VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 10

DRY SWALES

VERSION 2.0
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SECTION 1: DESCRIPTION

Dry swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface material (other than mulch and ornamental plants).

The dry swale is a soil filter system that temporarily stores and then filters the desired Treatment Volume (*Tv*). Dry swales rely on a pre-mixed soil media filter below the channel that is the same as that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. In most cases, however, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Dry swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

SECTION 2: PERFORMANCE

The primary pollutant removal mechanisms operating in swales are settling, filtering infiltration and plant uptake. The overall stormwater functions of the dry swale are summarized in **Table 10.1**.

Table 10.1. Summary of Stormwater Functions Provided by Dry Swales

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40%	60%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	20%	40%
Total Phosphorus (TP) Mass Load Removal	52%	76%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	25%	35%
Total Nitrogen (TN) Mass Load Removal	55%	74%
Channel Protection	Use the Virginia Runoff reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** Design for extra storage (optional; as needed) on the surface, in the engineered soil matrix, and in the stone/underdrain layer to accommodate a larger storm, and use NRCS TR-55 Runoff Equations[2] to compute the CN Adjustment.	
Flood Mitigation	Partial. Reduced Curve Numbers and Time of Concentration	
[1] Change in the event mean concentration (EMC) through the practice. The actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*). [2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events, based on the retention storage provided by the practice(s).		

Sources: CWP and CSN (2008), CWP, 2007

Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new development and redevelopment projects. **Chapter 6** of the 2013 *Virginia Stormwater Management Handbook* (2nd Edition) provides a more thorough discussion of the site planning process and design considerations as related to Environmental Site Design and potential LEED credits. However, VDCR is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources.**

Table 10.2. Potential LEED® Credits for Dry Swales[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS5.1	Site Development: Protect or Restore Habitat[2]
Sustainable Sites	SS5.2	Site Development: Maximize Open Space
Sustainable Sites	SS6.1	Stormwater Design: Quantity Control
Sustainable Sites	SS6.2	Stormwater Design: Quality Control
Water Efficiency	WE1.1	Water Efficient Landscaping: Reduce by 50%
Water Efficiency	WE1.2	Water Efficient Landscaping: No Potable Water Use or No Irrigation

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.

[2] Not applicable for *turf* covered dry swales since turf grass is not considered native, adaptive, or biologically diverse.

SECTION 3: DESIGN TABLE

A ***Dry Conveyance Swale*** is a linear adaptation of the bioretention basin that is aligned along a contributing impervious cover such as a roadway or parking lot. The length of the swale is generally equivalent to that of the contributing impervious area. The runoff enters the dry conveyance swale as lateral sheet flow and the total contributing drainage area cumulatively increases along the length of the swale. The treatment component of the swale can extend to a greater length for additional or storage.

A ***Dry Treatment Swale*** is located to accept runoff as concentrated flow or sheet flow from non-linear drainage areas at one or more locations and, due to site constraints or other issues, is configured as a linear practice (as opposed to a bioretention configuration). A dry treatment swale can also be used to convey stormwater from the contributing drainage area to a discharge point; however, the cumulative drainage area does not necessarily increase along the linear dimension.

Both the *Dry Conveyance Swale* and the *Dry Treatment Swale* can be configured as a Level 1 or Level 2 design (see **Table 10.3**). The difference is that the typical contributing drainage area of a *Dry Conveyance Swale* is impervious, with an adjacent grass filter strip (or other acceptable measure as described in **Section 6.4**) providing pre-treatment.

Table 10.3. Dry Swale Design Criteria

Level 1 Design (RR:40; TP:20; TN:25)	**Level 2 Design (RR:60; TP:40; TN: 35)**
Sizing (**Sec. 6.1**): Surface Area (sq. ft.) = (T_v– the volume reduced by an upstream BMP) / Storage depth [1]	Sizing (**Sec. 6.1**): Surface Area sq. ft.) = {(1.1)(T_v) – the volume reduced by an upstream BMP } / Storage Depth [1]
Effective swale slope ≤ 2%[2]	Effective swale slope ≤ 1%[2]
Media Depth: minimum = 18 inches; Recommended maximum = 36 inches	Media Depth minimum = 24 inches Recommended maximum = 36 inches
Sub-soil testing (**Section 6.2**): not needed if an underdrain is used; min. infiltration rate must be > 1/2 inch/hour to remove the underdrain requirement;	Sub-soil testing (**Section 6.2**): one soil profile and two infiltration tests for dry swales up to 50 linear feet; add one additional infiltration test for dry swales up to 100 linear feet; Refer to **Section 6.2** for swales longer than 100 linear feet; min. infiltration rate must be > 1/2 inch/hour to remove the underdrain requirement
Underdrain (**Section 6.7**): Schedule 40 PVC with clean-outs	Underdrain and Underground Storage Layer (**Section 6.7**): Schedule 40 PVC with clean outs, and a minimum 12-inch stone sump below the invert; ***OR*** none if the soil infiltration requirements are met (see **Section 6.2**)
Media (**Section 6.6**): supplied by the vendor; tested for an acceptable hydraulic conductivity (or permeability) and phosphorus content [3]	
Inflow: sheet or concentrated flow with appropriate pre-treatment	
Pre-Treatment (**Section 6.4**): a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.	
On-line design	Off-line design or multiple treatment cells
Turf cover	Turf cover, with trees and shrubs
Building Setbacks [4] (**Section 5**): 10 feet if down-gradient from building or level (coastal plain); 50 feet if up-gradient. (Refer to additional setback criteria in **Section 5**)	

[1] The storage depth is the sum of the Void Ratio (V_r) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth (Refer to **Section 6.1**)

[2] The effective swale slope can be achieved through the use of check dams – 12-inch height maximum

[3] Refer to Stormwater Design Specification No. 9: Bioretention for soil specifications

[4] These are recommendations for simple building foundations. If an in-ground basement or other special conditions exist, the design should be reviewed by a licensed engineer. Also, a special footing or drainage design may be used to justify a reduction of the setbacks noted above.

Figure 10.1. Typical Dry Swale in commercial/office setting

SECTION 4: TYPICAL DETAILS

Figures 10.2 through 10.6 below provide typical schematics for dry swales.

