# Evaluation of Level Spreaders in the Piedmont of North Carolina

***Final Report***


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## 1.0 Introduction

In 1998, the State of North Carolina implemented rules protecting riparian buffers in several major river basins. The rules require that diffuse flow of stormwater runoff be maintained in the riparian area by dispersing concentrated flow. In response the North Carolina Division of Water Quality (NCDENR) recommended the use of level spreaders and developed draft design standards in October 2001. Level spreaders are used as a stormwater Best Management Practice (BMP) that can potentially be utilized to increase stormwater connectivity to riparian buffers. It is unknown whether these design standards adequately achieve the goals of water quality protection and diffusion of flow.

The Biological and Agricultural Engineering Department at North Carolina State University received a grant from the North Carolina Department of Environment and Natural Resources in December of 2005 to evaluate level spreaders as stormwater best management practices. The intent of this study was to visit locations where level spreaders were currently in use and perform various qualitative and quantitative analyses.

The positive impact of riparian buffers on water quality has been documented (Osmond et al., 2002), and it was anticipated that by increasing the connectivity of these natural systems, water quality in North Carolina's sensitive waters could be improved. The current design standard will be revisited in this report to evaluate the performance of the standard and suggest design modifications that can be adopted to make level spreader designs more functional.

Overall, 24 level spreaders in Wake and Franklin counties were located and visited. Detailed observations were made at 20 of these locations, while more general observations were made at the remaining 4 locations.

### 1.1 Level Spreader System Description

Level spreader systems consist of three parts (Figure 1). The first part of the system is the forebay. The forebay is used for the preliminary treatment of stormwater. A forebay is essentially an excavated bowl-shaped feature that acts to slow the influent water and allow sediment and debris to settle. Forebays can contain rip rap to reduce the amount of sediment lost to erosion within the forebay itself. However, it is important to remember that since these systems must be periodically dredged to remove the captured sediments, an excess of rip rap can complicate this process. Essentially these systems act like the sediment basins used for sediment and erosion control.

After the stormwater passes though the forebay, it enters a concrete, rock, or grassed channel. This is the main body of the level spreader. The lower side (called the downslope side) of the channel is constructed so that it is essentially level along the length of the channel. Often, this lower side, or level spreader lip, is constructed of concrete or rock so that it is resistant to erosion. As stormwater enters the channel, it rises to channel capacity and exits evenly over the lip. This system functions much like a large weir.

After the stormwater passes over the level spreader lip, it enters the riparian buffer. The riparian buffer, often simply called the buffer, is the vegetated area along streams, rivers, and other water bodies. As the stormwater passes through the buffer, some of the water infiltrates while the rest is treated for sediment and nutrients.

