URBAN Waterways

Level Spreaders: Overview, Design, and Maintenance

Level spreaders are stormwater structures that can support the filtering action of riparian buffers if designed and installed properly.

This publication presents the latest research findings on level spreaders in North Carolina and describes recommended practices for designing, installing, and maintaining these structures.

Since 1998, North Carolina has implemented rules to protect riparian buffers in several major river basins. These rules require that concentrated stormwater runoff be diffused, or spread, prior to discharge into a riparian area. To accomplish this, the Division of Water Quality (DWQ) in the N.C. Department of Environment and Natural Resources (NCDENR) recommended the use of level spreaders and developed initial design standards in October 2001. An overview of level spreaders and riparian buffers can be found in *Urban Stormwater Structural Best Management Practices*, AG-588-01, of the Urban Waterways series. This fact sheet provides more detailed information on designing, installing, and maintaining level spreaders.

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DIFFUSE FLOW: WHAT IS IT?

Diffuse flow, sometimes called *sheet flow*, occurs when water spreads out evenly across an area (Figure 1). In contrast, when stormwater collects in a drainage system and flows to a stream via a pipe, swale, or ditch, it does not make enough contact with or bypasses the *riparian buffer*—a vegetated area along streams, rivers, and other water bodies that helps to filter runoff and prevent erosion. Riparian buffers can improve water quality in urban environments by reducing stormwater peak flow, reducing runoff volume through infiltration, and removing nutrients and sediment through physical and biological processes. They are most effective, however, when stormwater flows through them at a shallow, uniform depth—the diffuse flow that well-designed level spreaders can provide.

LEVEL SPREADER SYSTEMS: AN OVERVIEW

Level spreader systems consist of three parts: the forebay, the channel, and the riparian buffer (Figure 2).

Figure 1. A level spreader providing diffuse flow (Frank Hahne, Mecklenburg County)

FOREBAY. The first part of the system is the forebay, which is used for the preliminary treatment of stormwater. It is an excavated, bowl-shaped feature that slows the influent stormwater and allows heavy sediment and debris to settle. The forebay may be lined with riprap to reduce erosion within the excavated area. The uneven riprap surfaces function as small sediment traps. When a level spreader is used to disperse outflow from a detention pond, a forebay may be necessary to reduce runoff velocity before the outflow reaches the level spreader.

CHANNEL. After the stormwater passes though the forebay, it enters a concrete, rock, or grassed channel—the main body of the level spreader. This is a dead-end channel because it does not directly connect the watershed to the stream. Instead, the channel is a long, shallow impoundment that fills to the level of its lower side. The lower side (the *downslope side*) of the channel is constructed so that it is level along its full length. This lower side, or *level spreader lip*, is often constructed of concrete or rock so that it resists erosion. As stormwater enters the channel, it rises until it fills the channel and exits evenly over the lip. The downslope side of the system functions as a long, broad-crested weir.

RIPARIAN BUFFER. After the stormwater passes over the level spreader lip, it enters the riparian buffer, often simply called the buffer. As the stormwater passes through the buffer vegetation, some of the water infiltrates. Ideally, the buffer will remove sediment and nutrients from runoff before it reaches the stream.

