# *Level Spreaders and Off-Site Discharges of Stormwater to Non-Surface Waters*

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## I. FORWARD

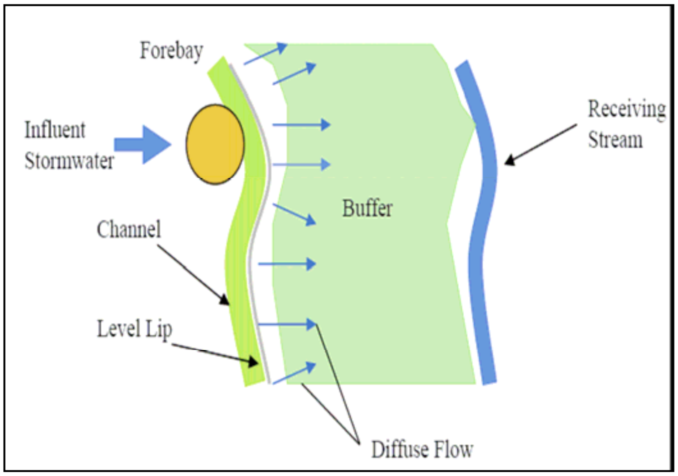
This paper compliments the guidance provided in the *Pennsylvania Stormwater Management Best Management Practices Manual* (*BMP Manual*,) Technical Guidance Document 363-0300-002 12/30/2006, specifically *BMP 6.8.1: Level Spreaders*. This paper also references the *Pennsylvania Erosion and Sediment Pollution Control Program Manual* (*E&S Manual*), Technical Guidance Document 363-2134-008 4/15/2000. Both of these documents are available online www.depweb.state.pa.us: click the following: Forms and Publications (eLibrary), Technical Guidance Final Documents, Watershed Management.

## II. BACKGROUND

Favorable conditions in the real estate market and the demand for housing have created a significant boom in land development, particularly in urban and suburban areas. Due to high property values, many sites that were previously passed over as "not developable" are now sought for development. As a result, federal, state and local regulatory agencies have experienced an increase in high complexity projects, some of which only involve a few acres. In addition, the NPDES Phase 2 Revisions (March 2003), which reduced the permitting threshold from 5 acres to 1 acre, has also significantly increased the number of projects encountered by these agencies. As a result, there is an increased demand for guidance and direction for both the project proponent and the regulator.

This paper focuses on the situation where point-source stormwater discharges are proposed to be directed to off-site areas that are not surface waters of the Commonwealth (i.e. uplands) or to areas unsuitable for carrying storm event flows. This can include overland flows that discharge to an open area, or follow an existing swale or other natural flow path lacking clearly defined bed and banks. Often these sites involve discharges that traverse over one hundred feet before reaching a surface water body. The flow path of these stormwater discharges often cross adjoining properties owned by other parties, which adds another layer of complexity to the issue. Even though these proposed stormwater discharges might follow an existing swale or other natural flow path, they normally exceed the volume and duration of the stormwater that currently follows the same flow path (prior to land development activities). This increased *flow exposure* may cause adverse impacts on the conveyance system or the receiving stream. These proposed stormwater discharges typically result in accelerated erosion and damages, often times on adjoining properties. A typical outfall structure with a riprap energy dissipater is not sufficient to deal with this issue. Faced with this situation, the BMP of choice by developers and their consultants has typically been the level spreader – in some shape or form.

Lack of guidance on level spreaders for this purpose has led to many stormwater plans that have failed to address this type of situation correctly. The "typical" level spreader (as shown to the right) and associated guidance found in most available reference materials is intended for stormwater discharges adjacent to riparian buffers or wetlands releasing the "water quality" storm or other smaller storm event. The situation described in the previous paragraph is different and calls for an "atypical" level spreader designed to discharge all anticipated flow without an opportunity for a stable bypass for high flows. This paper describes situations where a level spreader may or may not be appropriate and provides guidance on proper planning, design, and construction and, as a result, should help alleviate the potential for off-site erosion, flooding, or property damage caused by uncontrolled stormwater discharges.




Source: *Evaluation of Level Spreaders in the Piedmont of North Carolina*

Due to numerous issues related to this subject matter, a technical work group involving PA DEP, PennDOT and the conservation districts of Bucks, Chester, Delaware, Montgomery and Lehigh Counties was convened to deal with the issue of uncontrolled stormwater discharges. The findings of the technical work group were incorporated in this paper.

## III. INTRODUCTION TO LEVEL SPREADERS

Level spreaders are structures that are designed to uniformly distribute concentrated flow over a large area essentially converting concentrated flow to sheet flow. Level spreaders come in many types and functions, depending on the peak rate of inflow, the site conditions, the duration of use, and the type of pollutant (if any). Infiltration and water quality functions are both possibilities, which are dependent on site constraints. Examples of common level spreaders include: concrete sills (or lips), curbs, earthen berms, and level perforated pipes discharging to the surface or sub-surface. (See **Figures 3 and 5** for sample illustrations)

Typically, level spreaders function as follows:

1. Concentrated flow <u>enters</u> the level spreader through a pipe, ditch, or swale.
2. The concentrated flow is <u>impeded</u> and its energy is dissipated.
3. The flow is <u>distributed</u> over the length of the level spreader.
4. The velocity of the flow is <u>reduced</u> to a level that can be tolerated down slope.
5. Water is <u>discharged</u> simultaneously across the same elevation, theoretically, in a uniform manner along the entire length.

Source: Chester County Conservation District

## IV. PRACTICAL CONSIDERATIONS

Prior to specifying a level spreader, the designer should consider the following items, to the maximum extent practicable:

1. Avoid and minimize potential conflicts with discharges to non-surface waters, all together.
2. Fully consider alternatives that would have less impact on the environment, including constructing conveyances for anticipated flows (either open channel or closed channel) to a surface water feature or to a storm sewer capable of carrying those flows. The developer would be responsible for working with adjacent property owners for consent.
3. Endeavor to maximize volume reduction and other stormwater BMPs– both non-structural and structural – throughout the site. (not just in the vicinity of a detention basin)
4. Limit the formation of concentrated flow, since it is simpler to maintain sheet flow discharge rather than to redistribute it after it is concentrated.

## V. ENGINEERING CONSIDERATIONS

1. Level Spreaders must be constructed and maintained level (i.e. constructed along an existing contour). Small variations in height on the downstream lip will quickly result in gullies. Experience suggests that variations of more than **0.05%** slope along the weir (approx. 0.25 inches per 42 feet of weir) will in time cause water to quickly reconcentrate and potentially erode areas down slope of the level spreader. (Hunt et al, 2001) It is imperative that the site selected for level spreader installment be nearly level before construction. Variations in existing ground elevation of more than **4 inches** across the entire length of the level spreader can make "level" construction difficult. (See **Item 7**)
2. Specific site conditions, such as topography, vegetative cover, soil, and geologic conditions must be considered prior to design. <u>Field verification is essential to achieve project success</u>. Level spreaders are not applicable in areas comprised of easily erodible soils (including fill) and/or sparse vegetation. Undisturbed earth with a grass cover is much more resistant to erosion than fill– despite thorough compaction. Even with

what appears to be a good young stand of grass over fill, erosion is likely to occur. Level spreaders should be located away from newly deposited earth.

3. Designers should consider the following items for level spreaders with respect to optimizing performance, maximizing effectiveness, and reducing the potential for reconcentrated flow:

  ○ Land Surface Shape: When siting a level spreader, the designer should avoid locating the level spreader on concave slopes or concave contours. See **Figure 1**.