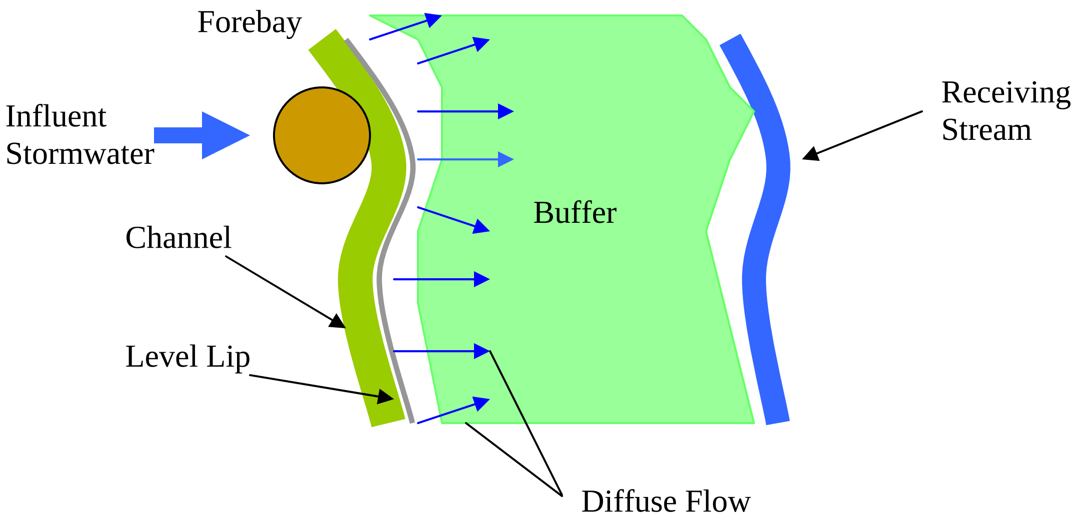


Figure 1: Level Spreader System

## 2.0 Site Evaluation Procedure

The sample set was primarily selected from a group of level spreaders that were submitted to DWQ as part of the 401/404 permit process. The sample level spreaders were chosen from this group based on the availability of design information in their project plans. Other level spreaders in the sample set were located by faculty of the Biological and Agricultural Engineering Department at North Carolina State University. Extensive photo-documentation was performed at all locations. Twenty-four level spreaders were evaluated in all, 23 in Wake County and 1 in Franklin County. Various land uses were treated by the level spreaders. Eleven of the level spreaders received runoff from commercial land uses, 5 from residential land uses, 5 from street drainage, 2 from institutional land uses, and 1 from an industrial land use. Nearly all of the level spreaders were sited in clay or clay – loam soils.

Twenty sites were chosen for detailed data gathering. Data acquisition involved a survey of the level spreader lip and the downslope buffer to estimate slopes. Between 2 and 8 survey points were taken with a laser level at each level spreader – riparian buffer location depending on level spreader length. Visual observations were made to analyze the condition of the existing spreader, to evaluate the content and condition of the riparian buffer, and to search for signs of water reconcentration. Observations included the following: evidence of maintenance, materials used to construct level spreader, perpendicular length from level spreader lip to stream bank, level spreader dimensions, signs of level spreader lip failure, buffer description (forested or thick ground cover), and signs of erosion / reconcentration.

Site information, both measured and observed, was coupled with data gathered from design plans and through conversation with designers. The design data that was obtained included design flow and design length. These data were used to determine whether or not the level spreaders were sized according to NCDENR standards.

## 3.0 Results

Detailed evaluations were made at 20 level spreaders (Table 1). It was observed that *none* of the level spreaders were functioning as intended. Flow reconcentration was found at all project sites at some point between the level spreader and the stream. Additionally, nearly 1/3 of the level spreaders were breached (6 locations), causing them to *never* produce diffuse flow. Level spreader failures occurred for a number of reasons. Recurring problems with the level spreaders included: (1) lack of maintenance, (2) poor design, (3) poor construction methods, (4) level spreader lip not level, (5) constructed of easily eroded materials such as ABC stone or earth, (6) downslope characteristics and topography, and (7) human interference. In many cases, a level spreader may have failed for multiple reasons. Table 2 shows the most common reasons that led to failure and the number of level spreaders associated with each failure type.

**Table 1: Description of 20 Level Spreaders Evaluated In Depth**

| Level Spreader Code | Length (ft) | Construction Material | Buffer Slope Range (%) |
|---|---|---|---|
| 1 | 90 | concrete | 0 - 5 |
| 2 | 15 | rip rap | 0 - 5 |
| 3 | 15 | rip rap | 5 - 10 |
| 4 | 18 | rip rap | > 10 |
| 5 | 200 | earth | > 10 |
| 6 | 68 | earth | 0 - 5 |
| 7 | 10 | rip rap | > 10 |
| 8 | 80 | graded stone | 0 - 5 |
| 9 | 100 | graded stone | 0 - 5 |
| 10 | 100 | graded stone | 0 - 5 |
| 11 | 51 | graded stone | 5 - 10 |
| 12 | 25 | graded stone | > 10 |
| 13 | 30 | rip rap | > 10 |
| 14 | 17 | rip rap | 5 - 10 |
| 15 | 356 | concrete | 5 - 10 |
| 16 | 220 | earth | 5 - 10 |
| 17 | 100 | abc stone | 0 – 5 |
| 18 | 136 | concrete | 0 – 5 |
| 19 | 97 | concrete | 5 – 10 |
| 20 | 127 | concrete | 0 – 5 |

Note: Graded stone is used to describe stone mixture ranging from approximately #57 sized stone to 3 - 4 inch cobbles.