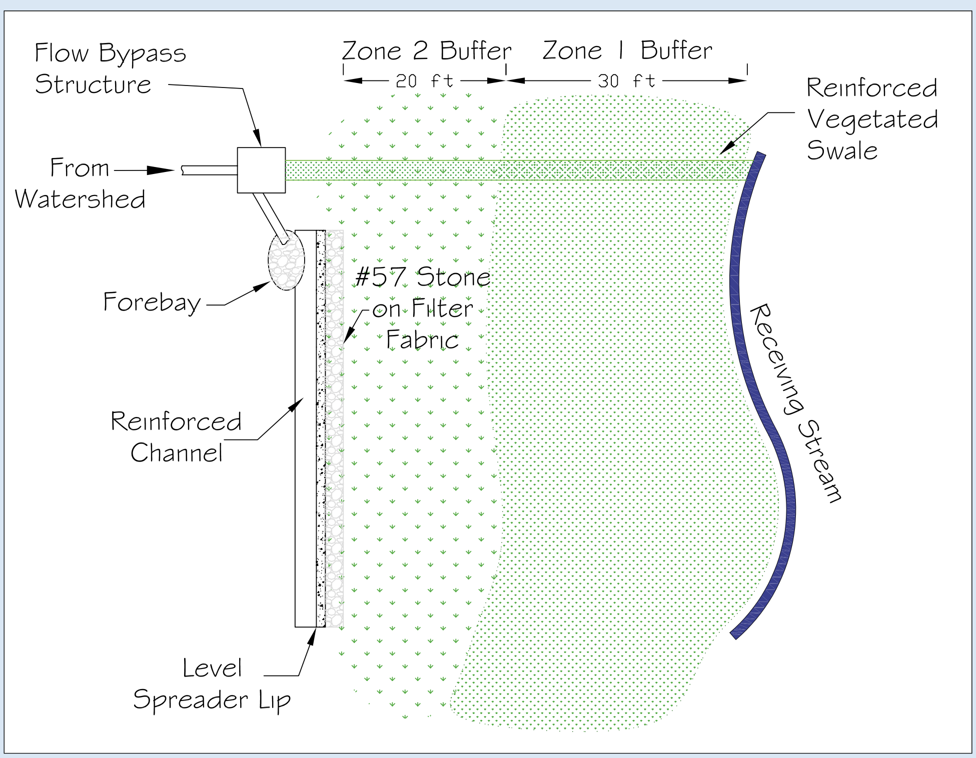

Figure 2. Level spreader system

RECENT LEVEL SPREADER RESEARCH

The Biological and Agricultural Engineering Department at North Carolina State University received a grant from NCDENR in December 2005 to evaluate level spreaders as stormwater best management practices (BMPs). The researchers visited 24 locations where level spreaders were in use and performed various qualitative and quantitative analyses.

The results of the study indicated that none of the level spreader–riparian buffer systems was able to provide diffuse flow through the riparian buffer from the level spreader to the stream. Common causes for failure to maintain diffuse flow included the following:

- Lack of maintenance.
- Poor design.
- Riparian topography, vegetation, or both .
- Poor construction methods (level spreader lip not level; channel built with easily eroded materials as in Figure 3).
- Human interference after the level spreader has been constructed.

This field evaluation indicated that level spreader systems in North Carolina would benefit from design revisions, construction guidance, and maintenance. As a result, the design guidelines developed by NCDENR in October 2001 were revisited and revised in the summer of 2006.

Figure 3. Failure at level spreader constructed with ABC stone

DESIGN RECOMMENDATIONS

Based on this research, the following recommendations should be considered when designing level spreaders.

Level spreader lip. A level spreader system obviously needs a stable lip that cannot be eroded. Concrete level spreaders can be built with minimal slope along the length of the channel's downslope side. Concrete level spreaders resist erosion better than level spreaders made of earth, gravel, or both. If a flow greater than the design flow is routed over a level spreader made of concrete, the level spreader lip will not be damaged. Level spreaders made of earth, gravel, or both should not be used in any urban applications because they routinely fail. Another stable material is a metal gutter. Like concrete level spreaders, pre-fabricated metal level spreaders can be expected to remain level with minimal maintenance.

Ideally, the lip of the concrete level spreader should be higher than the existing ground by 3 to 6 inches. This allows water to pass over the lip without interference from buffer vegetation. To limit any erosion that could occur as water falls from the top of the level spreader to the existing soil, a layer of filter fabric should be extended a distance of 3 feet from the level spreader lip towards the buffer. Stone, such as No. 57 aggregate, should be placed on top of the filter fabric (3 to 4 inches deep) to reduce erosion just downslope of the level spreader (Figure 4). A 3-foot wide strip of erosion control matting can be used in place of the filter fabric and No. 57 stone combination. However, such an area must be stable and have adequate vegetation before receiving stormwater.