  ○ Soil slope: Gentle/gradual uniform slopes are ideal, with a maximum slope of **6%** from level spreader to toe of slope (i.e. top of stream bank). The first **10 feet** of buffer/vegetated filter strip down slope of the level spreader should not exceed **4%** slope. For greater slopes or if construction of a level spreader can not be accomplished without clearing/removing down slope vegetation, the designer should not use a level spreader and instead install a typical conduit and outfall extending to an adequate surface water body or storm sewer. (See **Section VIII** on *Outfall Design*) If significant issues with bedrock are encountered, then permanent slope pipes may be considered, if allowable at the local level.

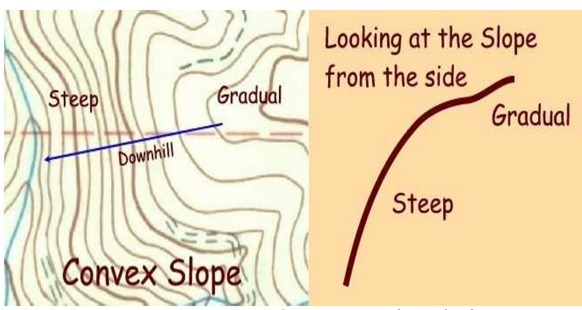
  ○ Slope Length: The maximum distance to a receiving stream or storm sewer should be about **100 feet**. Greater distances may be considered on a case-by-case basis for very mild slopes ($\leq$ **1%**) and heavily vegetated (grassy) areas but ideally should not exceed **150 feet**. When greater distances cannot be avoided, the designer should incorporate other mitigative measures such as:

    a. Incorporating an infiltration BMP with the goal of providing no discharge of storm events up to the **10-year storm**. (e.g. See *BMP Manual*, *6.4.4 Infiltration Trench*)

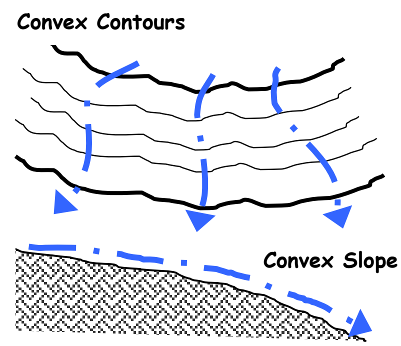
    b. Limiting the drainage area to **1 acre** or less with minimal runoff from impervious areas.

**Figure 1. Convex Contours and Slopes are Less Susceptible to Reconcentrating Flows.**

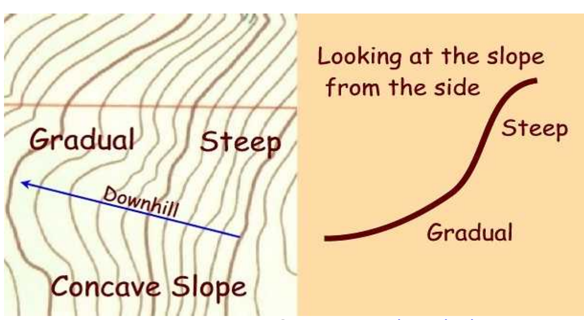
Optimal




Source: www.therockerbox.com




Less Favorable

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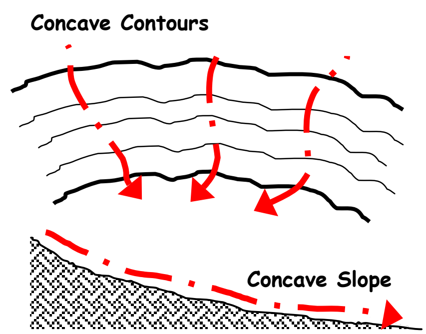



4.

Hydraulics and Hydrology for Level Spreaders:

a. Level spreaders, in this context, shall safely diffuse flows up to the **100-year storm.** A minimum design criterion per the BMP Manual is the **10-year storm** – conditions permitting**.** This is due to the inability to bypass and to accommodate the magnitude of anticipated discharges.

b. The drainage area to a given level spreader should be limited to **5 acres** or less, which should encourage smaller and more manageable BMPs, both during and after construction. For conveyances with drainage areas exceeding 5 acres, multiple outfalls/level spreaders are preferable to a single outfall/level spreader. A maximum flow rate or volume may be imposed in critical areas, such as special protection watersheds, impaired watersheds, etc. The recommendations in this paper could be relaxed for very small drainage areas (< **500 square feet**), such as disconnected rooftops, etc.

c. Level spreader length is the lineal measurement of weir required to discharge anticipated flows. It is measured perpendicular to the direction of flow. Level spreader length is primarily dependent on the influent rate and the type of down slope cover. The level spreader length needs to be designed so that the allowable down slope velocity is not exceeded. Other factors include the discharge pipe diameter (if applicable) and the number and size of perforations along the discharge pipe (if applicable). Generally, level spreaders should have a minimum length of **10 feet** and a maximum length of **200 feet.**

   1) Refer to **Section VII** for a more comprehensive description of the considerations involved in designing level spreaders and determining proper length.

   2) The *BMP Manual* recommends level spreader lengths for two ground cover conditions:

      - Dense grass ground cover (13 linear feet for every 1 cfs of flow).

      - Forested areas w/ no ground cover. (100 linear feet for every 1 cfs of flow)

      These conditions represent two extremes and it can be argued that most projects would fall somewhere in between. It is essential that a site analysis of the down slope condition (up to the receiving stream) be performed to properly determinate the maximum allowable velocity. Designers should be very cautious in using "rules of thumb" without understanding the underlying principles and assumptions.

      i. For instance, the *13 linear feet per cfs of discharge* is based on optimal ground cover conditions (dense grass) and no existing erosion formations.

      ii. Ground cover for the other extreme condition, forested areas (*100 linear feet per cfs of discharge)*, is based on little to no vegetal ground cover. As discussed in **Section VII**, this recommendation may be overly conservative for the situation where a good mulch ground layer exists. (e.g. mature forest)

      iii. Therefore, in natural conditions, the range for level spreader length per cfs of discharge should fall between **13** and **100 linear feet**. This range is almost one order of magnitude; hence it further emphasizes the need for the designer to understand the down slope area and its limitations.

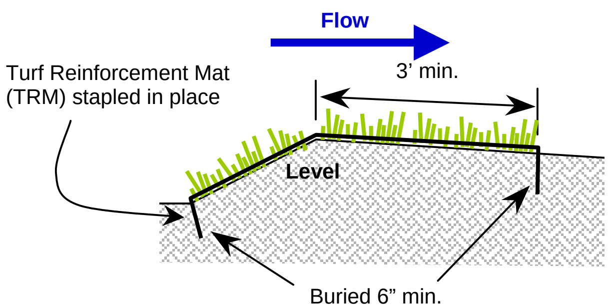
   3) For designs involving a subsurface discharge utilizing a perforated pipe, determination of the perforation discharge per linear foot of pipe may dictate the total required length of level spreader. Follow the design criteria described in *BMP 6.8.1: Level Spreaders* in the *BMP Manual*. This may require information from the pipe manufacturer including perforation dimensions and average head above the perforation.

d. Prior to discharge entering a level spreader, the flow should pass through a drop manhole/inlet to dissipate most of the energy. The pipe entering the level spreader should be at a maximum **1% slope.** For channel flow, the grade of the last **20 feet** of the channel before the level spreader should create a smooth transition from the channel grade to the level spreader and, where possible, should be less than or equal to **1%**.

e. Level spreaders with design flows (**Q**$_{100}$) in excess of **4 cfs** should have a rigid lip consisting of non-erodible material, typically concrete curbing with the invert founded below the frost line and anchored into the soil with an appropriately-sized concrete footer. (NRCS IL-570, 1999)

f. A vegetated lip may be suitable for low flows depending on soil characteristics. In these instances, the lip should be protected with a turf reinforcement mat (TRM), for a minimum of **3 feet** down slope to prevent erosion and to enable establishment of vegetation. (See **Figure 2**). More design considerations involving earthen berms are described in *BMP 6.4.10: Infiltration Berms*.