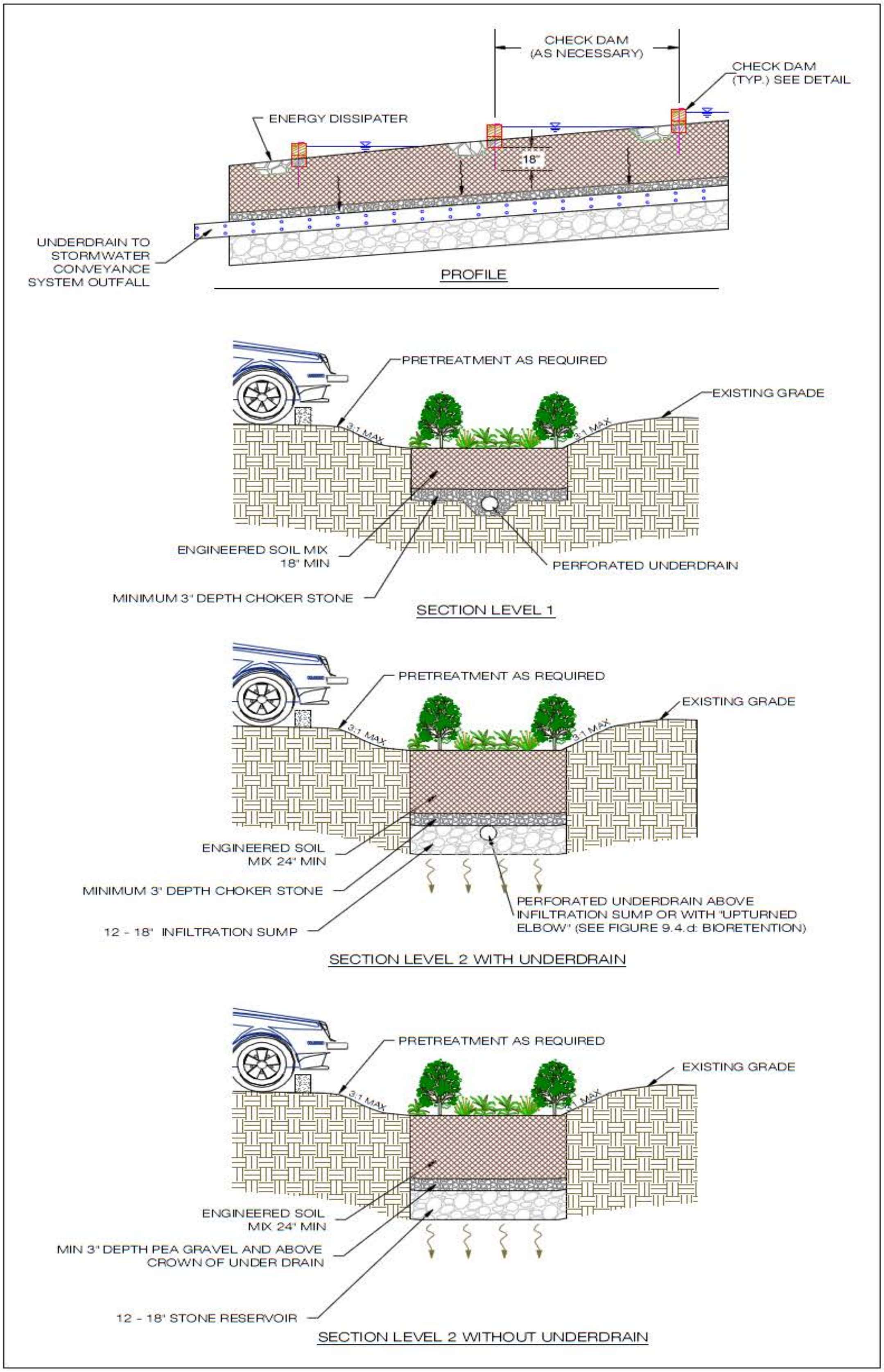

Figure 10.2. Typical Details for Level 1 and 2 Dry Swales

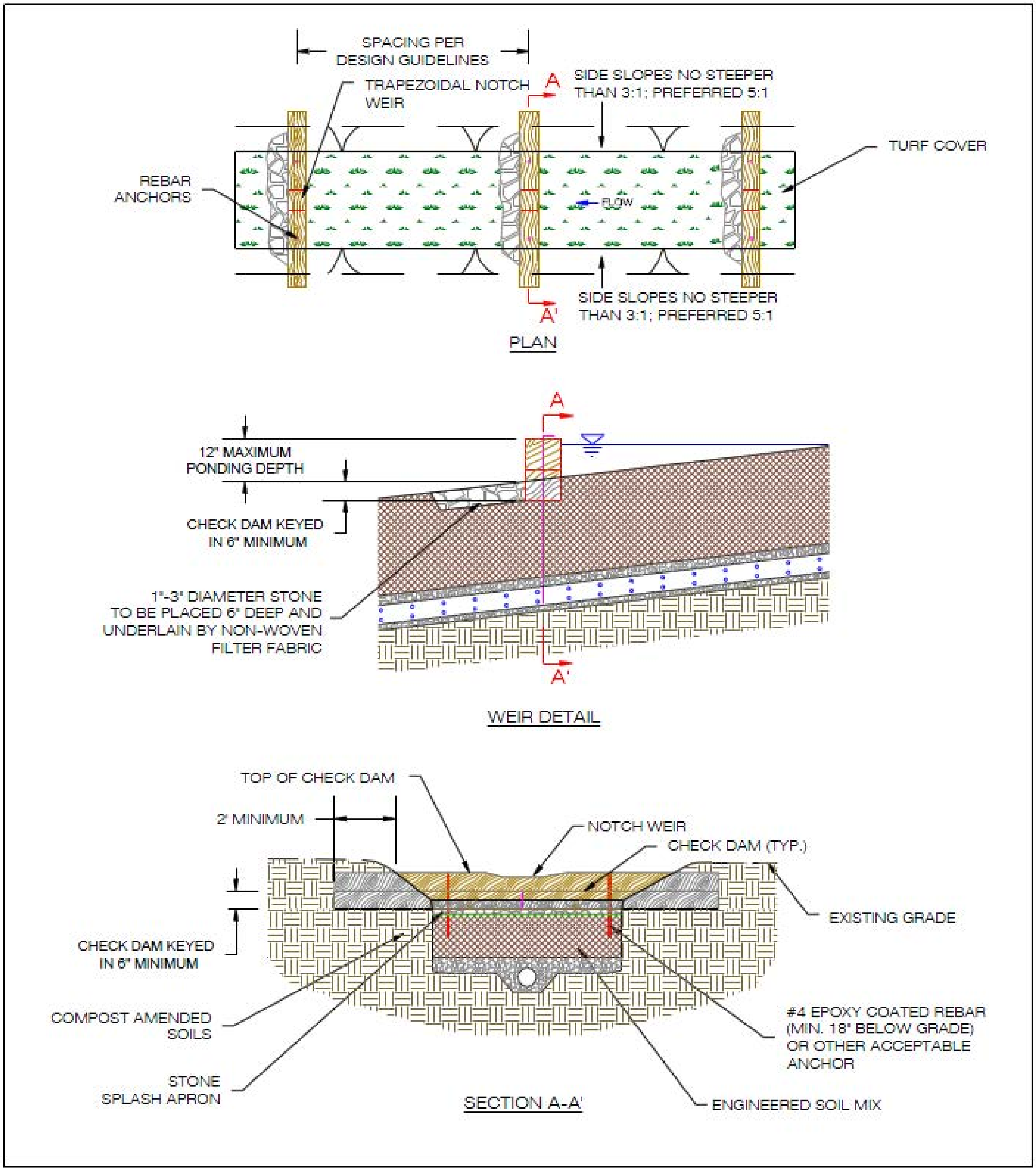

Figure 10.3. Typical Detail for Dry Swale Check Dam

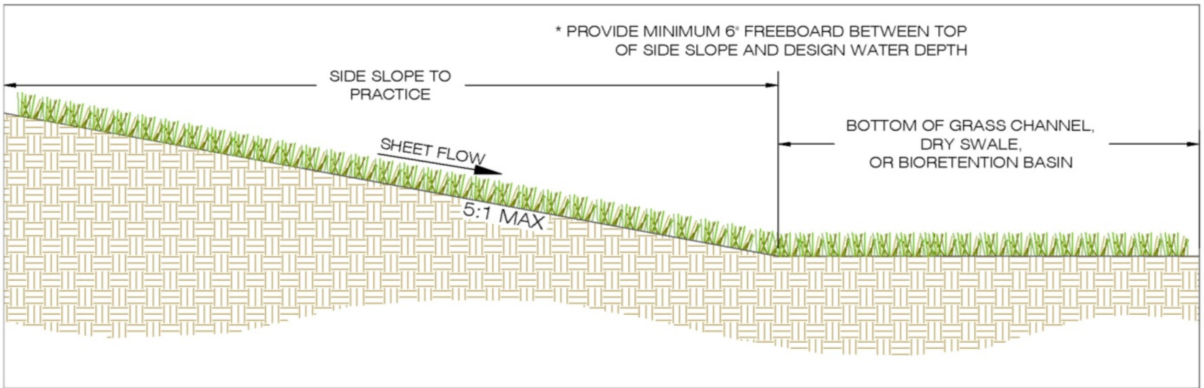

Figure 10.4a. Pretreatment I – Grass Filter for Sheet Flow

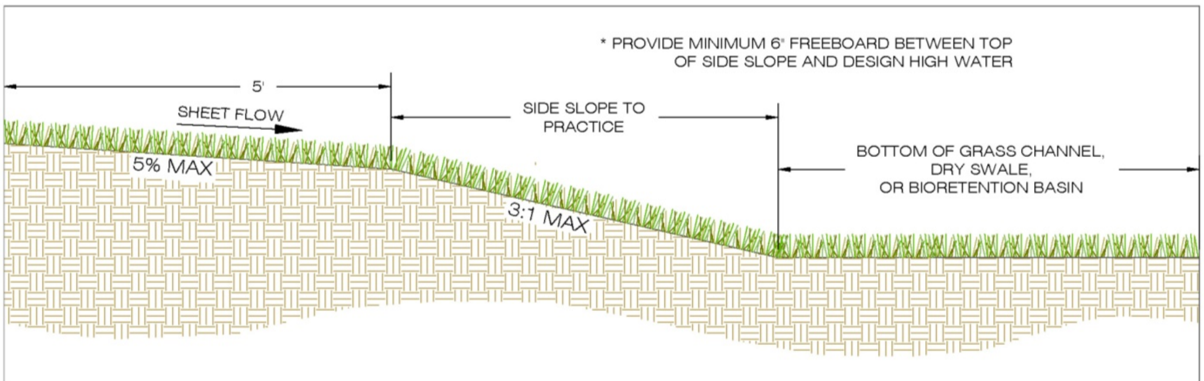

Figure 10.4b. Pretreatment II – Grass Filter for Sheet Flow

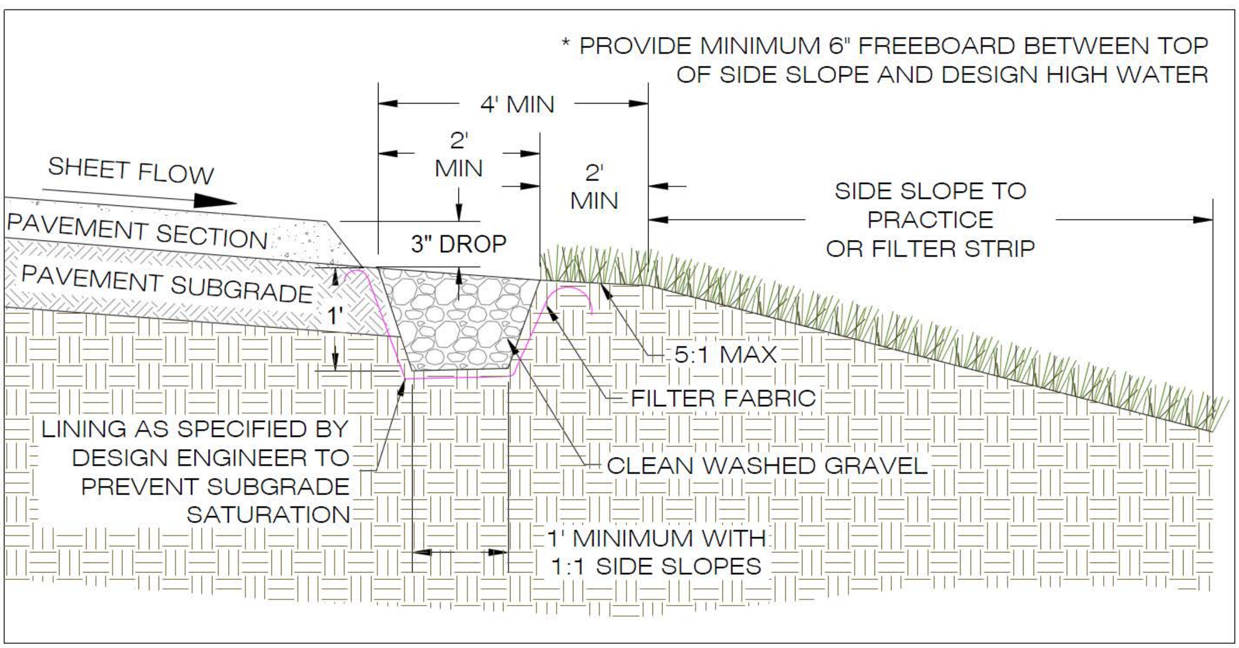

Figure 10.5: Pretreatment – Gravel Diaphragm for Sheet Flow from Impervious or Pervious

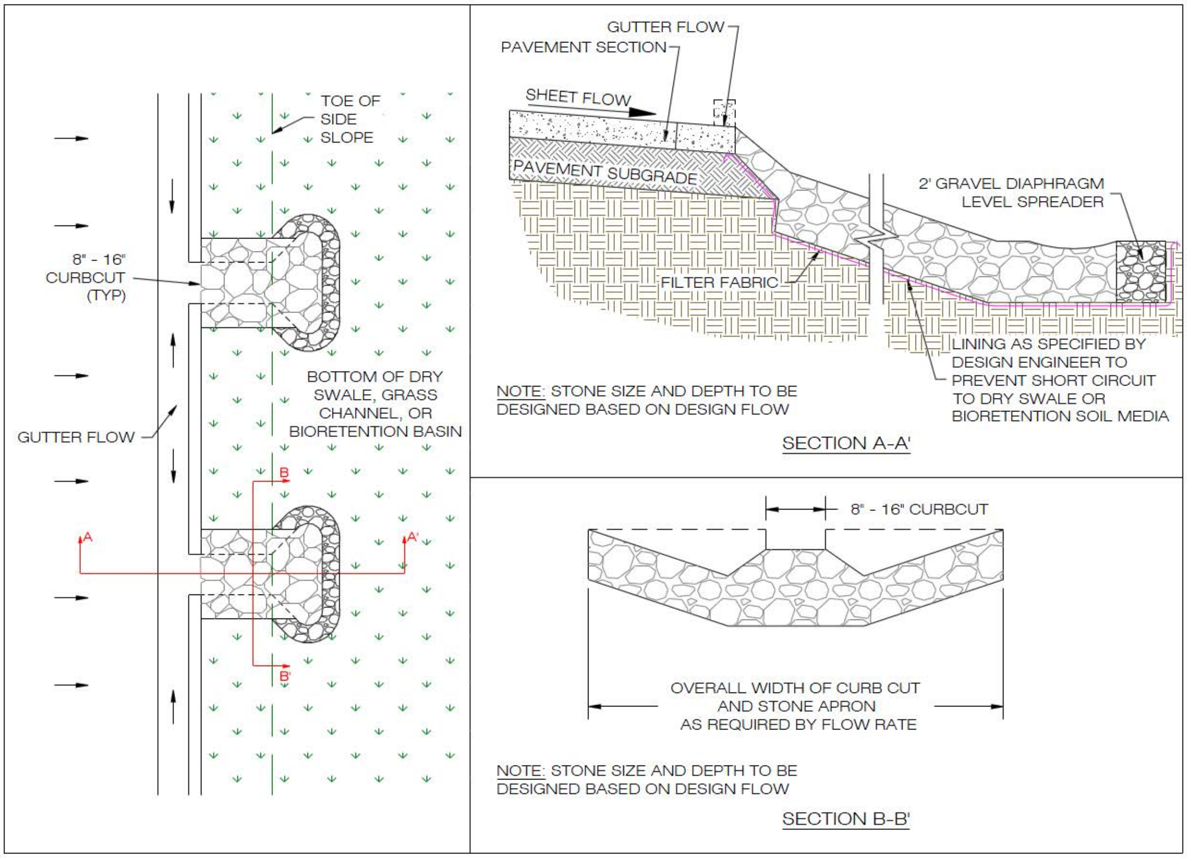

Figure 10.6: Pre-Treatment – Gravel Flow Spreader for Concentrated Flow

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

5.1 Physical Feasibility

Dry swales can be implemented on a variety of development sites where density and topography permit their application. Some key feasibility issues for dry swales include the following:

Available Space. Dry swale footprints can fit into relatively narrow corridors between utilities, roads, parking areas, or other site constraints. Dry swales should be approximately 3% to 5% of the size of the contributing drainage area depending on the amount of impervious cover, similar to bioretention basins, although with a different geometry.

Site Topography. Dry swales should be constructed in areas with longitudinal slopes of less than 4%, but preferably less than 2%. Check dams can be used to reduce the effective slope of the swale and lengthen the contact time to enhance filtering and/or infiltration. Steeper slopes adjacent to and upstream of the swale can generate rapid runoff velocities into the swale that may carry a high sediment loading (refer to pre-treatment criteria in **Section 6.4**). Likewise steep slopes adjacent to the downstream edge may be subject to saturation and failure.

Contributing Drainage Area. The maximum contributing drainage area to a dry swale should be 5 acres, but preferably less. When dry swales treat larger drainage areas, the velocity of flow through the surface channel often becomes too great to treat runoff or prevent erosion in the channel. Similarly, the longitudinal flow of runoff through the soil, stone, and underdrain may cause hydraulic overloading at the downstream sections of the dry swale. An alternative is to provide a series of inlets or diversions that convey the treated water to an outlet location.

Available Hydraulic Head. Dry swales area fundamentally constrained by the invert elevation of the downstream conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the dry swale into the storm drain system. In general, 3 to 4 feet of elevation above this outlet invert, plus the longitudinal slope of the linear dry swale is needed to create the hydraulic head needed to drive stormwater through the proposed filter bed. Less hydraulic head is needed if the underlying soils are permeable enough to dispense with the underdrain.

Hydraulic Capacity. Dry swales that are designed as an on-line practice must be designed with enough capacity to (1) convey runoff from the 2-year at a non-erosive velocity, and (2) contain the 10-year flow within the banks of the swale. This means that the swale's surface dimensions are more often determined by the need to pass the 10-year storm events, which can be a constraint in the siting of *Dry Conveyance Swales* within existing rights-of-way (e.g., constrained by sidewalks). Dry swales can be designed as an off-line practice by using periodic diversion or overflow structures to take the runoff in excess of the design Tv_{BMP} to an alternative conveyance system.