Level spreader dimensions. Level spreader dimensions have a broad range, and no combination seems to be superior. The width of a level spreader, however, should be at least three times wider than the diameter of the inlet culvert. The design depth, or depth between the invert of the level spreader channel and the level spreader lip, is currently recommended to be *no less than* either 9 inches or half of the inlet culvert diameter, whichever is greater.

When discharging into a buffer with thick ground cover, there must be 13 feet of level spreader for every 1 cubic foot per second (cfs) of flow. This design specification is based on maximum flow velocities and is intended to limit erosion in the buffer. Grass, for example, is more resistant to erosion than mulch and detritus. Therefore, a shorter length of level spreader is needed upslope of grass than upslope of mature woods. In forested buffers, this number varies based on the width of the riparian buffer. The wider the riparian buffer, particularly wooded buffers, the more stormwater will infiltrate the buffer. When infiltration within the buffer is taken into account, the length of level spreader per unit of flow can be reduced:

- A level spreader discharging onto a 50-foot wide wooded riparian buffer should be sized at 65 feet per 1 cfs of flow.
- Discharging onto a 100-foot wide wooded buffer requires 50 feet of level spreader per 1 cfs of flow.
- Discharging onto a 150-foot wide wooded buffer requires 40 feet of level spreader per 1 cfs of flow.

The minimum length of any level spreader should be 13 feet, and the maximum allowable length by DWQ standards is 130 feet. A summary of the sizing guidelines for level spreader lip length is shown in Table 1.

Table 1. Level Spreader Lip Sizing Guidelines

Riparian Buffer Vegetation	Riparian Buffer Width (ft)	Length of Level Spreader (ft per 1 cfs of flow)
Thick ground cover	For any width	13
Forested	50	65
Forested	100	50
Forested	150	40

Forebay inclusion. Forebays should be utilized in level spreader systems to dissipate energy and reduce the sediment that accumulates behind the level spreader lip (Figure 5). The forebay is essentially a bowl-shaped depression lined on the bottom and sides with Class B rip rap. The forebay should be sized so that it is at least 0.2 percent of the contributing catchment's impervious or paved surface area. The catchment is the land area draining to the system.

The depth of the forebay where the stormwater initially enters should be 3 feet. The forebay should then slope upward to a depth of 1 foot prior to discharging into the level spreader (Figure 5).

Flow-bypass. If runoff from high intensity storms (those that deliver more than 1 inch of rain per hour) is allowed to flow through a level-spreader and riparian-buffer system that is not designed to handle such storms, erosion can occur within the buffer. Thus, during heavy rain storms that produce more runoff than can be infiltrated by the buffer, excess stormwater should bypass the buffer and be sent through a protected channel to a predetermined, protected stream entry point. This is achieved by allowing the runoff produced by a rainfall intensity of 1 inch per hour to enter the level spreader while diverting runoff from heavier rainfalls to the stream. The *bypass channel*, or *swale*, should employ turf reinforcement matting or rip rap.