**Figure 2. Turf Reinforcement Mat (TRM) for Level Spreader with Vegetated Lip**

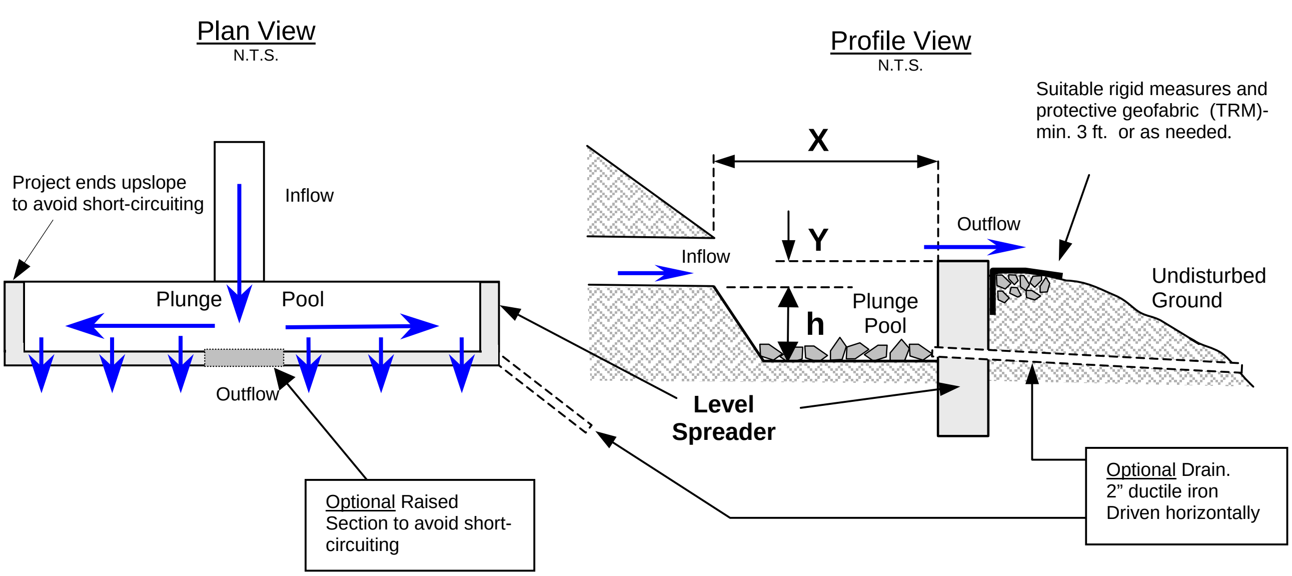



g. It is noted that level spreaders constructed out of earthen berms, pre-cast concrete curb sections, etc. are likely to require continual maintenance in order to keep them level. Experience has shown that a cast-in-place concrete berm with the invert below the frost line requires less maintenance and is most likely to sustain long-term use than earthen berms and pre-cast concrete curb sections. Timber should be avoided due to issues with deformation and decomposition.

h. There should be a smooth transition between the level spreader and native ground. Ideally, the lip of the concrete level spreader should be no higher than **3 to 4 inches** off the existing ground. (Hathaway & Hunt, 2006) This would allow water to pass over the lip with minimal interference from vegetation. (See **Item 7c** and **Figure 4**)

5. Level spreader orientation, where practicable, should be designed to allow for an even flow distribution. This is typically accomplished by utilizing a T-shape. (See **Figures 3** and **5**)

**Figure 3. Typical Orientation of Level Spreader with Surface Discharge**



6. Functional considerations for level spreaders:

   a. Avoid short-circuiting and overloading in the plunge pool (surface discharge):

      i. To avoid short-circuiting, the ends of the level spreader weir should be projected upslope, slanted upgradient and keyed into the slope.

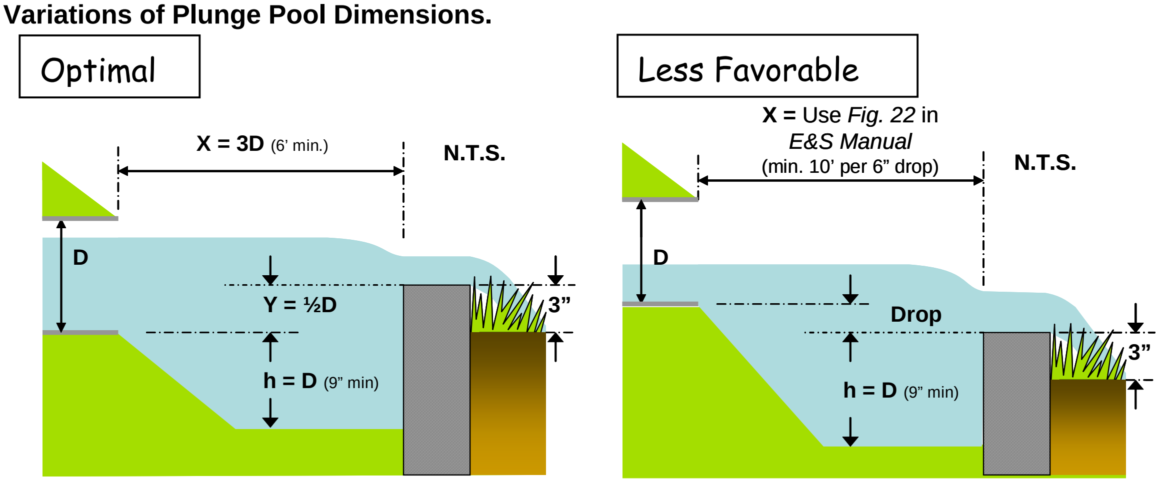
      ii. The level spreader should include a plunge pool with sufficient depth (**h**) to minimize short-circuiting potential. At a minimum, **h** should be the greater of **9 inches** or the inside diameter (**D**) of the inflow pipe (Hathaway & Hunt, 2006). For channel flow, the designer can use the equivalent pipe diameter. Riprap placed in the bottom of the plunge pool should be sized according to anticipated inflow velocities. Use the recommended riprap gradation in Table 9 of the *E&S Manual*. (Minimum **R-3**)

      iii. The vertical separation (**Y**) between the inflow (pipe or channel) and outflow (weir) inverts should provide sufficient freeboard to allow for energy dissipation. At a minimum, **Y** should be equal to half of the inside pipe diameter (**D**). Where freeboard is not possible, there should be a minimum **6-inch** drop per **10 linear feet** of plunge pool length (See Profile View of **Figure 3**).

      iv. The level spreader should provide sufficient length **(X)** between the inflow point and the outflow weir to avoid overtopping. If the distance (X) does not meet this criterion, the potential for short-circuiting will increase significantly below the inflow point. In this situation, the level spreader can include a raised middle section down slope of the inflow point to prevent overtopping and to direct flow laterally. The crest of the raised section should be equal to the crown elevation of the inflow pipe. (See Plan View of **Figure 3**)

      v. Recommended values for **X**: (See **Figure 4**)
         If **Y** ≥ ½**D**, then **X = 3D** (Minimum 8')
         If **Y** < ½**D**, then use *Figure 22* in *E&S Manual to find* **X.** (Minimum 10')

**Figure 4. Variations of Plunge Pool Dimensions.**




   b. Accommodate draining the plunge pool (surface discharge):

      i. To preserve infiltration capacity, the underlying soils should remain undisturbed, uncompacted, and protected from heavy equipment.