**Table 2: Common Failures Among Level Spreaders**

| Trait That Could Cause Failure | Number of Level Spreaders with Trait |
|---|---|
| lack of maintenance | 12 |
| poor design | 11 |
| poor construction methods | 3 |
| level spreader lip not level | 7 |
| built with easily eroded materials | 6 |
| riparian buffer topography / content | 11 |
| human interference | 2 |

## 3.1 Common Failures Among Level Spreaders

### *3.1.1 Maintenance*

At least 12 of the 24 level spreaders were not maintained as evidenced by trees and shrubs on the level lip. The vegetation was a barrier to flow, causing outflow to concentrate as it passed over the level spreader. In some cases sediment and gross solids accumulated in the level spreader, eventually burying the structure. Due to preferential flow, small channel formation occurred immediately downslope of the level spreader. It is hypothesized that annual visits to the level spreaders would have helped prevent failure downslope due to the preferential flow created by the lack of maintenance. Additionally, adding a forebay to the level spreader may help capture some sediment and debris that would otherwise gather behind the level spreader lip.

In one example of a lack of maintenance, an abundance of leaves and sediment was built up behind and on top of a concrete level spreader (Figures 2 and 3). In some areas, it was impossible to locate the level spreader without digging through 3 – 4 inches of debris (Figure 4). This accumulation eliminated the intended function of this level spreader by allowing stormwater to pass over the level spreader lip without spreading evenly across the whole system.

Figure 2: Level Spreader just after construction

Figure 3: Level spreader approximately 3.5 years after construction

Figure 4: Level spreader lip buried beneath debris

*3.1.2 Poor Design*

Eleven of the 24 level spreaders were not designed properly. Designs were classified as poor for a number of reasons including: presence of an improperly designed flow splitting device, attempting to make the edge of a retention pond serve as the level spreader, and a failure to size the level spreader length properly. Of the 20 level spreaders studied in detail, 9 were not long enough according to NCDENR design standards.

*3.1.3 Poor Construction*

Three of the 24 level spreaders were not constructed properly. Two of these systems were constructed with rip rap level lips. The level lips were not adequately tied into the adjoining soil, allowing stormwater to bypass the level lip, passing between the edge of the level spreader and the bordering soil (Figures 5 and 6). In the third system, silt fence was used downslope of the level spreader during site construction and was never removed. The silt fence provided a barrier between the level spreader and the riparian buffer, causing reconcentration of the stormwater.

Figure 5: Swale leading to Level Spreader – Level Spreader Circled

Figure 6: Rip rap level spreader with evidence of short circuiting

*3.1.4 Level Spreader Lip Not Level*

Seven of the level spreaders were not level, having an average slope greater than 2%. Low areas on the level spreader lip experience a greater depth of flow and, thus, greater erosive velocity. This is of particular concern with earthen systems which erode under high velocities. Concrete level spreaders had the lowest average slope (0.04%), followed by earthen systems (0.19%), graded stone (1.78%), and rip rap (4.7%). Although earthen level spreaders had the second smallest average slope, breaches were noted in low sections of these systems at a number of sites (4 of the 6 earth or ABC stone level spreaders). Table 3 shows the results of the surveys performed on the 20 level spreaders.