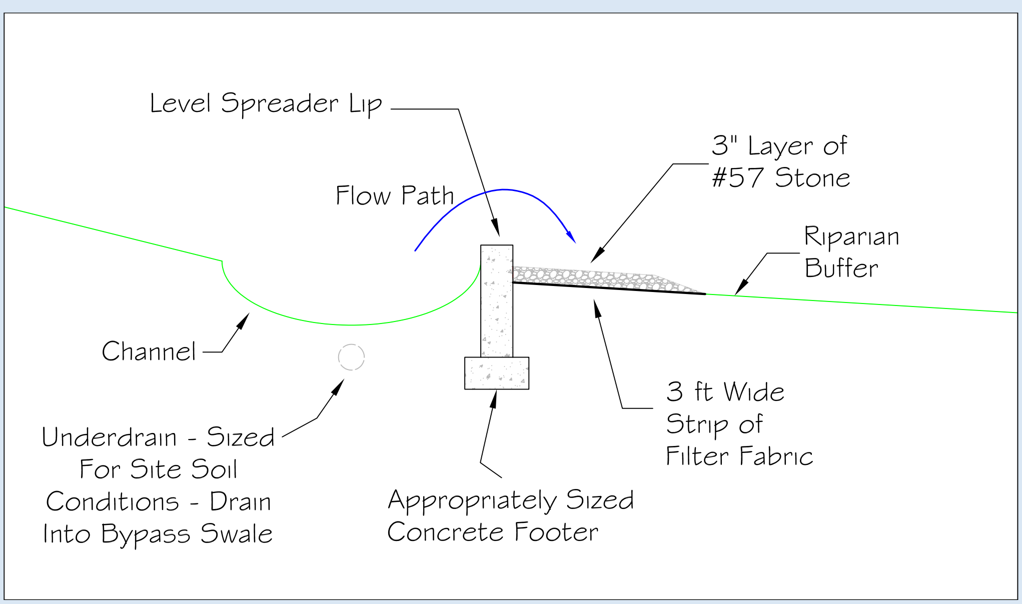

Figure 4. Sample cross section of a concrete level spreader

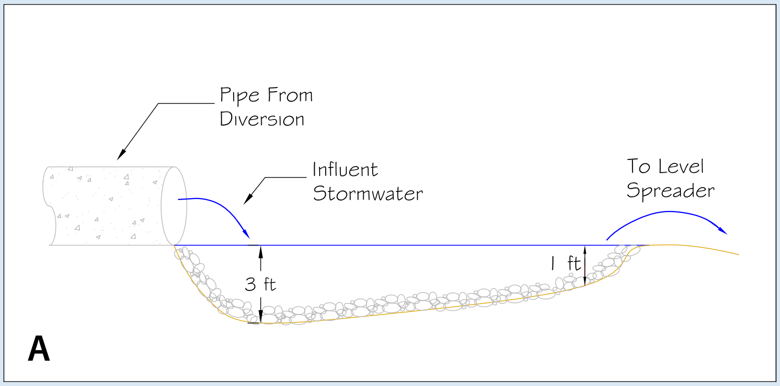

Figure 5. (A) Forebay schematic. (B) Image of level spreader with forebay

Maximum slope. The first 10 feet of riparian buffer downslope of the level spreader should have a slope less than or equal to 4 percent.

The overall slope of the buffer should not exceed 6 percent for wooded buffers and 8 percent for buffers containing thick ground cover (such as grass). When slopes are greater than this, other practices, such as bioretention, stormwater wetlands, and ponds, can be used to reduce peak flows and provide water quality improvements. However, on a case-by-case basis, the DWQ may approve a series of level spreaders for riparian buffer slopes of 12 to 15 percent. This approval is contingent on a site visit and the professional judgment of the DWQ permitter.

MAINTENANCE

Level spreaders require *at least* yearly maintenance to remove trees and shrubs that begin to grow on the level spreader lip or that impede flow just downslope of the level spreader (in the section of No. 57 stone from Figure 4). Any debris and sediment that build up in the level spreader, forebay, and channel should be removed annually and after storms greater than or equal to a *two-year storm*—the precipitation associated with a 24-hour storm event that occurs, on average, once every two years (Figures 6 and 7). In North Carolina, the two-year storm ranges from 3.5 to 4.25 inches over a 24-hour period. Additionally, the level spreader channel and the riparian buffer should be examined annually and after storms greater than or equal to the two-year storm for possible erosion and gulley formation.

If possible, the buffer vegetation immediately downslope of the level spreader lip should be mowed

Figure 6. Level spreader just after construction

Figure 7: Sediment and debris build-up after approximately 4.5 years of operation

regularly to encourage low, dense growth and to facilitate inspection. The use of perennial, dense, low-growing ground covers (such as common bermudagrass) downslope of the lip may help to maintain diffuse flow.

These issues should be addressed immediately to restore proper function. If erosion is apparent, corrective action must be taken, such as installing erosion control matting and possibly regrading. NCDENR must be notified before any work is performed in the protected buffer.

RIPARIAN BUFFER TOPOGRAPHY

Riparian buffers are highly variable. Depending on internal buffer topography, water will tend to re-concentrate, almost immediately in some cases. Certain level-spreader and riparian-buffer systems may only partially disperse influent concentrated flow. The systems still can improve water quality and reduce flow peaks. However, level spreaders should be situated in areas away from natural swales, depressions, and mounds where diffuse flow is more attainable. If the riparian buffer is not conducive to diffuse flow, other BMPs should be considered.