Depth to Water Table. Designers should ensure that the bottom of the dry swale is at least 2 feet above the seasonally high groundwater table, to ensure that groundwater does not intersect the filter bed, since this could lead to groundwater contamination or practice failure. The separation distance may be reduced to 12 inches in coastal plain residential settings (Refer to **Section 7.2 –** Regional Adaptations).

Soils. Soil conditions do not constrain the use of dry swales, although they normally determine whether an underdrain is needed. Low-permeability soils with an infiltration rate of less than 1/2 inch per hour, such as those classified in Hydrologic Soil Groups (HSG) C and D, will usually require an underdrain. Designers must verify site-specific soil permeability at the proposed location using the methods for on-site soil investigation presented in **Appendix 8-A of Stormwater Design Specification No. 8 (Infiltration)**, in order to eliminate the requirements for an underdrain.

Utilities. Interference with underground utilities should be avoided, particularly water and sewer lines. Designers should consult local utility design guidance for the horizontal and vertical clearance between utilities and the swale configuration. Likewise, the routing of other utilities such as phone, cable, electric, etc., through dry swales should be avoided in order to minimize disturbance of the utilities or the swale during the maintenance of either..

Avoidance of Irrigation or Baseflow. Dry swales should be located to so as to avoid inputs of springs, irrigation systems, chlorinated wash-water, or other dry weather flows.

Setbacks. Given their landscape position, dry swales are not subject to normal building setbacks. The bottom elevation of swales should be at least 1 foot below the invert of an adjacent road bed. To avoid seepage and frost heave concerns, dry swales should not be hydraulically connected to structure foundations or pavement. Setbacks to structures and roads may vary based on the conditions (see **Table 10.3** above). Expected effluent concentrations of typical urban runoff (TP, TN, metals) from dry swales are reported by the International BMP Database, and are considered to be acceptable in terms of groundwater impacts provided that the feasibility factors of water table, hotspot land uses, karst (**Section 7**) are met. However, if ground-water contamination is a concern, it is recommended that ground-water mapping be conducted to determine possible connections to adjacent ground-water wells. Otherwise, it is recommended that at a minimum, dry swales be located a horizontal distance of 50 feet from any water supply well, 35 feet from septic systems (20 feet if the swale is lined and includes an underdrain), and at least 5 feet from down-gradient wet utility lines. Dry utility lines such as gas, electric, cable and telephone may cross under the dry swale if they are protected in accordance with the particular utility requirements and can be routinely accessed without disturbing the dry swale.