      ii. If standing water in the plunge pool is a potential issue (e.g., mosquitoes, icing, etc), the level spreader should include a drainpipe with a discharge point located in a well-vegetated area and/or include soil stabilization measures, as appropriate. (See **Figure 3**) A **2-inch** diameter drainpipe is recommended with a minimum **1% slope.** Where possible, installation of the drainpipe should extend laterally so that the discharge point is located outside of the flow path of the level spreader. Where this is not possible, installation by trench method should be avoided since it may create a preferential seepage pathway for surface flow and erosion. In certain instances, the drainpipe (ductile iron) may be driven horizontally with a sledgehammer.

c. For subsurface discharge level spreaders (no plunge pool):

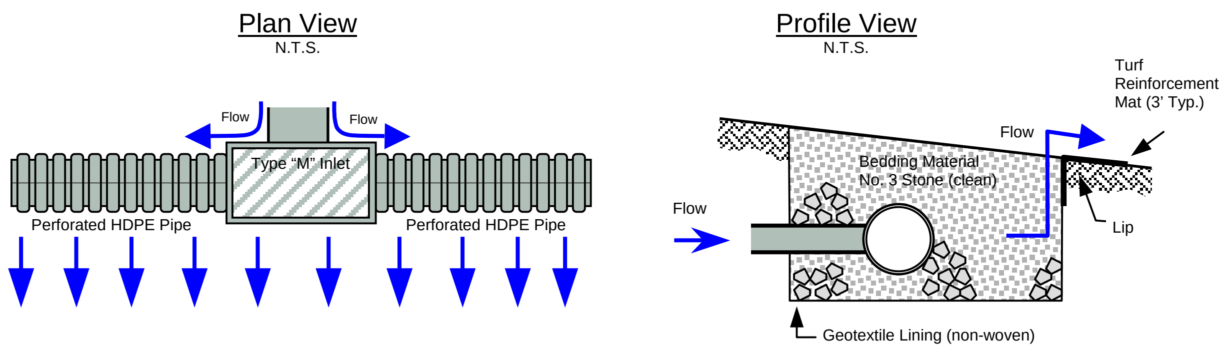
i. When installing perforated pipe (level), area must be carefully excavated into the existing grade to maintain a level lip. A rigid lip may also be utilized, as appropriate.

ii. Turf Reinforcement Mat should be installed for minimum of **3 feet** down slope of lip.

iii. Perforated pipes should include end treatments consisting of clean-outs or Type M inlets, which can also help accommodate future maintenance.

iv. Select non-woven geotextile lining based on soil type (sands, silts, clays, etc.).

**Figure 5. Typical Orientation of Level Spreader with Subsurface Discharge**




7. <u>Soil Stabilization Issues</u>:

The area down slope of the level spreader should be undisturbed. At a minimum, the first **three feet** down slope from a level spreader should be stabilized with soil/turf reinforcement mat and the area should be stabilized with grass or other approved vegetation. There should be a minimum uniform ground cover of **90%**. If vegetation along the flow path is insufficient, it should be enhanced to maximize erosion protection prior to any discharges. If a level spreader is installed above a disturbed area without a good vegetative cover, erosion rills can quickly form. Even sheet flow can cause significant erosion on disturbed areas. (See **Section IX)**

a. Because of the possibility of high-prolonged discharge from structural level spreaders, the area in the immediate vicinity of the discharge should be properly stabilized. Such stabilization may include rigid measures (stone, riprap, etc.) to help protect surrounding vegetation. (see Profile View of **Figure 3**)

b. Level spreaders are **<u>not</u>** intended for sediment removal. Significant sediment deposition in a level spreader will considerably reduce its effectiveness. During construction, suitable erosion and sediment pollution control BMPs should be utilized upslope of level spreaders. This aside, maintenance measures would still be required both during construction and after the drainage area is stabilized, including replacement of bedding material and geotextile stabilization (if applicable). In these instances, it would be preferable for the discharge pipe to be at the surface rather than subsurface.

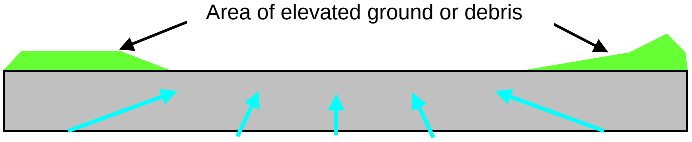
c. The down slope side of the level spreader should be clear of elevated ground and debris.

i. Elevated areas need to be carefully graded to create a smooth transition; backfilling is not recommended.

ii. Another potential problem after construction is debris such as earth, wood, and other organic matter that may accumulate immediately down slope of the level spreader. Both of these situations effectively block water as it tries to flow over the level spreader and may force it to quickly re-concentrate. (See **Figure 6**)

d. Consider the time of year available for proper establishment of vegetation prior to construction of the level spreader. Temporary stabilization may be achieved in sparsely vegetated areas with a compost blanket (min. **3"**). If a grass cover needs to be re-established in the receiving area construction may be limited to the growing season.

**Figure 6. View of Level Spreader Face Looking Downslope**




Source: *Evaluation of Level Spreaders in the Piedmont of North Carolina*

8. Operation and Maintenance (O&M):

   Because of construction-related problems, the performance of level spreaders should be monitored for **2 years** on a **quarterly basis** and **semi-annually** thereafter. Inspections should also be made following rainfall events exceeding **1-inch.** Prior to placing the level spreader into service, a qualified professional, preferably the designer should inspect the structure once it is fully constructed so that necessary adjustments or repairs can be made before the contractor leaves the site. Routine monitoring and maintenance is already a requirement of both the Erosion and Sediment Control Plan and the Post Construction Stormwater Management Plan. Monitoring includes both the level spreader and the down slope area, up to and including the receiving stream (See **Section VI.3**, *Authorization from Off Site Property Owners*).

   a. Monitoring should be documented in inspection reports submitted to the Conservation District along with a summary of any repairs or adjustments completed. Modifications may need prior approval. As-built drawings should be submitted by the end of the 2-year monitoring period verifying that the level spreader was built as designed and performing as intended.

   b. The Conservation District and Township Engineer should be notified during key stages of construction (including the construction of a level spreader) to allow for site inspections at their discretion.

   c. A long term O&M plan should be prepared, in conjunction with all proposed stormwater BMPs, identifying:
      1) Who will be responsible,
      2) What O&M procedures are planned and
      3) When these measures will be performed (frequency).
         i. Include provisions for replacing components surpassing their useful life.
         ii. Periodic cleaning out of sediment that is expected to accumulate over time to maintain its capacity.

   d. Erosion and Sediment (E&S) Control consideration: As mentioned in **Item 7**, level spreaders should not be used as a primary E&S BMP. When used down slope of a sediment basin/trap, it should be off-line during construction or (where applicable) the bedding material and geotextile lining should be replaced after the drainage area is stabilized.

   e. Level spreaders should be located only where safe and legal ingress and egress can be obtained for post-construction inspection and maintenance.

