Gravel (AASHTO #8 or ASTM equivalent) or where steep (6% +) use clean bank-run AASHTO #57 or ASTM equivalent (1-inch maximum).	Diaphragm should be 2 ft. wide, 1 ft. deep, and at least 3 in. below the edge of pavement.
Permeable Berm	40% excavated soil, 40% sand, and 20% pea gravel to serve as the media for the berm.	
Geotextile	Needled, non-woven, polypropylene geotextile meeting the following specifications: Grab Tensile Strength (ASTM D4632): > 120 lbs. Mullen Burst Strength (ASTM D3786): > 225 lbs./sq. in. Flow Rate (ASTM D4491): > 125 gpm/sq. ft. Apparent Opening Size (ASTM D4751): US #70 or #80 sieve	
Engineered Level Spreader	Level Spreader lip should be concrete, timber, or other rigid material; Reinforced channel on upstream of lip: Specification 3.13 in WVDEP (2006): Rolled Erosion Control Products (biodegradable or permanent if warranted by velocities) See Hathaway and Hunt (2006) or Henrico County Environmental Program Manual (Henrico County, no date), or WVDEP (2006).	
Erosion Control Fabric or Matting	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least two growing seasons Specification 3.13 in WVDEP, 2006).	
Topsoil	If existing topsoil is inadequate to support dense turf growth, imported top soil (loamy sand or sandy loam texture), with less than 5% clay content, corrected pH at 6 to 7, a soluble salt content not exceeding 500 parts per million, and an organic matter content of at least 2% shall be used. Topsoil shall be uniformly distributed and lightly compacted to a minimum depth of 6 to 8 inches.	
Compost	Compost shall be derived from plant material and provided by a member of the U.S. Composting Seal of Testing Assurance program, as outlined in **Appendix D**.	

SF-6. Design Adaptations

SF-6.1. Karst Terrain

Conservation Area areas are highly recommended in karst terrain, particularly when storm flow discharges to the outer boundary of a karst protection area (see CSN, 2009).

Vegetated Filter Strips can also be used to treat runoff from small areas of impervious cover (e.g., less than 5,000 square feet).

In no case should the use of Vegetated Filter Strips or Conservation Areas be considered as a replacement for an adequate receiving system for developed-condition stormwater discharges, unless the adequacy of the design has been demonstrated as consistent with good engineering practice, design sources for karst terrain (such as CSN, 2009), and the local plan approving authority.

SF-6.2. Linear Highway Sites

Vegetated Filter Strips are highly recommended to treat highway runoff if the median and/or road shoulder is wide enough to provide an adequate flow path.

SF-6.3. Stormwater Retrofitting

Vegetated Filter Strips and Conservation Areas are versatile practices for retrofitting. Some of the chief considerations for retrofitting are accounting for the current use and/or condition of pervious areas and determining if they can be successfully re-designated as a runoff management practice.

For more information on retrofitting, see the Center for Watershed Protection's manual, Urban Stormwater Retrofit Practices (Schueler et al., 2007).

SF-7. Construction and Installation

SF-7.1. Construction Sequence for Conservation Areas

The Conservation Areas must be fully protected during the construction stage of development and kept outside the limits of disturbance on the Erosion and Sediment (E&S) Control Plan.

- No clearing, grading or heavy equipment access is allowed except temporary disturbances associated with incidental utility construction, restoration operations or management of nuisance vegetation.
- The perimeter of the Conservation Area shall be protected by super silt fence, chain link fence, orange safety fence, or other measures to prevent sediment discharge and access by construction equipment.
- The limits of disturbance should be clearly shown on all construction drawings and identified and protected in the field by acceptable signage, silt fence, snow fence or other protective barrier.
- Construction of the gravel diaphragm or engineered level spreader shall not commence until the contributing drainage area has been stabilized and perimeter E&S controls have been removed and cleaned out.
- Some light grading may be needed at the Conservation Area boundary; this should be done with tracked vehicles to prevent compaction.
- Stormwater should not be diverted into the Conservation Area until the gravel diaphragm and/or level spreader are installed and stabilized.

SF-7.2. Construction Sequence for Vegetated Filter Strips

Vegetated Filter Strips can be within the limits of disturbance during construction. The following procedures should be followed during construction:

- Before site work begins, vegetated Filter Strip boundaries should be clearly marked.
- Only vehicular traffic used for Filter Strip construction should be allowed within 10 feet of the Filter Strip boundary (City of Portland, 2004).
- If existing topsoil is stripped during grading, it shall be stockpiled for later use.
- Construction runoff should be directed away from the proposed Filter Strip site, using perimeter silt fence, or, preferably, a diversion dike.
- Construction of the gravel diaphragm or engineered level spreader shall not commence until the contributing drainage area has been stabilized and perimeter E&S controls have been removed and cleaned out.
- Vegetated Filter Strips require light grading to achieve desired elevations and slopes. This should be done with tracked vehicles to prevent compaction. Topsoil and or compost amendments should be incorporated evenly across the Filter Strip area, stabilized with seed, and protected by biodegradable erosion control matting or blankets.
- Stormwater should not be diverted into the Filter Strip until the turf cover is dense and well established.

SF-7.3. Construction Inspection

Construction inspection is critical to obtain adequate spot elevations, to ensure the gravel diaphragm and/or engineered level spreader is completely level, on the same contour, and constructed to the correct design elevation. As-built surveys should be required to ensure compliance with design standards. Inspectors should evaluate the performance of the Filter Strip after the first big storm to look for evidence of gullies, outflanking, undercutting or sparse vegetative cover. Spot repairs should be made, as needed.

An example construction phase inspection checklist is available in Appendix A.

SF-8. Maintenance Criteria

SF-8.1. Maintenance Agreements

Maintenance agreements must be executed between the owner and the local authority. The agreements will specify the property owner's primary maintenance responsibilities and authorize local agency staff to access the property for inspection or corrective action in the event that proper maintenance is not preformed.

All Filter Strips must be covered by a drainage easement or other documentation to allow inspection and maintenance by local authority staff. If the filter area is a natural Conservation Area, it must be protected by a perpetual easement or deed restriction that assigns the responsible party to ensure that no future development, disturbance or clearing may occur within the area, except as stipulated in the vegetation maintenance plan.

When Filter Strips and Conservation Areas are applied on private residential lots, homeowners will need to (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to modified maintenance agreements as described above.

Maintenance of these areas should be integrated into routine landscape maintenance tasks. If landscaping contractors will be expected to perform maintenance, their contracts should contain specifics on unique or in the case of Conservation Areas, minimal, landscaping needs.

Maintenance tasks and frequency will vary depending on the size and location of the landscaping template chosen, and the type of surface cover in the practice. A generalized checklist of common maintenance tasks is provided in **Appendix A** of the Manual.

SF-8.2. Maintenance Inspections

Annual inspections are used to trigger maintenance operations such as sediment removal, spot re-vegetation and level spreader repair. Ideally, inspections should be conducted in the non-growing season when it easier to see the flow path. As noted above, example maintenance inspection checklists for sheet flow to a Filter Strip or Conservation Area are found in **Appendix A**.

Inspections should include the following items:

- Flow does not short-circuit the Filter Strip;
- Debris and sediment have not built up at the top of the Filter Strip;
- Foot or vehicular traffic does not compromise the gravel diaphragm;
- Scour and erosion do not occur within the Filter Strip;
- Sediments are cleaned out of level spreader, forebays and flow splitters; and
- Vegetative density exceeds a 90% cover in the boundary zone or grass filter.

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