Hotspot Land Use. Runoff from hotspot land uses should not be treated with infiltrating dry swales (i.e., constructed *without* an underdrain). For a list of potential stormwater hotspots, please consult **Section 10.1** of **Stormwater Design Specification No. 8 (Infiltration)**. An impermeable liner should be used for filtration of hotspot runoff.

Community Acceptance. Common community concerns with dry swales include the continued ability to mow grass, landscape preferences, weeds, standing water, and mosquitoes. Dry swales are actually a positive stormwater management alternative, because all these concerns can be fully addressed through the design process and proper on-going operation and routine maintenance. If dry swales are installed on private lots, homeowners will need to be educated on their routine maintenance needs, must understand the long-term maintenance plan, and may be subject to a legally binding maintenance agreement (see **Section 9**). The short ponding time of 6 hours is much less than the time required for one mosquito breeding cycle, so well-maintained dry swales should not create mosquito problems or be difficult to mow. The local government my require that dry swales be placed in a drainage or maintenance easement in order to ensure long term maintenance.

5.2 Potential Dry Swale Applications

The linear nature of dry swales makes them well-suited to treat highway or low- and medium-density residential road runoff, if there is adequate right-of-way width and distance between driveways and entrances.

Road medians or shoulders. Dry swales can be placed adjacent to the roadway shoulder in lieu of a typical drainage ditch, or if the road crown is sloped towards the median, the dry swale can similarly replace the drainage feature in the median, in both cases using a curb-less edge.

Right-of-way or commercial setback. A linear configuration can be used to convey runoff in sheet flow from the roadway, or a grass channel or pipe may convey flows to the bioretention practice.

Commercial buildings. In lieu of a foundation planter, a dry swale can be configured along a minimal setback from the drip line of a structure. Similarly, roof leaders can be directed to dry swales within a courtyard or along the perimeter of a walkway or other pedestrian feature adjacent to a structure.

***Parking Lots*.** Dry swales are well suited to be placed along the perimeter of small parking lots, or driveways.

Dry Extended Detention (ED) basin. A dry swale can be located along the edge or upper shelf of an extended detention basin to capture sheet flow entering the basin form immediately adjacent drainage areas, or as the final conveyance of runoff to the pre-treatment forebay.

SECTION 6: DESIGN CRITERIA

6.1. Sizing of Dry Conveyance and Dry Treatment Swales

Sizing of the surface area (SA) for dry swales is based on the computed BMP design Treatment Volume, Tv_{BMP}. The Tv_{BMP} is treatment volume based on the contributing drainage area Tv_{DA}, less any volume reduced by upstream runoff reduction practices. The required surface area (in square feet) is computed as the Tv_{BMP}. (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of the soil media, the gravel, and surface ponding (in feet) multiplied by the accepted porosity.

The accepted porosity (η) for each of the materials is (see **Figure 10.7** below):

Dry Swale Soil Media η = 0.25
Gravel η = 0.40
Surface Storage behind check dams η = 1.0

The equivalent storage depth for the Level 1 design (without considering surface ponding) is therefore computed as:

Equation 10.1. Dry Swale Level 1 Design Storage Depth

$$(1.5 \text{ ft.} \times 0.25) + (0.25 \text{ ft.} \times 0.40) = 0.5 \text{ ft.}$$

And the equivalent storage depth for the Level 2 design (without considering surface ponding) is computed as:

Equation 10.2. Dry Swale Level 2 Design Storage Depth

$$(2.0 \text{ ft.} \times 0.25) + (1.0 \text{ ft.} \times 0.40) = 0.9 \text{ ft}$$

The effective storage depths will vary according to the actual design depths of the soil media and gravel layer.

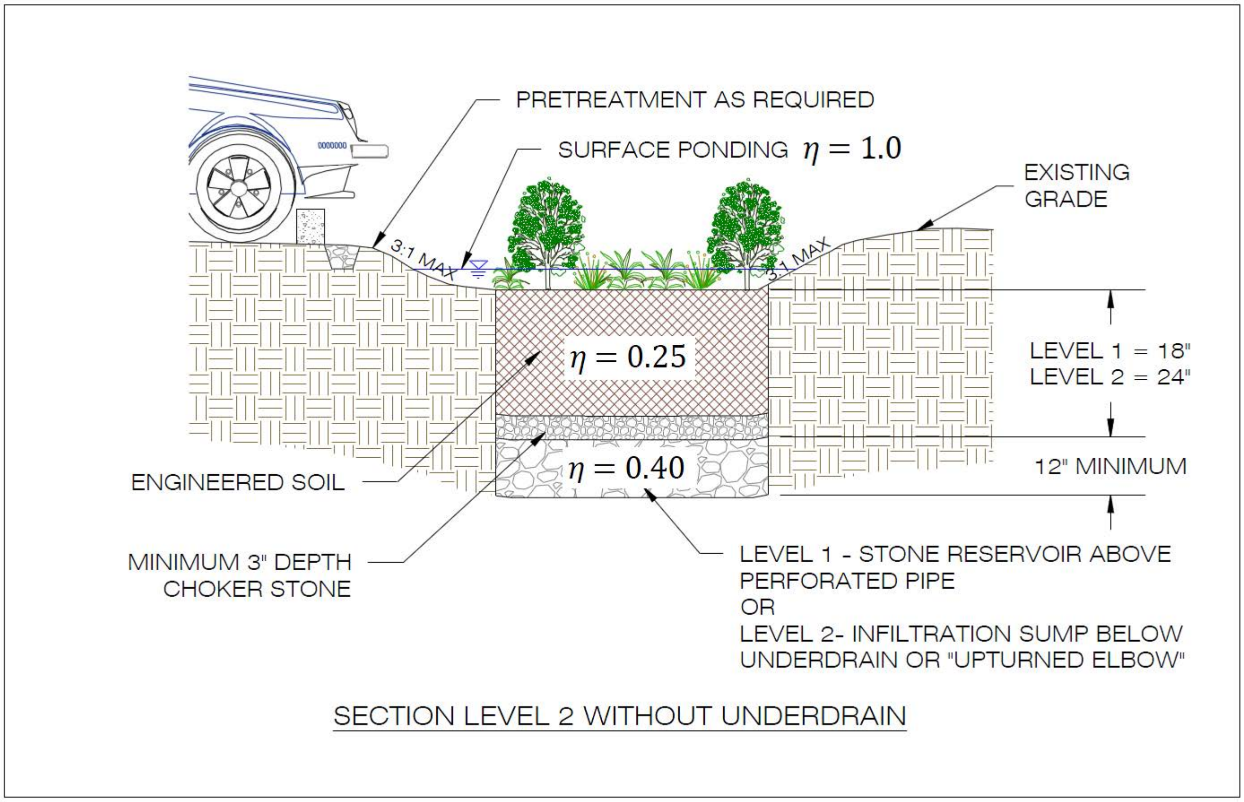

Figure 10.7 Dry Swale Section with Porosity for Volume Computations

Equations 10.3 or **10.4** below are used to calculate the required surface area, SA, of the Level 1 and Level 2 swales described in Equations 1 and 2. If the dry swale includes check dams to decrease the effective swale longitudinal slope, or to simply create storage volume, it is recommended that the designer estimate the design width of the swale and compute the storage volume retained by the check dams, and subtract it from the BMP design treatment volume, Tv_{BMP}, of dry swale. This will be an interative computation if the design width of the dry swale is different than that which is used to estimate the surface storage. **Figure 10.8** illustrates the storage volume created by 12-inch check dams on a Level 1 dry swale with a longitudinal slope of 3% (to create an effective longitudinal slope of 2%).

The Level 1 Dry Swale Surface Area (SA) is computed as:

Equation 10.3. Dry Swale Level 1 Design Surface Area (SA)

$$\text{SA (sq. ft.)} = (Tv_{BMP} - \text{volume of surface storage}) / 0.5 \text{ ft.}$$

And the Level 2 Dry Swale SA is computed as:

Equation 10.4. Dry Swale Level 2 Design Surface Area (SA)

$$\text{SA (sq. ft.)} = [(1.1 * Tv_{BMP}) - \text{volume of surface storage}) / 0.9 \text{ ft.}$$

Where:

SA = Minimum surface area of Dry Swale (sq. ft.)
Tv_{BMP} = BMP design Treatment Volume (cu. ft.) = [(1.0 in.)(R_v)(A)] / 12

(**NOTE**: R_v = the composite volumetric runoff coefficient from the VRRM Compliance Spreadsheet, or **Chapter 11**.)

The final dry swale design geometry will be determined by dividing the SA by the swale length to compute the required width; or by dividing the SA by the desired width to compute the required length.