## VI. LEGAL CONSIDERATIONS

1. Adequacy of Off-Site Discharge: (also see **Item 3**, *Authorization from Off-site Property Owners*)
   The developer/designer will need to demonstrate that the proposed construction and/or post-construction stormwater discharge will not cause erosion or damage down slope and to any adjoining properties. Therefore, designs involving off-site stormwater discharge to non-surface waters should include the following information:

a. A written analysis, entitled "**Adequacy of Off-Site Discharge**" signed and sealed by a licensed professional engineer that clearly, concisely, and accurately describes the situation along with any supporting computations, etc.

i. The written analysis should include an evaluation of existing land cover, vegetative species (and their condition), topography, geology, down slope property owners, etc., and a description of the soils erodibility and absorption characteristics.

ii. This analysis can not be achieved solely through a desktop review; a site visit is required.

iii. A copy of this written analysis should be included both in the narrative and on the plan drawings in the event these documents are separated.

iv. Where there is a discharge onto or through adjacent properties prior to release to a stream, designers shall demonstrate how down slope properties will be protected.

b. A plan drawing detailing the flow path from discharge point to confluence with a surface water of the Commonwealth and identifying the soil types, erodibility factors, and consideration of vegetative cover.

c. Sequential color photos of the entire proposed flow path with a map showing the location and orientation of each photo. Plan should include the location and orientation of each photo.

d. A contingency plan and agreement should be prepared to deal with damages from the level spreader that may occur down slope (including parcels owned by others). The applicant may also set aside funds in escrow for this purpose. This would be at the discretion of the municipality. (Also see **Item 3**)

e. The minimum distance between a proposed discharge point (including the level spreader) and a down slope property boundary should be a minimum of **fifteen (15) feet**. (CCWRA, 2005) The regulating authority(ies) may require that the setback distance be increased based upon factors such as accessibility, topography, soil conditions, the size of structures, the location of structures, and discharge rates. A drainage easement may also be required. (See **Item 3**)

2. Municipal Coordination:
The municipality has a key role in stormwater management, including the use of level spreaders. The following criteria should be used to ensure the municipality's role, particularly when there is an issue encountered with an off-site discharge:

a. The municipal engineer should be contacted by the applicant early in the process to open the lines of communication.

b. A copy of the written analysis (described in **Item 1**) should be submitted to the municipal engineer by the applicant.

c. The municipality should provide a letter verifying the project's consistency with applicable local ordinances, a copy of which should be submitted to other reviewing agencies with any permit applications.

3. Authorization from Off-site Property Owner(s):
In cases involving discharges to off-site properties where a point-source discharge did not previously exist, the developer/consultant will need to:

a. Document property owner(s) consent through easement, right-of-way or other acceptable documentation.

b. Document property owner(s) consent to access and repair any erosion or other damages that may occur in the future.

In some cases, a level spreader will not be feasible and the only option the applicant will have is to reach an agreement with the off-site property owner to construct a conveyance (i.e., a pipe or channel) to an adequate discharge point. (See **Section VIII**, *Outfall Design*) DEP is also in the process of developing a related fact sheet, which may provide further guidance on the issue.

## VII. LEVEL SPREADER DESIGN CONSIDERATIONS

The primary reference of the information in this section has been taken from *Designing Level Spreaders to Treat Stormwater Runoff.* (W.F. Hunt, D.E. Line, R.A. McLaughlin, N.B. Rajbhandari, R.E. Sheffield; North Carolina State University, 2001)

**Maximum Flows**
The maximum allowable flow that a level spreader effectively distributes is a function of:

1. the ability to slow down the inflow before it flows over the level spreader and;

2. the length of the level spreader.

If the plunge pool is a small stormwater pond and the level spreader is several hundred feet long then the maximum flow allowed to spill over a level spreader is considerably high. To avoid failures, the plunge pool should be designed with a length (**X**) sufficient to dissipate the energy of inflows prior to reaching the weir crest of the level spreader. (See **Section V**.**6** and **Figure 3**) This is dependent on the inflow velocity.

**Design Storms**
For the purposes described in this paper, level spreaders should be constructed to effectively diffuse anticipated flows up the **100-year storm**. For this reason, these structures must be limited in their drainage areas. (**5 acres maximum**) Level spreaders may be multi-functional and can incorporate both water quality treatment and infiltration as part of a treatment train – but since these facilities are located at the tail end of the train, they should not be a primary BMP.

The length of the level spreader is primarily determined by peak flow rate. There are many methods that are commonly used to determine peak flow from small watersheds, including the NRCS Soil Cover Complex Method (a.k.a. Curve Number Method). Peak rate computations are commonly dictated by local ordinance and this paper will not cover those computations.

**Design to Avoid Downstream Erosion**
Down slope conditions are also essential when determining allowable flows and the length of level spreader, in particular, the existing soil cover (e.g., grass, mulch, or a thicket.)

**Allowable Velocities**
The maximum allowable velocity is a function of ground cover. The maximum allowable velocities for down slope soil covers are listed in **Table 1**. Please note that tree and shrub riparian buffer is assumed to have a mulch ground cover (or no ground cover).

**Table 1. Allowable Velocities for Down Slope Covers for Channeled Flows**

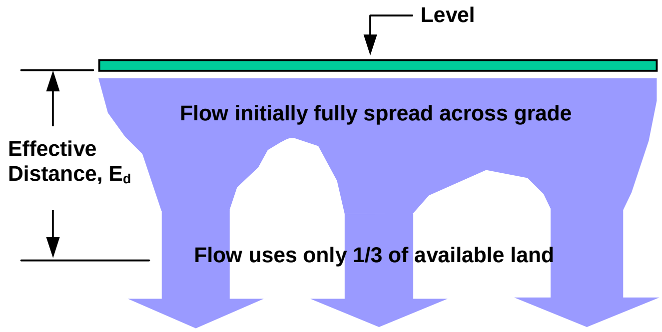
| Ground Cover | Allowable Velocity |
|---|---|
| Grass* | 4 fps |
| Gravel | 5 fps |
| Mulch | 1-2 fps |

* See E&S Manual for more information on permissible velocities for grass and other cover types. Allowable velocities for grass can vary from 2.5 fps to as much as 8 fps. 4 fps has been selected as a conservative figure for design purposes.

Source: *Designing Level Spreaders to Treat Stormwater Runoff*

The level spreader length needs to be designed so that the allowable velocity is not exceeded. It is important that the design consider that water will recollect as it flows down slope. Studies have shown that water distributed across a grade may recollect in as little as **10-12 feet**. Because recollection is inevitable, the amount of area needed for concentrated flow to develop should be estimated. How much recollection is allowable until flow can no longer be considered sheet flow? Sheet flow becomes concentrated flow once water is using only **33%** of the available land in the flow path (Hunt et al, 2001). Refer to **Figure 7**. The distance down slope of the level spreader where only **33%** of available land is used can be described as the level spreader's Effective Distance, or $\mathbf{E_d}$. Flow beyond the level spreader's effective distance would be considered to be concentrated flow, not sheet flow.

**Figure 7. Concentration of Flow Down Slope of Level Spreader**




Source: *Designing Level Spreaders to Treat Stormwater Runoff*

Therefore, level spreaders must be designed to ensure non-erosive velocities not only at the time water passes over the level spreader (when flow is theoretically completely dispersed), but also at the time water has reached the Effective Distance. The latter being the limiting parameter (i.e., erosive velocities are not exceeded once the flow has traveled the effective distance.). As such, discharge velocities from level spreaders should be **33%** or less of the allowable down slope velocities based on cover. As an example, if a mulch ground covering is able to withstand velocities as high as 2 feet per second (fps), then the level spreader discharge velocity should be 0.67 fps, or 1/3 of the erosive velocity. If the vegetation/ground cover along the flow path is insufficient to protect against erosion, then it should be enhanced to maximize erosion protection.

**Calculating Level Spreader Length**

The designer's main goal for level spreaders is to ensure an appropriate length of the discharge feature – a length that does not allow for erosive velocities down slope. Allowable velocities over a level spreader are summarized in **Table 2**. The designer can also find more information on allowable velocities (a.k.a. permissible velocities) and other criteria for ground cover from the E&S Manual, including Tables 5 through 7a related to: *Erodible Soils in Pennsylvania; Maximum Permissible Shear Stresses for Various Channel Liners; Classification of Vegetative Covers as to Degree of Retardance;* and *Maximum Permissible Velocities for Channels Lined with Vegetation*.