**Table 3: Slopes of Level Spreader Lips**

| Material | Number | Average Slope (%) | Slope Range (%) |
|---|---|---|---|
| concrete | 5 | 0.04 | 0.01 – 0.13 |
| rip-rap | 6 | 4.70 | 1.6 – 7.0 |
| earthen / ABC stone | 4 | 0.19 | 0.02 – 0.42 |
| graded stone | 5 | 1.78 | 0.88 – 2.87 |

Another point of concern when constructing level spreaders is the grade surrounding and immediately downslope of the level spreader (Figure 7). At one concrete level spreader location, the level spreader was adequately level (average slope = 0.02) and yet water seemed to be concentrating toward the middle of the level spreader. Upon examination, the water was being routed more dominantly through the middle of the level spreader because the soil elevation immediately downslope of the level spreader was higher on the ends then in the middle. Thus, the level spreader proper can be level and yet the surrounding soil grade can still cause preferential flow.

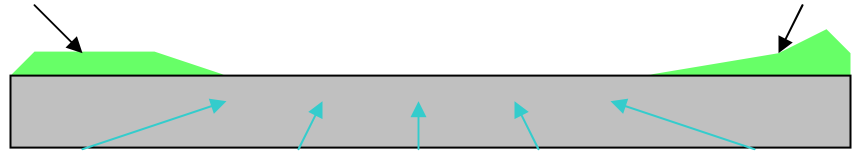


Figure 7: View from level spreader face looking downslope into buffer

*3.1.5 Construction Material*

All 6 of the level spreaders constructed of earth or ABC stone were breached. These systems are unable to handle the erosive velocity of the stormwater passing over the level spreader (Figure 8). In three of four cases, the breach in the level spreader was on the lower side of the level spreader. It is possible that an increase in flow over one side of the level spreader resulted in higher erosive velocities and, thus, a head cut on the level lip.

Figure 8: Breach on ABC stone level spreader

The most promising systems that were visited, from the standpoint of stability, were made of concrete. Six of the 24 level spreaders were constructed of concrete. As indicated in Table 3, the average slope of the concrete level lip was smaller than that of level lips made of any other material. It is believed that these concrete lips can be constructed level with a greater consistency than can be expected from other material types. Additionally, these systems are more resistant to erosion than earthen/gravel systems should a large storm pass over the level spreader.

*3.1.6 Riparian Buffer Topography*

Throughout the course of the study, it was observed that the topography and the vegetative content of the riparian buffer impacted overall system effectiveness. Stormwater reconcentration due to passage through forested areas (Figure 9), natural swales (Figure 10), and natural wetland areas was common. At least 11 of the 24 level spreader – riparian buffer systems showed some failure due to riparian buffer topography. Additionally, incised stream banks may prove to be an obstacle to non-erosive overland flow from the level spreader to the stream. Incised streams typically have steeply sloped banks, overland flow could flow over these banks, causing a head cut to develop. Please note, though, that bank headcuts was not thoroughly investigated in this study.

Figure 9: Large vegetation downslope causes concentrated flow


Figure 10: Natural swale downstream of level spreader (circled in yellow)

*3.1.7 Human Interference*
There were two instances of human interference observed. In one case, a ditch appeared to have been hand-dug from the level spreader through the riparian buffer to the stream (Figures 11 and 12). In the second case, a 4 inch corrugated plastic pipe, which was carrying stormwater intended for the level spreader, was draped over the structure allowing the discharge to bypass the level spreader (Figure 13).


Figure 11: Earthen level spreader with channel

Figure 12: Channel with apparent shovel marks


Figure 13: Drainage pipe laid over top of level spreader

## 3.2 Other Observations of Design Features and Function

*3.2.1 Buffer Slope*
The buffer slope data was divided into three categories (Figure 14), one representing buffer slopes from 0 to 5 %, one representing buffer slopes from 5 to 10 %, and one representing buffer slopes greater than 10 %. In the 5 to 10% category, the largest slope was 8.4%, nominally 8%. North Carolina standards indicate that level spreaders should not be installed on slopes greater than 8% when discharging into a buffer consisting of thick ground cover and no greater than 6% when discharging into a forested buffer. There were some instances in which this was not the case. In the five cases where the slope was greater than 10%, no additional measures, such as level spreaders in series, were taken.