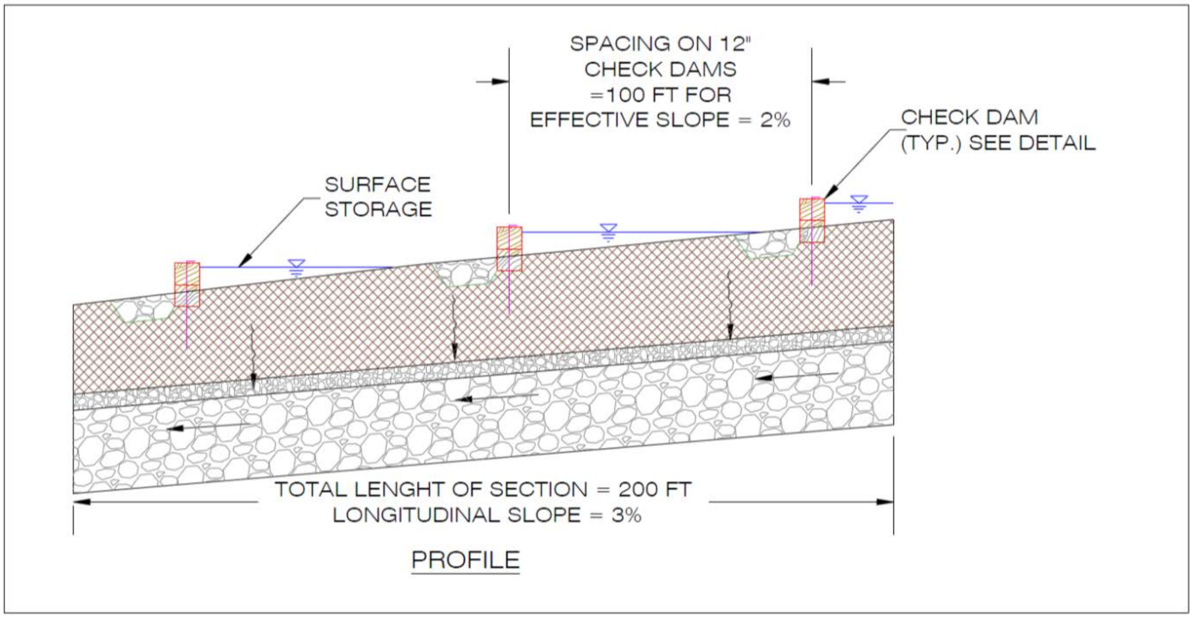

Figure 10.8 Spacing of Check Dams for Surface Storage and Effective Slope

Sizing for Stormwater Quantity

In order to accommodate a greater stormwater quantity credit for channel protection or flood control, designers may be able to create additional surface storage by expanding the surface ponding behind the check dams by either increasing the number of check dams, or by expanding the swale width at selected areas. However, the expanded surface storage footprint is limited to the ponding area directly behind the check dams and is also limited to twice the channel bottom width. Care must be taken to ensure that (1) the check dams are properly entrenched into the side slopes of the swale, and (2) adequate overflow capacity is provided over the weir.

6.2. Soil Infiltration Rate Testing

The second key sizing decision is to measure the infiltration rate of subsoils below the dry swale area to determine if an underdrain will be needed. The infiltration rate of the subsoil must exceed 1/2 inch per hour to avoid installation of an underdrain. The acceptable methods for on-site soil infiltration rate testing are outlined in Appendix 8-A of Design Specification No. 8 (Infiltration). One soil profile and one infiltration (permeability) tests should be conducted for each dry swale. Add one additional infiltration test for dry swales between 50 and 100 linear feet, and for dry swales longer than 100 linear feet, add one additional soil profile for each additional 100 linear feet, and one additional infiltration test conducted for each additional 50 linear feet of the swale.

6.3. Dry Swale Geometry

Design guidance regarding the geometry and layout of dry swales is provided below.

Shape. Typical dry swale design references a trapezoidal shape. Construction typically results in a slightly rounded or parabolic shape and is acceptable for aesthetic, maintenance and hydraulic reasons, however, the boundary of the soil filter area must be within the bottom area of the constructed swale. In either case, the design is simplified by assuming a trapezoidal cross-section.

Side Slopes. The side slopes of dry swales should be no steeper than 3H:1V. Flatter slopes (5H:1V) are recommended where adequate space is available, to enhance pre-treatment of sheet flows entering the swale and for maintenance considerations (i.e., mowing).. Swales should have a minimum bottom width of 2 to 4 feet as required to achieve the design flow depth and velocity requirements. If a swale will be wider than 6 feet, the designer should incorporate berms, check dams, level spreaders or multi-level cross-sections to prevent braiding and erosion of the swale bottom.

Swale Longitudinal Slope. The longitudinal slope of the swale should be moderately flat to permit the temporary ponding of the *Tv* within the channel. The recommended swale slope is less than or equal to 2% for a Level 1 design and less than or equal to 1% for a Level 2 design, though slopes up to 4% are acceptable if check dams are used. A dry swale designed with a longitudinal slope less than 1% may be restricted by the locality. The minimum recommended slope for an on-line dry swale is 0.5%. An off-line dry swale may be designed with a longitudinal slope of less than 0.5% and function similar to a bioretention practice, although this option may be limited by the locality. Refer to **Table 10.4** for check dam spacing based on the swale longitudinal slope.

Check dams. Check dams are constructed of timbers, concrete, gabions, or other durable (non-erodible) material and serve to hold pockets of runoff at the swale surface that will eventually filter throught he soil media to the underdrain. Check dams should meet the following criteria:

- Check dams must be firmly anchored into the side-slopes to prevent outflanking during the maximum design flow (typically the 10-year frequency event unless designed to be an off-line practice);
- The height of the check dam relative to the normal channel elevation should not exceed 12 inches.
- The top weir of each check dam should include a contained overflow section (depressed weir) to pass the design storms safely (no erosion or outflanking) (see **Figure 10.4**);
- Armoring may be needed on the downhill side of the check dam overflow section to prevent erosion. The combined overflow section and armoring must be designed to spread runoff evenly over the dry swale’s filter bed surface.

Soil Plugs. Soil plugs serve to help minimize the potential for blow-out of the soil media underneath the check dams, due to hydrostatic pressure from the upstream ponding. Soil plugs are appropriate for dry swales (1) on slopes of 4% or greater, or (2) with 12-inch high check dams.

Table 10.4. Typical Check Dam (CD) Spacing to Achieve Effective Swale Slope

Swale Longitudinal Slope	LEVEL 1	LEVEL 2		
	Spacing [1] of 12-inch High (max.) Check Dams [2, 3] to Create an Effective Slope of 2%	Spacing [1] of 12-inch High (max.) Check Dams [2, 3] to Create an Effective Slope of		
		0	to	1%
0.5%	–	200 ft.	to	–
1.0%	–	100 ft.	to	–
1.5%	–	67 ft.	to	200 ft.
2.0%	–	50 ft.	to	100 ft.
2.5%	200 ft.	40 ft.	to	67 ft.
3.0%	100 ft.	33 ft.	to	50 ft.
3.5%	67 ft.	30 ft.	to	40 ft.
4.0%	50 ft.	25 ft.	to	33 ft.
4.5% [4]	40 ft.	20 ft.	to	30 ft.
5.0% [4]	40 ft.	20 ft.	to	30 ft.

Notes:

[1] The spacing dimension is half of the above distances if a 6-inch check dam is used.

[2] A Check dams requires a stone energy dissipater at its downstream toe.

[3] Check dams require weep holes at the channel invert. Swales with slopes less than 2% will require multiple weep holes (at least 3) in each check dam.

[4] *Dry Conveyance Swales* and *Treatment Swales* with slopes greater than 4% require special design considerations, such as drop structures to accommodate greater than 12-inch high check dams (and therefore a flatter effective slope), in order to ensure non-erosive flows.

Ponding Depth. Drop structures or check dams can be used to create ponding cells along the length of the swale. The maximum ponding depth in a swale should not exceed 12 inches at the most downstream point.

Drawdown. Dry swales should be designed so that the desired *Tv* is completely filtered within 6 hours or less. This drawdown time can be achieved by using the soil media mix specified in **Section 6.6** and an underdrain along the bottom of the swale, or native soils with adequate permeability, as verified through testing (see **Section 6.2**).

Underdrain. Underdrains are provided in dry swales to ensure that they drain properly after storms.

- The underdrain should have a minimum diameter of 4 inches (or larger as required by the *Tv* design flow) and be encased in a 12-inch deep gravel bed.
- Two layers of stone should be used. A choker stone layer, consisting of #8 or #78 stone at least 3 inches deep, should be installed immediately below the filter media. Below the choker stone layer, the main underdrain layer should be at least 12 inches deep and composed on 1-inch double washed stone.
- The underdrain pipe should be set at least 4 inches above the bottom of the stone layer.