**Using Allowable Velocities to Establish Level Spreader Length**

With an allowable velocity selected based upon down slope ground cover, it is now possible to calculate the necessary level spreader length. The calculation is based on two equations: (1) the Weir Equation and (2) the Continuity Equation, both of which are described below.

Weir Equation:

It is assumed that the level spreader functions as a long weir. Flow over a weir is described by the following equation and illustrated in **Figure 8**.

$$\mathbf{Q = C_w * L * H^{3/2}}$$

Where

Q = Flow (cfs)
L = Length of Level Spreader (feet)
$C_w$ = Weir Coefficient (assume 3.0)
H = Driving Head (feet)

Flow over the level spreader is a function of its length and the height of water upslope. Increasing the length of the weir reduces the height of water for a given flow rate, as they are directly related. This is important because the combination of water height and weir length dictate the level spreader discharge velocity. This relationship is shown in the second equation, the continuity equation.

Continuity Equation:

$$Q = V * A$$

Where, Q = Flow (cfs)
V = Velocity (feet)
A = Cross-Sectional Area of Flow ($ft^2$) = $L * 2/3H$

Again, the allowable velocity is selected based on the type of cover down slope of the level spreader (e.g., grass, gravel, mulch). Therefore, the above two equations can be combined to solve for V as follows:

$$V = 1.5 * C_w * H^{1/2}$$

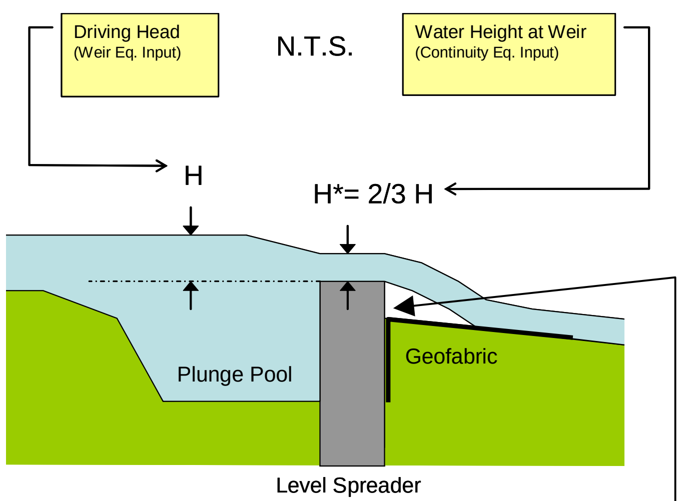
Using the above equation, the height of water above the weir may be calculated. The resulting height would then be inserted into the weir equation to calculate the length of level spreader needed to distribute a given flow.

**Table 2. Maximum Velocities of Flow Across Level Spreader**

| Down Slope Ground Cover | Velocity at Level Spreader V (fps) | Driving Head H (feet) | "Equivalent" Water Height over Level Spreader, H*=2/3H |
|---|---|---|---|
| Grass/Thicket | 1.33 | 0.09 | 0.058 |
| Gravel | 1.50 | 0.11 | 0.074 |
| Mulch (Trees, Shrubs) | 0.67 | 0.02 | 0.015 |

Source: *Designing Level Spreaders to Treat Stormwater Runoff*

**Figure 8. Weir Equation Inputs**




Source: *Designing Level Spreaders to Treat Stormwater Runoff*

Note: There should be a smooth transition between the level spreader and native ground. Ideally, the lip of the concrete level spreader should be no higher than **3 - 4 inches** above the existing ground. This would allow water to pass over the lip without interference from vegetation. See **Section V** and **Figure 3.**

**Table 3. Level Spreader Lengths for Various Downslope Covers and Discharges**

| Q (cfs) | Gravel L (ft) | Grass/ Thicket/ Shrubs L (ft) | Mulch** or No Cover L (ft) | Using equation $L = Q/ (C_w{*}H^{3/2})$ Notes: |
|---|---|---|---|---|
| 0.5 | 5* | 6* | 59 | |
| 1.0 | 9* | 13 | 118 | |
| 1.5 | 14 | 19 | 177 | |
| **1.7** | 16 | 21 | **200** | Mulch Limit** |
| 2.0 | 18 | 25 | N/A | |
| 3.0 | 27 | 37 | | |
| 4.0 | 37 | 49 | | |
| 5.0 | 46 | 62 | | |
| 10.0 | 91 | 123 | | |
| 15.0 | 137 | 185 | | |
| 16.0 | 146 | 198 | | |
| **16.2** | 148 | **200** | | Grass/Shrub/Thicket Limit |
| 20.0 | 183 | N/A | | |
| 21.0 | 192 | | | |
| **21.9** | **200** | | | Gravel Limit |

* use min. length of 10 feet
** see below suggestions regarding forested areas

Source: *Designing Level Spreaders to Treat Stormwater Runoff*

As mentioned in **Section V.4c** other guidance documents, including the *BMP Manual*, recommend **13 linear feet** of level spreader per **1 cfs** of flow. As can be seen in **Table 3** above, this is consistent for the condition when there is excellent vegetative ground cover down slope. (i.e. thicket/shrubs/grass) It also assumes that there are no existing erosion problems down slope. It is not uncommon to find areas of lush vegetation followed by an area of sparse vegetation. It is crucial that designers perform a thorough site assessment and not use this as a general rule of thumb for all conditions. The most controlling factor is the allowable velocity, which should be based on the worse case down slope ground cover condition. The designer would need to verify the condition of the ground cover for the entire slope up to the receiving stream, preferably in the winter. An alternative would be to improve the down slope area to achieve the design cover condition - prior to discharge.

The results of recent research (Hathaway and Hunt, 2006) has suggested that wooded riparian buffers having a good mulch cover exhibit positive features such as absorption and infiltration which are often ignored. For the purposes of this paper, a good mulch cover should measure a minimum **3 inches** thick. When these attributes within the buffer are taken into account and documented during a site assessment, the length of level spreader per unit of flow may be reduced. This reduction can be significant due to the long lengths of level spreader required for the "mulch/no cover condition" – i.e. 100 linear feet/cfs. Based on this information, the recommended design length of level spreader can be reduced as follows, in relation to riparian buffer width and the dominant hydrologic soil group (HSG) for the down slope area:

**Table 4. Reduced Level Spreader Lengths for Wooded Riparian Buffers**

| | **HSG A or B** | **HSG C or D** |
|---|---|---|
| **Wooded Riparian Buffer Width** (ft) | **Length of Level Spreader per CFS of flow** (ft) | |
| 50 | 65 | 80 |
| 100 | 50 | 70 |
| 150 | 40 | 55 |

Source: *Evaluation of Level Spreaders in the Piedmont of North Carolina.*

## VIII. OUTFALL DESIGN

As previously mentioned, if it is determined that a level spreader is not feasible for a project, the developer will need to modify the project to either avoid the conflict or to convey the point source discharge to a surface water or storm sewer which is capable of handling anticipated flows. This is typically done by extending a conduit through the area and terminating at a watercourse with an outfall structure. Outfall structures are regulated as water obstructions pursuant to the Chapter 105 Regulations – *Dam Safety and Waterway Management*. (July 1, 1979, revised October 12, 1991) Permitting may fall under the following categories:

- **Waiver - 105.12(a)(2)** – If the receiving stream has a drainage area less than **100 acres**.
- **General Permit No. 4** – In most cases, the project will qualify for a GP but the applicant would be responsible for making sure they meet the eligibility requirements and conditions.
- **Joint Permit** – Outfalls not qualifying for a waiver or GP will need a Joint Permit. For more information, refer to the Pennsylvania Chapter 105 Joint Application for a Water Obstruction and Encroachment Permit.