SUMMARY

Table 2 shows suggested site selection, design, and maintenance criteria for level spreader systems. Level spreader design is not as technically challenging as other stormwater BMP designs. Nevertheless, siting and installing a level spreader that functions properly is challenging. The design criteria described in this publication represent elements of good level spreader design but do not ensure overall system effectiveness. For the system to function as intended, it must be maintained, and the internal topography of the riparian buffer must be conducive to keeping flow diffuse. *Before designing a level spreader system, the designer should visit the site. This site visit is highly recommended.* If conditions are not suitable for the installation of the level spreader (for example, if the slope is too steep or adequate space is not available), other stormwater BMPs should be used.

Table 2: Level Spreader Site Selection, Design, and Maintenance Recommendations

Item	Recommendation
Level spreader lip material	A concrete or sturdy metal lip should be used in all level spreaders. The lip should be tied into the soil with an appropriately sized concrete footer or similar footer.
Level spreader lip dimensions	The concrete lip should extend 3 to 6 inches above the existing grade on the buffer side. Just after the lip, a 3-foot wide, 3- to 4-inch thick layer of No. 57 stone should be used to minimize erosion due to the water spilling over the level lip. This gravel should be laid on top of filter fabric that has been tied into the soil.
Buffer slope	Riparian buffer slopes should not exceed 8% when discharging into a densely vegetated buffer and 6% when discharging into a forested buffer. A series of level spreaders may be approved by DWQ for buffer slopes up to 12 to 15%.
Flow bypass	Only the amount of flow associated with a rainfall intensity of 1 inch/hour should be routed through the level spreader. All additional flow should be routed to the stream via a properly designed and maintained swale or pipe. Stream banks should be protected at the point where the additional flow will be discharged.
Forebay	A forebay, or some other form of pretreatment, should be a part of any level spreader design. The forebay surface area should be no less than 0.2% of the contributing catchment's impervious surface area.
Maintenance	Level spreaders should be maintained yearly and after storms greater than or equal to a two-year, 24-hour event. Sediment and debris should be removed from the forebay and from the channel behind the level lip. All trees and vegetation that grow in the section of no. 57 stone should be removed. The grass in all swales should be maintained, and the level spreader and buffer should be checked for signs of erosion. Erosion that is discovered in the buffer should be addressed through the application of erosion control mat and through re-grading if necessary. NCDENR must be notified prior to any work performed in a protected riparian buffer.

RESOURCES

RELATED FACT SHEETS in the Urban Waterways series, North Carolina Cooperative Extension, and North Carolina Agricultural Research Service Bulletins, N.C. State University:

Hunt, W. F. 2000. *Urban Stormwater Structural Best Management Practices (BMPs)* (AG-588-01). Online: http://www.bae.ncsu..edu/stormwater/PublicationFiles/UrbanBMPS199.pdf

Hunt, W. F., and L. L. Szpir. 2006. *Permeable Pavements, Green Roofs, and Cisterns: Practices for Low Impact Development* (AGW-588-06). Online: http://www.bae.ncsu.edu/stormwater/PublicationFiles/BMPs4LID.pdf

Osmond, D. L., J. W. Gilliam, and R. O. Evans. 2002. *Riparian Buffers and Controlled Drainage to Reduce Agricultural Nonpoint Source Pollution*. N.C. Agricultural Research Service Technical Bulletin 318. Online: http://www.soil.ncsu.edu/lockers/Osmond_D/web/RiparianBuffers.pdf

RELATED WEB SITES

BAE Stormwater Group
www.bae.ncsu.edu/stormwater
Highlights of stormwater research projects and Extension programs provided across North Carolina by N.C. State University's Biological and Agricultural Engineering Department.

State of North Carolina
www.stormwater.org
NCDENR's stormwater site.

http://h20.enr.state.nc.us/su/Manuals_Factsheets.htm
DWQ manuals, fact sheets, and a link to the revised level spreader design guidelines.

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