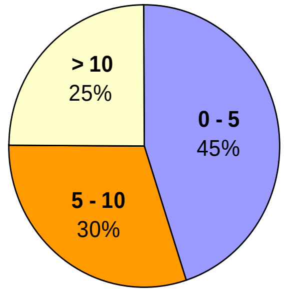


Figure 14: Percent of level speaders in each buffer slope

Four of the five level spreaders with slopes larger than 10% were discharging into forested buffers, the fifth level spreader was located very close (10 ft) to a stream and can be disregarded. At three of the four sites where the buffer slope was larger than 10%, there was significant erosion in the buffer. The slope of the buffer would, in part, determine the velocity of the stormwater as it makes its way to the stream. With a higher slope, the water would travel at a higher velocity and, thus, be more likely to cause erosion in the buffer. Based on visual observations made at the sites, the slope thresholds presented in the North Carolina standards seem appropriate. Unfortunately, due to the almost immediate reconcentration of flow that was seen in many instances, the results of this study cannot verify this assertion.

It should also be noted that in approximately nine instances, fill material was used to bring the level spreader up to the design elevation, this includes instances where earthen berms were used. This practice resulted in a steep slope between the lip of the level spreader and the non-fill material below. Unfortunately, in four of the cases, this may have contributed to the function of the level spreader being compromised. The steep slopes from the level spreader lip over the fill soil to the existing soil elevation cause increased velocities down the back slope of the level spreader and eventually, if the level spreader is made of an erosive material such as earth, a head cut can form. The fill slope is more likely to erode as it takes time for vegetation, which fortifies the slope, to be established. In the cases where the fill soil did not erode, a berm had been formed and completely covered with geofabric, helping the soil to be resistant to erosion.

*3.2.2 Forebays*

Approximately half of the level spreaders that were evaluated in depth clearly did not have a forebay. Forebays could add substantial stability to the systems by removing some of the sediment and debris that normally accumulate behind these systems. Additionally, forebays provide energy dissipation reducing the velocity with which the enters the level spreader, potentially reducing the likelihood of failure in the long term. Nearly all BMPs have pretreatment such as a forebay.

*3.2.3 Bypass of Large Storms*

Through review of site plans, it was determined that at least two of the level spreaders were designed with a flow splitter that would bypass larger storms. This is potentially a way to reduce erosion in the riparian buffer. Per the NCDENR design guidelines, where site constraints prohibit the typical level spreader design, allowance is made by staff members to bypass the runoff from storms larger than the 1” water quality storm on a case by case basis. The benefit of such a system is that larger storms will not be forced to flow across the level spreader. If a storm larger than the design storm were to be routed through the level spreader, the level spreader could experience a high depth of flow, which could cause an erosion channel in the level spreader lip. Additionally, such a storm may cause an erosion channel to form in the riparian buffer itself, which could continue to get worse in future, often smaller, less intense storms.

*3.2.4 Protection at the Stream Bank*

As discussed in Section 3.2.3, a potential detriment to water quality identified during this project was stream bank erosion. As water passes over an incised stream bank, a head cut can form and travel from the stream into the buffer. At one project site, rip rap was added to the stream bank in the location where the majority of the level spreader runoff would reconcentrate (Figures 15 and 16). This allowed the level spreader runoff to enter into the stream without eroding the bank. This practice would help eliminate erosion of the stream bank and reduce the risk of a head cut. Materials such as erosion control mat could be used instead of rip rap. Identifying the probable location of reconcentration at the stream bank may not always be possible, but would result in less soil loss from the bank. Use of rip rap or any channel liner, however, must be balanced by other design needs such as temperature mitigation and stream habitat that vegetated banks provide.