Experience has shown that many stormwater plans have been proposed in a manner discharging into upland areas to avoid Chapter 105 – Water Obstruction and Encroachment Permitting. These proposals are typically unacceptable unless they are being prepared to protect a riparian buffer or wetland, in which case, a typical level spreader design might be appropriate. (See illustration in **Section II**) Under no circumstances should a point source be discharged above the floodway and allowed to scour a channel down to the watercourse. In these instances, the designer should extend the outfall to the edge of the stream and take into account the following factors:

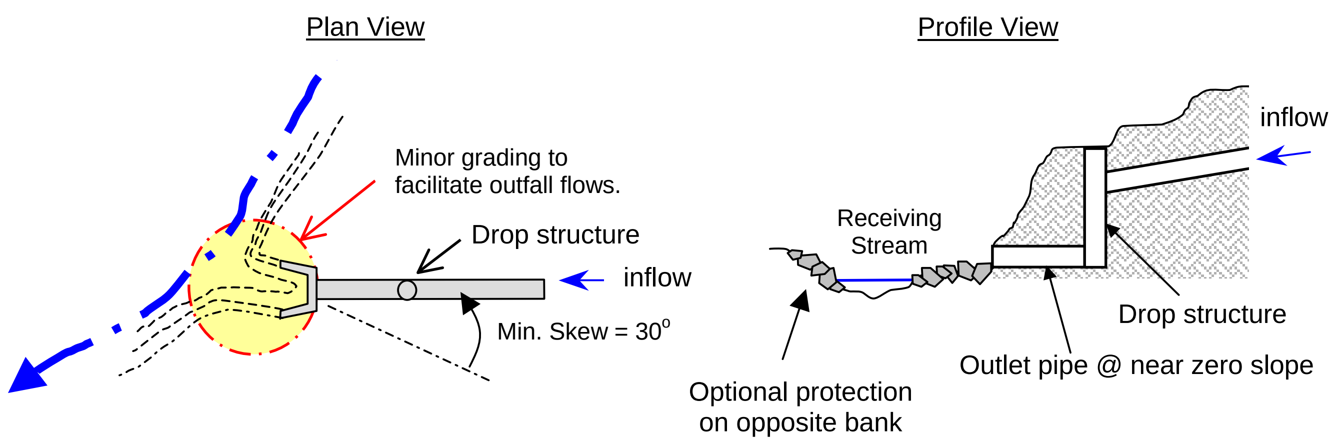
1. Orientation of the outfall with respect to the flow direction of the stream. Rather than be positioned perpendicular to the stream, the outfall should be designed at a skew of **30$^{o}$** or more to maintain harmonious stream current and to avoid scouring the opposite stream bank during high flows. Depending on the size of the receiving channel, it may be necessary to install protective measures on the opposite bank. Note that there should be no riprap placed in the stream bed.

2. The size of the outfall should be commensurate with the size of the receiving stream and should not over-burden the stream and thereby cause downstream erosion.

3. The outfall conduit should, wherever possible, go through a drop structure to dissipate the energy in the pipe, rather than relying on riprap at the end of the pipe. The outfall pipe should have a slope at or near **zero**.

4. Where riprap is appropriate, it should be keyed into the ground as opposed to piled in front of the outfall, which creates a flow obstruction. Riprap should not extend across the stream channel or cause an obstruction of stream flows. Refer to **General Permit No. 4** for further guidance.

**Figure 9. Outfall Layout**



## IX. REMEDIAL ACTIONS

As previously mentioned in **Section VII**, *water will recollect as it flows down slope* and *recollection is inevitable*. The design and planning recommendations in this paper are intended to avoid issues with failures and gully/rill formation, but plans also need to be in place for when any such unfortunate events may occur.

One of the most common problems experienced with level spreaders is the formation of rills, which if left unattended can become gullies. Rills that exceed **3 inches** in depth may be considered gullies. The most important point here is to identify and address these problems early by following these simple steps: (1) stop the erosion, (2) repair the damage, and (3) prevent future damage.

It is best to redirect flow away from the affected area until repairs can be completed and the area stabilized. This can be accomplished by a temporary slope pipe or other diversion, but care must be taken not to create erosion problems elsewhere. Seasonal variations are also an issue, particularly with permanent stabilization/revegetation. As discussed in **Section VI.7**, a minimum uniform cover of **90%** is required to protect down slope areas. Care should be taken through out the flow path, up to the receiving stream. A level spreader should never discharge to a disturbed area until vegetative cover is established.

**Figure 10. Rill/Gully Repair** (N.T.S)

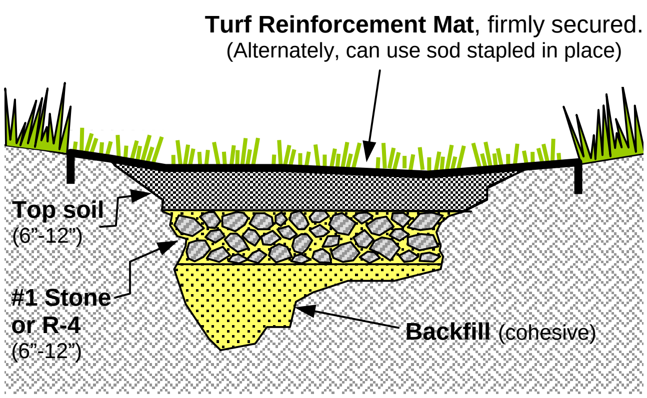
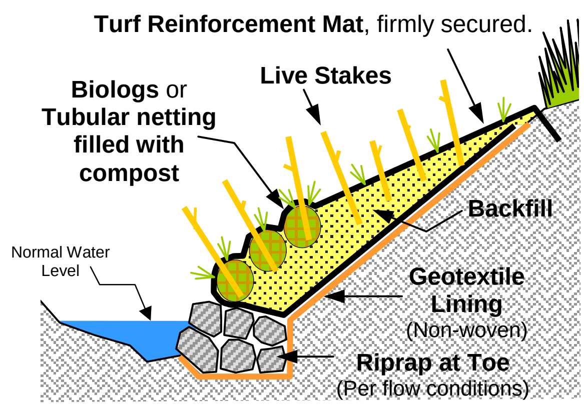



**Figure 11. Stream Bank/Gully Repair** (N.T.S.)



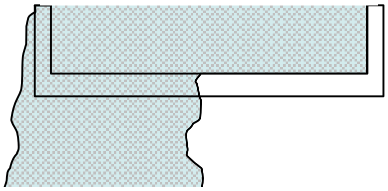

Source: *Filtrexx - Edgesaver*

Rills and/or gullies can express themselves anywhere along the flow path. In some instances, they appear at the stream bank. Stream banks are susceptible to erosion from a variety of sources and directions. Accelerated erosion along a stream bank is normally due to the stream geometry being out of equilibrium with its watershed, which is beyond the control of the plan designer. As water passes over a denuded stream bank, a head cut can form and travel from the stream into the buffer. The plan designer should ensure that an exposed stream bank does not exist along the flow path. If so, there are a variety of stream bank stabilization methods, including traditional "hard engineering" techniques, such as riprap; softer techniques such as "bioengineering slope stabilization" or a combination of the two. See **Figure 11** above. For more details, the designer may reference **General Permit No. 3** or various references for bioengineering such as Chapter 18 of the *NRCS, Engineering Field Handbook* available at www.info.usda.gov/CED/ftp/CED/EFH-Ch18.pdf. The goal is to create a natural and stabilized system that doesn't require any significant long-term maintenance. There are a variety of "green" and environmentally-friendly products available on the market which can be utilized jointly with bioengineering techniques to provide quality results.