6.4. Pre-treatment

Pre-treatment for a *Dry Conveyance Swale* is in the form of a grass filter strip (minimum 10 ft. wide) along the length of the contributing impervious cover. Pre-treatment for a *Dry Treatment Swale* is required at the inflow points along the length of the dry swale, to trap coarse sediment particles before they reach the filter bed to prevent premature clogging. Several pre-treatment measures are feasible, depending on whether the specific location in the dry swale system will be receiving sheet flow, shallow concentrated flow, or fully concentrated flow:

- ***Initial Sediment Forebay*** (channel flow). This grass cell is located at the upper end of the dry swale segment usually formed with check dams and should have a 2:1 length to width ratio and a storage volume equivalent to at least 15% of the total *Tv*.
- ***Tree Check dams*** (channel flow). These are street tree mounds that are placed within the bottom of a dry swale up to an elevation of 9 to 12 inches above the channel invert. One side has a gravel or river stone bypass to allow storm runoff to percolate through.
- ***Grass Filter Strip*** (sheet flow). Grass filter strips extend from the edge of the pavement to the bottom of the dry swale at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) slope and 3:1 or flatter side slopes on the dry swale. (**See Figure 10.4**)
- ***Gravel Diaphragm*** (sheet flow). A gravel diaphragm located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop. The stone must be sized according to the expected rate of discharge. (**See Figure 10.5**)
- ***Pea Gravel Flow Spreader*** (concentrated flow). The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points, and should have a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the swale. (**See Figure 10.6**)

6.5. Conveyance and Overflow

The bottom width and slope of a dry swale should be designed such that ~~a~~ the velocity of flow from a 1-inch rainfall will not exceed 3 feet per second. Check dams may be used to achieve the needed runoff reduction volume, as well as to reduce the flow velocity (refer to Stormwater Design Specification No. 3: Grass Swale, for additional guidance on channel design). Check dams should be spaced based on channel slope and ponding requirements, consistent with the criteria in **Table 10.4**.

The swale should also convey the locally required design storms (usually the 2-year storm at a non-erosive velocity, and the 10-year storm within the banks with at least 3 inches of freeboard). The analysis should evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams. Refer to Stormwater Design Specification No. 3: Grass Channels, for design criteria pertaining to maximum velocities and depth of flow.

A dry swale may be designed as an off-line system, with a flow splitter or diversion to divert runoff in excess of the design capacity to an adjacent conveyance system. Or, strategically placed overflow inlets may be placed along the length of the swale to periodically pick up water and reduce the hydraulic loading at the downstream limits.

6.6. Filter Media

Dry swales require replacement of native soils with a prepared soil media. The soil media provides adequate drainage, supports plant growth, and facilitates pollutant removal within the Dry Swale. At least 18 inches of soil media should be added above the choker stone layer to create an acceptable filter. The recipe for the soil media is identical to that used for bioretention and is provided in **Table 10.5** below (refer to **Stormwater Design Specification No. 9: Bioretention**, for additional soil media specifications). The soil media should be certified by the supplier as meeting the intent of the soil specifications as described in **Section 6.6** of **Specification No. 9**. One design adaptation is to use 100% sand for the first 18 inches of the filter and add a combination of topsoil and leaf compost for the top 4 inches, where turf cover will be maintained.

6.7. Underdrain and Underground Storage Layer

Some Level 2 dry swale designs will not use an underdrain (where soil infiltration rates meet minimum standards (see **Section 6.2** and the design table in **Section 3**). For Level 2 designs with an underdrain, an underground storage layer, consisting of a minimum 12 inches of stone, should be incorporated below the invert of the underdrain (Refer to **Design Specification No. 9: Bioretention** for additional information on the use of an "upturned elbow" to create the infiltration sump). The depth of the storage layer will depend on the target treatment and storage volumes needed to meet water quality, channel protection, and/or flood protection criteria. However, the bottom of the storage layer must be at least 2 feet above the seasonally high groundwater table. The storage layer should consist of clean, washed #57 stone or an approved infiltration module.

A dry swale should include observation wells with cleanout pipes at regular frequency along the length of the swale. The wells should be tied into any T's or Y's in the underdrain system, and should extend upwards to be flush with surface, with a vented cap.

6.8. Landscaping and Planting Plan

Designers should choose native grasses, herbaceous plants, or trees that can withstand both wet and dry periods and relatively high velocity flows for planting within the channel. Salt tolerant grass species should be chosen for dry swales located along roads. Taller and denser grasses are preferable, although the species is less important than good stabilization and dense vegetative cover. Grass species should have the following characteristics: a deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; and an ability to recover growth following inundation. To find a list of plant species suitable for use in dry swales, consult the Virginia Erosion and Sediment Control Handbook.

6.9. Dry Swale Material Specifications

Table 10.5 outlines the standard material specifications for constructing dry swales**.**

Table 10.5. Dry Swale Material Specifications

Material	Specification	Notes

Filter Media Composition	Filter Media to contain (specific media component composition is described in **Section 6.6** of **Spec No. 9**: • 85-88% sand • 8-12% soil fines • 3-5% qualified organic matter	The volume of filter media for construction should be is based on 110% of the plan volume to account for settling.
Filter Media Testing	Available P between 7 and 23 mg/kg.; CEC greater than 10 (to the extent possible)	The media should be certified by the supplier as meeting the intent of these specifications (refer to **Stormwater Design Spec No. 9: Bioretention**, for additional soil media information.
Surface Cover	Turf, river stone, select bioretention landscaping.	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter.	
Filter Fabric	Use an appropriate material for the application based on AASHTO M288-06. Fabric should have a flow rate of > 125 gpm/sq. ft. (ASTM D4491), and an Apparent Opening Size (AOS) equivalent to a US # 70 or # 80 sieve (ASTM D4751). The geotextile AOS selection is based on the percent passing the No. 200 sieve in "A" Soil subgrade, using FHWA or AASHTO selection criteria. Apply on the sides and immediately above the underdrain only.] For hotspots and certain karst sites only, use an appropriate liner on the bottom.	
Choking Layer	A 2 to 4 inch layer of sand over a 2 inch layer of choker stone (typically #8 or # 89 washed gravel) laid above the underdrain stone.	
Stone and/or Storage Layer	1 inch stone should be double-washed and clean and free of all fines (e.g., VDOT #57 stone).	A 9 to 18 inch layer (depending on the desired depth of the storage layer)
Underdrains, Cleanouts, and Observation Wells	6-inch rigid schedule 40 PVC pipe, with 3/8-inch perforations(or equivalent corrugated HDPE), with 3/8-inch perforations at 6 inches on center;	Install perforated pipe for the full length of the dry swale cell. Use non-perforated pipe, as needed, to connect with the storm drain system.
Vegetation	Plant species as as specified on the landscaping plan	
Check Dams	Use non-erosive material such as wood, gabions, riprap, or concrete. All check dams should be underlain with filter fabric, and include weep holes. Wood used for check dams should consist of pressure-treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	
Erosion Control Fabric	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats (EC3) that are durable enough to last at least 2 growing seasons.	