Experience has shown that there are many other potential factors leading to level spreader failure, many of which have been covered through the recommendations in this paper. A list of common failures, potential causes and suggested fixes are provided in **Figure 12**. When necessary, a level spreader may be replaced with a stable conveyance and outfall to a surface water feature or to a storm sewer capable of carrying those flows. This subject was previously discussed in various places, including **Section VIII**.

**Figure 12 – Common Level Spreader Failures**

## Unlevel



**Cause:**

- Differential Settlement
- Frost Heaving
- Poor Construction

**Fix:**

- Rebuild
- Retrofit
  - Affix a level plate/weir on down slope (d/s) end

## Short Circuiting

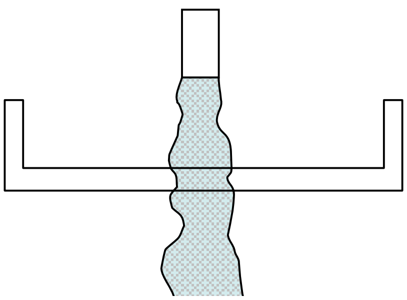
**Cause:**

- Poor Planning
- Poor Construction

**Fix:**

- Retrofit
  - Extend concrete ends upslope and key-in
  - Repair erosion and revegetate d/s

## Overtopping



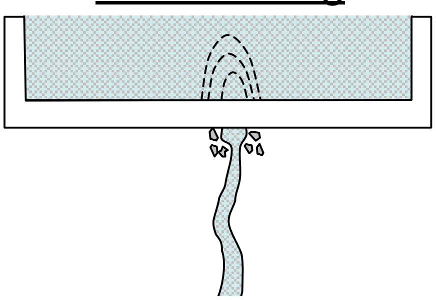
**Cause:**

- Poor horizontal and/or vertical alignment
- Inadequate plunge pool length/depth
- Weir too close to outlet pipe.

**Fix:**

- Rebuild
- Retrofit
  - Construct raised middle section to divert flow and block overtopping
  - Pull back outlet pipe

## Undercutting



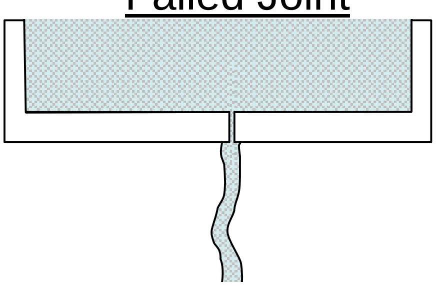
**Cause:**

- Poor construction
- Inadequate weir invert
- Inadequate depth of footer
- Constructing on fill
- Vandalism

**Fix:**

- Rebuild
- Retrofit
  - Flowable fill u/s
  - Repair erosion and revegetate d/s
  - Protect from unauthorized acts

## Failed Joint



**Cause:**

- Poor construction
- Inadequate joint filler
- Vandalism

**Fix:**

Retrofit
- Plate or weir
- Install proper joint filler resistant to freeze/thaw
- Repair erosion and revegetate d/s
- Protect from unauthorized acts

## X. SELECTED REFERENCES

*Pennsylvania Stormwater Best Management Practices Manual* (PA DEP, December 30, 2006)

*Pennsylvania Erosion and Sediment Pollution Control Manual* (PA DEP, March 2000)

*Designing Level Spreaders to Treat Stormwater Runoff* (W.F. Hunt, D.E. Line, R.A. McLaughlin, N.B. Rajbhandari, R.E. Sheffield; North Carolina State University, 2001)

*Level Spreader Design Guidelines-Final Version* (C. F. Van Der Wiele, North Carolina Department of Environment and Natural Resources, Division of Water Quality, Effective January 1, 2007)

*Evaluation of Level Spreaders in the Piedmont of North Carolina- Final Report* (Jon Hathaway, EI and William F. Hunt PE, PhD, Department of Biological and Agricultural Engineering, North Carolina State University- July 2006)

*Urban Waterways – Level Spreaders: Overview, Design and Maintenance.* (Jon Hathaway, EI and William F. Hunt PE, PhD, Department of Biological and Agricultural Engineering, North Carolina State University- Cooperative Extension Office -November 2006)

*Post-Construction SWM Model Ordinance* (Chester County Water Resources Authority, January 4, 2005)

*Standard Drawing No. IL-570* (USDA, NRCS, Illinois Urban Manual, January 29, 1999)

*Level Spreader Effectiveness Evaluation, Final Report* (Caltrans, May 2002)

*Design and Long Term Performance of an Innovative Level Spreader Basin Outfall Structure*, (Eric S. Steinhauser and Owen Esterly - World Water Congress 2003).

*Effectiveness and Cost of Improving Vegetated Filter Zones by Installing Level Spreaders to Disperse Agricultural Runoff.* (Dennis William Hazel, Doctoral Thesis, North Carolina State University- 2000)

Internet References:

www.therockerbox.com/how_to_use_a_map_5.htm

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## XI. ACKNOWLEDGEMENTS

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## Checklist for Designing Level Spreader Discharges

Project Name: ____________________

Project No.: ______________________

Location: ________________________

Date: ____________________

Prior considerations:

- ☐ Avoid and minimize discharge to non-surface waters
- ☐ Consider less impacting alternatives
- ☐ Maximize volume control BMPs throughout the site
- ☐ Prevent concentrating flow

Site Evaluation/Limitations:

- ☐ Site Assessment performed to determine site constraints (including a **site visit**)
- ☐ Level area – along existing contour

Have fully evaluated and considered:

- ☐ Topography
- ☐ Vegetative cover
- ☐ Soil type(s)
- ☐ Geologic conditions

Meets optimum conditions:

- ☐ Land surface shape
- ☐ Max. Soil slope = ____%
- ☐ Slope length = _______ ft.

H&H Considerations:

- ☐ Designed for 100-year storm. $\mathbf{Q}_{100}$ = ______ cfs
- ☐ Drainage Area $\leq$ 5 acres
- ☐ Suitable weir length using guidance in Section V. **L** = _______ ft.
- ☐ Not exceeding 200 feet long
- ☐ Inflow less than 1% slope
- ☐ Proper Lip - Rigid Lip, if Q > 4cfs
- ☐ Smooth transition – both inflow and outflow.
- ☐ Proper orientation – T-shaped
- ☐ Infiltration capacity preserved

Avoids short-circuiting and/or overloading

- ☐ Sufficient **X** = ____', **Y** = ____' and **h** =____'. (surface discharges)
- ☐ Optional Raised Section (surface discharges)
- ☐ Ends keyed upslope (surface discharges)
- ☐ Includes adequately sized riprap (surface discharges)
- ☐ Equipped to drain the plunge pool
- ☐ Includes end treatments on perforated pipe. (subsurface discharges)
- ☐ Includes fabric or TRM on down slope (both surface and subsurface)

Soils Stabilization Issues:

- ☐ Located on undisturbed ground (no fill)
- ☐ Achieves minimum of 90% vegetative cover down slope
- ☐ Includes rigid measures to prevent erosion just below
- ☐ Down slope area clear of elevated ground, debris or any other obstructions

Other Items:

- ☐ O&M Considerations per **Section V.8**.
- ☐ "Adequacy of Off-Site Discharge" Analysis completed per **Section VI.1**.
- ☐ Municipal Coordination per **Section VI.2**.
- ☐ Authorization from Off-Site Property Owner(s) per **Section VI.3**.
- ☐ Outfall Design, if applicable, per **Section VIII**.