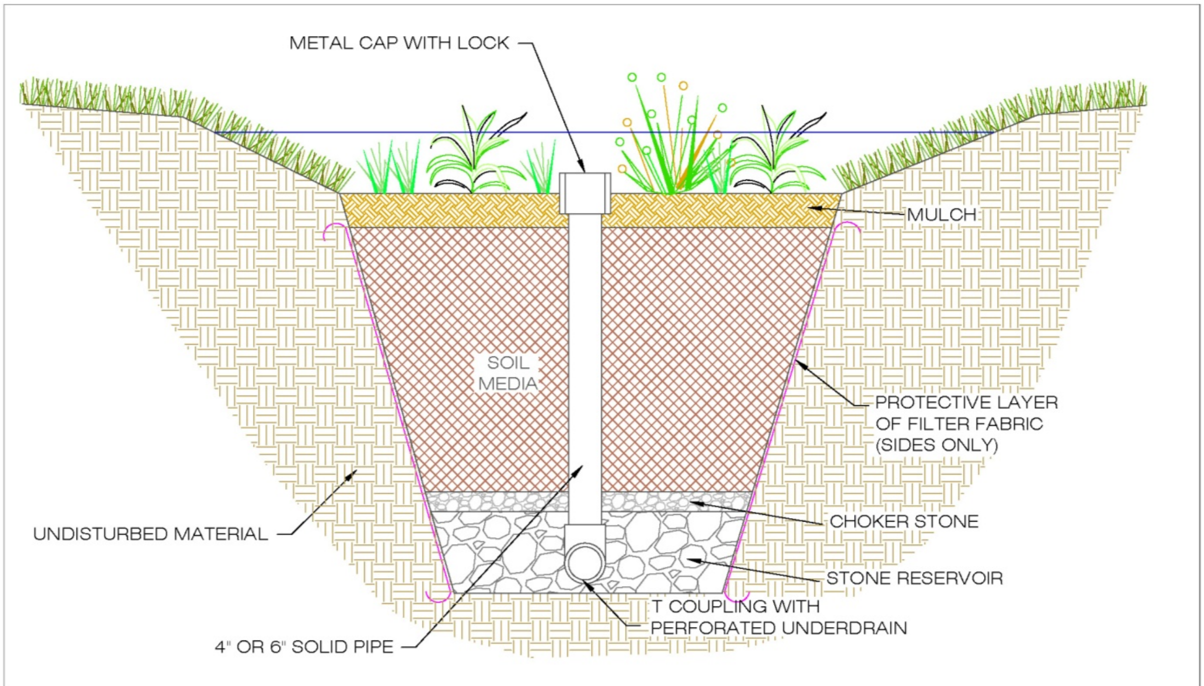

Figure 10.9. Dry Swale Observation Well

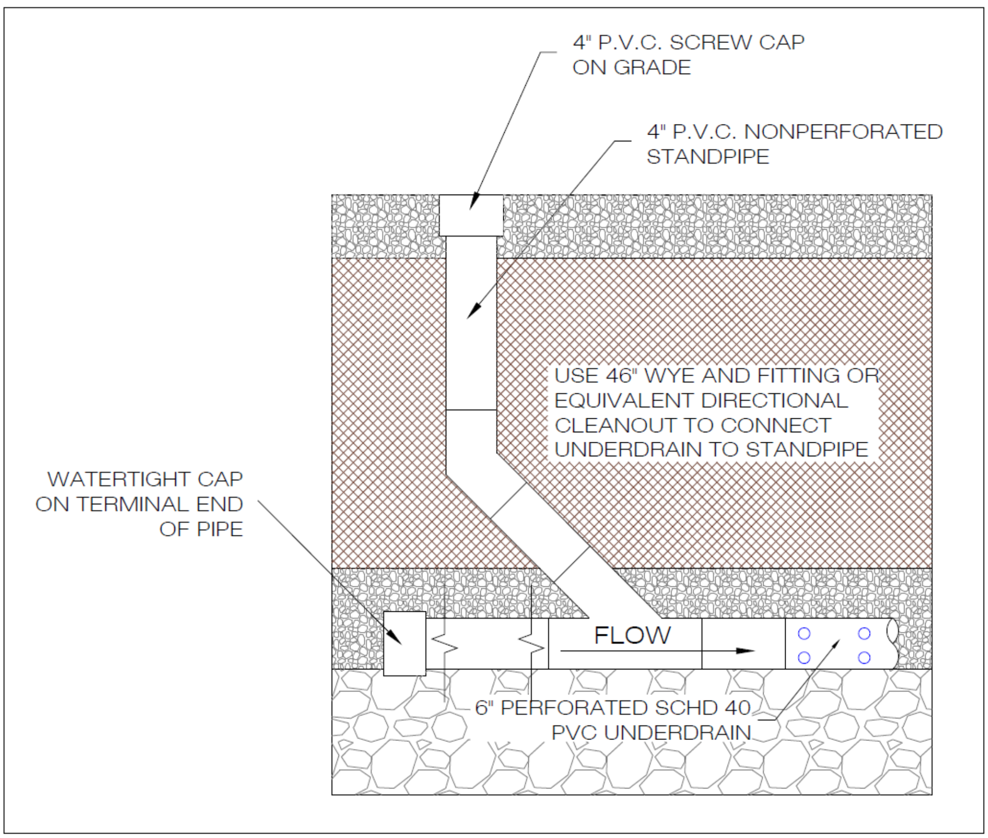

Figure 10.9. Dry Swale Underdrain Cleanout

SECTION 7: REGIONAL AND SPECIAL CASE DESIGN ADAPTATIONS

7.1. Karst Terrain

Shallow dry swales are an acceptable practice in the karst regions of the Ridge and Valley province. To prevent sinkhole formation and possible groundwater contamination, dry swales should use impermeable liners and underdrains. Therefore, Level 2 dry swale designs that rely on infiltration are not recommended in any area with a moderate or high risk of sinkhole formation (Hyland, 2005).

If a dry swale facility is located in an area of sinkhole formation, standard setbacks to buildings should be increased.

7.2. Coastal Plain

The flat terrain, low head and high water table of many coastal plain sites can constrain the application of dry swales (particularly Level 2 designs). Swales perform poorly in extremely flat terrain because they lack enough grade to ensure positive drainage. However, the use of multiple storage cells can help conserve hydraulic head, relying on the underdrain to drain at a minimal slope to the drainage system. In these situations, the following design adaptations apply:

- The minimum depth to the seasonally high groundwater table from the invert of the system can be 1 foot, as long as the dry swale is equipped with a large diameter underdrain.
- A minimum underdrain slope of 0.5% should be maintained to ensure positive drainage.
- The underdrain should be tied into the drainage ditch system.
- If the surface cover is to landscaped with plants (as opposed to turf), the mix of plant species selected should reflect coastal plain plant communities and should be more wet-footed and salt-tolerant than those used in typical Piedmont applications.

While these design criteria permit dry swales to be used on a wider range of coastal plain sites, it is important to avoid installing dry swales on marginal sites. Other stormwater practices, such as Wet Swales, ditch wetland restoration, and smaller linear wetlands are preferred alternatives for coastal plain sites.

7.3. Steep Terrain

In areas of steep terrain, dry swales can be implemented with contributing slopes of up to 20% gradient, as long as a multiple cell design is used to dissipate erosive energy prior to filtering. This can be accomplished by terracing a series of dry swale cells to manage runoff across or down a slope. The drop in elevation between cells should be limited to 1 foot and armored with river stone or a suitable equivalent. A greater emphasis on properly engineered energy dissipaters and/or drop structures is warranted.

7.4. Cold Climate and Winter Performance

Dry swales can store snow and treat snowmelt runoff when they serve road or parking lot drainage. If roadway salt is applied within the CDA, dry swales should be planted with salt-tolerant nonwoody plant species. Consult the Minnesota Stormwater Manual for a list of salt-tolerant grass species (MSSC, 2005). The underdrain pipe should also extend below the frost line and be oversized by one pipe size to reduce the chances of freezing.

7.5. Linear Highway Sites

Dry swales are a preferred stormwater practice for linear highway sites. The design should be broken into multiple cells with outlets or overflow points to avoid large single areas of flow through the swale. Also, salt tolerant grass and/or plant species should be selected if salt compounds will be used to de-ice the contributing roadway in the winter.

SECTION 8: CONSTRUCTION

8.1. Construction Sequence

Construction Stage ESC Controls. Dry swales should be fully protected by silt fence or construction fencing, particularly if they will provide an infiltration function (i.e., have no underdrains). Ideally, dry swale areas should remain *outside* the limits of disturbance during construction to prevent soil compaction by heavy equipment.

Dry swale locations may be used for small sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the E&S Control plan specifying that the maximum excavation depth of the sediment trap/basin at the construction stage must (1) be at least 1 foot above the depth of the post-construction dry swale installation, (2) contain an underdrain, and (3) specify the use of proper procedures for conversion from a temporary practice to a permanent one, including de-watering, cleanout and stabilization.

8.2. Construction Sequence

The following is a typical construction sequence to properly install a dry swale, although the steps may be modified to adapt to different site conditions.

Step 1: Protection during Site Construction. As noted above, dry swales should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. However, this is seldom practical given that swales are a key part of the drainage system at most sites. In these cases, temporary E&S controls such as dikes, silt fences and other similar measures should be integrated into the swale design throughout the construction sequence. Specifically, barriers should be installed at key check dam locations, erosion control fabric should be used to protect the channel, and excavation should be no deeper than 2 feet above the proposed invert of the bottom of the planned underdrain. dry swales that lack underdrains (and rely on filtration) must be fully protected by silt fence or construction fencing to prevent compaction by heavy equipment during construction.

Step 2. Grading of the dry swale in preparation of installation of the gravel, underdrain, and soil media should begin only after the entire contributing drainage area has been stabilized by vegetation or runoff has been diverted away from the area. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed dry swale. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Identify any additional E&S controls that may be needed during swale construction, particularly to divert stormwater from the dry swale until the filter bed and side slopes are fully stabilized.

Step 4. Pre-treatment cells should be excavated first to trap sediments before they reach the planned filter beds.

Step 5. Excavators or backhoes should work from the sides to excavate the dry swale area to the appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the dry swale area.

Step 6. The bottom of the dry swale should be ripped, roto-tilled or otherwise scarified to promote greater infiltration.

Step 7. Place an acceptable filter fabric on the underground (excavated) sides of the dry swale with a minimum 6 inch overlap. Place the stone needed for storage layer over the filter bed. Perforate the underdrain pipe and check its slope. Add the remaining stone jacket, and then pack #57 stone to 3 inches above the top of the underdrain, and then add 3 inches of pea gravel as a filter layer.

Step 8. Obtain soil the media from a qualified vendor, and store it on an adjacent impervious area or plastic sheeting. After verifying that the media meets the specifications, add the soil media in 12-inch lifts until the desired top elevation of the dry swale is achieved. Wait a few days to check for settlement, and add additional media as needed.

Step 9. Install check dams, driveway culverts and internal pre-treatment features, as specified in the plan.

Step 10. Prepare planting holes for specified trees and shrubs, install erosion control fabric where needed, spread seed or lay sod, and install any temporary irrigation.

Step 11. Plant landscaping materials as shown in the landscaping plan, and water them weekly during the first 2 months. The construction contract should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.

Step 12. Conduct a final construction inspection and develop a punch list for facility acceptance. Log the GPS coordinates for each bioretention facility and submit them for entry into the local maintenance tracking database.

8.3. Construction Inspection

Inspections are needed during construction to ensure that the dry swale practice is built in accordance with these specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is consistent with the designer's intent. An example construction phase inspection checklist for dry swales is provided at the end of this specification.

Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of dry swale installation.

- Check the filter media to confirm that it meets specifications and is installed to the correct depth.
- Ensure that caps are placed on the upstream (but not the downstream) ends of the underdrains.
- Make sure the desired coverage of turf or erosion control fabric has been achieved following construction, both on the filter beds and their contributing side-slopes.
- Inspect check dams and pre-treatment structures to make sure they are properly installed and working effectively.
- Check that outfall protection/energy dissipation measures at concentrated inflow and outflow points are stable.
- Upon final acceptance, the GPS coordinates should be logged for all dry swales and submitted for entry into the local BMP maintenance tracking database.

The real test of a dry swale occurs after its first big storm. The post-storm inspection should focus on whether the desired sheetflow, shallow concentrated flows or fully concentrated flows assumed in the plan actually occur in the field. Also, inspectors should check that the dry swale surface drains completely within 6 to 12 hours after a storm.. Minor adjustments are normally needed as a result of this post-storm inspection (e.g., spot reseeding, gully repair, added armoring at inlets or outfalls, and check dam realignment.

SECTION 9: MAINTENANCE

9.1. Maintenance Agreements

The Virginia Stormwater Management regulations (4 VAC 50-60) specify the circumstances under which a maintenance agreement must be executed between the owner and the VSMP authority, and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- All dry swales must include a long term maintenance agreements consistent with the provisions of the VSMP regulations, and must include the recommended maintenance tasks and a copy of an annual inspection checklist.
- When dry swales are applied on private residential lots, homeowners should be educated regarding their routine maintenance needs by being provided a simple document that explains their purpose and routine maintenance needs.

- A deed restriction, drainage easement or other mechanism enforceable by the VSMP authority must be in place to help ensure that dry swales are maintained and not converted or disturbed, as well as to pass the knowledge along to any subsequent owners.
- The mechanism should, if possible, grant authority for VSMP authority to access the property for inspection or corrective action.

9.2. First Year Maintenance Operations

Initial and subsequent annual inspections are used to trigger maintenance operations such as sediment removal, spot revegetation and inlet stabilization. The following is a list of several key maintenance inspection points:

- ***Initial inspections.*** For the first 6 months following construction, the site should be inspected at least twice after storm events that exceed 1/2 inch of rainfall.
- ***Spot Reseeding.*** Inspectors should look for bare or eroding areas in the contributing drainage area or around the dry swale area, and make sure they are immediately stabilized with grass cover.
- ***Fertilization.*** One-time, spot start-up fertilization may be needed for initial seed and/or plantings.
- ***Watering.*** Depending on the time of year of initial planting, watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall.

9.3 Maintenance Inspections

Ideally, inspections of dry swales should be conducted in the spring of each year.

- Check to see if 95% turf cover or vegetation density has been achieved in the bed and banks of the dry swale.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the dry swale, and check for other signs of bypassing.
- Check for any winter- or salt-killed vegetation.
- Check inflow points for clogging or accumulated sand, sediment and trash, and remove it.
- Inspect dry swale side slopes and grass filter strips for evidence of any rill or gully erosion, and repair it.
- Check the dry swale for evidence of excessive ponding or concentrated flows, and take appropriate remedial action.
- When sediment accumulation is noted, look for any bare soil or sediment sources in the contributing drainage area, and stabilize them immediately.
- Check for clogged or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics.
- Inspect upstream and downstream of check dams for evidence of undercutting or erosion, and remove trash or blockages at weepholes.

Example maintenance inspection checklists for dry swales can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010).

9.3 Maintenance and Operation

Once established, dry swales have minimal maintenance needs outside of the spring clean up, regular mowing, and pruning and management of trees and shrubs.

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 48 hours after a storm, adjustments to the grading, rehabilitation of the surface infiltration, or underdrain repairs may be needed. The following represents an easiest to hardest selection of possible solutions:

- The surface of the filter bed can become clogged with fine sediment over time. This will be evidenced by accumulated sediment, a fine crust that builds up after the first several storm events, or cracking of the surface sediment layer). Remove accumulated sediment and till 2 to 3 inches of sand into the upper 8 to 12 inches of soil.
- Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil. If there is standing water on top, but not in the underdrain, then there is a clogged soil layer. If the underdrain and stand pipe indicates standing water, then the underdrain must be clogged and will need to be snaked.
- If the evidence indicates that a soil layer is clogged, install sand wicks from 3 inches below the surface to the underdrain layer. Sand wicks can be installed by excavating or augering (using a tree auger or similar tool) down to the gravel storage zone to create vertical columns which are then filled with a clean open-graded coarse sand material (coarse sand mix similar to the gradation used for the soil media). A sufficient number of wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility.
- Last resort - remove and replace some or all of the soil media.

Sample Construction Inspection Checklist for Dry Swales: The following checklist provides a basic outline of the anticipated items for the construction inspection of dry swales. This checklist does not necessarily distinguish between the use of an infiltration sump below an underdrain, or an infiltration sump with an "upturned elbow". Similarly, design variations between Level 1 and Level 2 dry swales and different configurations of check dams may not be clearly identified in this checklist. Inspectors should review the plans carefully, and adjust these items and the timing of inspection verification as needed to ensure the intent of the design is met. Finally, users of this information may wish to incorporate these items into a VSMP Authority Construction Checklist format consistent with the format used for erosion and sediment control and BMP construction inspections.

Pre-Construction Meeting

☐ Pre-construction meeting with the contractor designated to install the dry swale has been conducted.

☐ Identify the tentative schedule for construction and verify the requirements and schedule for interim inspections and sign-off.

☐ Subsurface investigation and soils report supports the placement of a dry swale in the proposed location.

☐ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage, etc.

☐ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.

☐ Area of the dry swale has not been impacted during construction.

☐ Stormwater has been diverted around the area of the dry swale and perimeter erosion control measures to protect the facility during construction have been installed. .

Excavation

☐ Compare the dry swale surface and invert design elevations with the actual constructed elevations of the inflow and outlet inverts and adjust design elevations as needed.

☐ Area of dry swale excavation is marked and the size and location conforms to plan.

☐ If the excavation area has been used as a sediment trap: verify that the bottom elevation of the proposed stone reservoir is lower than the bottom elevation of the existing trap.

☐ For Level 2 dry swale, ensure the bottom of the excavation is scarified prior to placement of stone.

☐ Subgrade surface is free of rocks and roots, and large voids. Any voids should be refilled with the base aggregate to create a level surface for the placement of aggregates and underdrain (if required).

☐ No groundwater seepage or standing water is present. Any standing water is dewatered to an acceptable dewatering device.

☐ Excavation of the dry swale has achieved proper grades, longitudinal slope, and the required geometry and elevations without compacting the bottom of the excavation.

☐ **Certification of Excavation Inspection**: Inspector certifies the successful completion of the excavation steps listed above.

Filter Layer, Underdrain, and Stone Reservoir Placement

☐ All aggregates, including, as required, the filter layer (choker stone & sand), the stone reservoir layer or infiltration sump conform to specifications as certified by quarry.

☐ Underdrain size and perforations meet the specifications.

☐ For Level 2 installations: placement of filter layer and initial lift of stone reservoir layer aggregates with underdrain or infiltration sump, spread (not dumped) to avoid aggregate segregation; or

☐ Impermeable liner, when required, meets project specifications and is placed in accordance with manufacturers specifications.

☐ Sides of excavation covered with geotextile, when required, prior to placing stone reservoir aggregate; no tears or holes, or excessive wrinkles are present.

☐ Placement of underdrain, observation wells, and underdrain fittings (45 degree wyes, cap at the upstream end, etc.) are in accordance with the approved plans.

☐ Elevations of underdrain and outlet structure are in accordance with approved plans, or as adjusted to meet field conditions.

☐ Placement of remaining lift of stone reservoir layer as needed to achieve the required reservoir depth.

☐ **Certification of Filter Layer and Underdrain Placement Inspection:** Inspector certifies the successful completion of the filter layer and underdrain placement steps listed above.

Dry Swale Soil Media Placement

☐ Soil media is certified by supplier or contractor as meeting the project specifications.

☐ Soil media is placed in 12-inch lifts to the design top elevation of the dry swale. Elevation has been verified after settlement (2 to 4 days after initial placement).

☐ Side slopes of ponding or flow area are feathered back at the required slope (no steeper than 3H:1V).

☐ Dry swale length, bottom width, side slopes, and longitudinal slope are in accordance with the approved plans.

☐ **Certification of Soil Media Placement Inspection:** Inspector certifies the successful completion of the soil media steps listed above.

Pretreatment and Check Dam Installation

☐ Placement of energy dissipators and pretreatment practices (forebays, gravel diaphragms, etc.) are installed in accordance with the approved plans.

☐ Riser, overflow weir, or other outflow structure is set to the proper elevation and functional; or.

☐ External bypass structure is built in accordance with the approved plans.

☐ Appropriate number and spacing of check dams are installed in accordance with the approved plans (verification of energy dissipators at downstream toe, depth keyed into dry swale flow line, and tied back into dry swale side slopes).

☐ Apply erosion control matting as required by approved plans or as needed to ensure adequate stabilization.

☐ All external erosion and sediment control practices have been removed.

☐ Follow-up inspection and as-built survey/certification has been scheduled.

☐ GPS coordinates have been documented for all dry swale installations on the parcel.

SECTION 10: REFERENCES

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