Figure 15: View of protected bank from back of level spreader

Figure 16: Close-up of protected bank

## 4.0 Conclusions and Design Recommendations

*Materials Used for Level Spreader Lip*

Based on this study, some conclusions and design recommendations can be made, these are summarized in Table 4. The most obvious need regarding level spreader systems is a stable level spreader lip that can not be eroded. The most stable systems that were visited were made of concrete. Concrete level spreaders can be built with minimal slope and are more resistant to erosion than earthen/gravel systems. If a flow larger than the design flow is routed over a level spreader made of concrete, the level spreader lip will not be damaged. This study indicates that earthen/ABC stone level spreaders should not be used in *any* applications, as they routinely fail.

Another concern regarding these systems is the grade of the ground surface in the buffer immediately downslope of the level spreader. Ideally, the lip of the concrete level spreader should be higher than the existing ground by 3 - 4 inches. This would allow water to pass over the lip without interference from buffer vegetation. To combat any erosion that could occur as water falls from the top of the level spreader to the existing soil, a layer of filter fabric or erosion control matting could be extended a distance of three feet from the level spreader lip into the buffer. Stone, such as No. 57, could be placed on top of the filter fabric to reduce erosion immediately downslope of the level spreader (Figure 17).

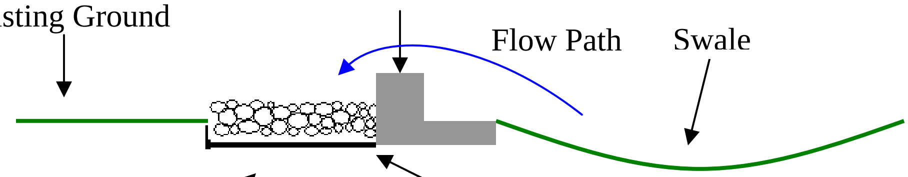


Figure 18: Example of concrete level spreader design

*Level Spreader Dimensions*
There were a broad range of level spreader dimensions, yet no combination was found to be superior. It is anticipated that the width of a level spreader could reasonably be constructed at three times the pipe diameter feeding the system, but no guidance is provided herein. The design depth is also debatable, but no less than either 9 inches or ½ of the inlet culvert diameter, whichever is greater, below the top of the level spreader lip would be acceptable. Current design standards specifically state that when discharging into a buffer with thick ground cover, there must be 13 ft of level spreader for every 1 cfs of flow. In forested buffers, this number increases to 100 ft of level spreader for every 1 cfs of flow. Although it is anticipated that flow will reconcentrate more quickly in forested buffers, it is likely that in most locations, a designer will argue that a given buffer consists of thick ground cover to avoid the additional 87 ft of level spreader per 1 cfs of flow.

Previous level spreader design guidance did not account for infiltration within the riparian buffer. The wider the riparian buffer, the more stormwater will infiltrate. When infiltration within the buffer is taken into account, the length of level spreader per unit of flow can be reduced. This is significant when discharging onto a forested buffer due to the large lengths of level spreader required. It is suggested that a level spreader discharging onto a 50 ft wide wooded riparian buffer be sized at 65 ft per 1 cfs of flow, discharging onto a 100 ft wide wooded buffer should require 50 ft of level spreader per 1 cfs of flow, and discharging onto a 150 ft wide wooded buffer should require 40 ft of level spreader per 1 cfs of flow.

*Forebay Inclusion*

Forebays should be utilized in these systems to dissipate energy and to reduce the sediment that accumulates behind the level spreader lip. The forebay will likely be an elongated bowl lined with class A rip rap. This could decrease maintenance efforts by reducing the frequency of sediment removal from behind the level spreader lip. While it is expected that forebays improve level spreader function, not enough anecdotal evidence was collected to verify this. The forebay's surface area should be no less than 0.2% of the contributing drainage area's impervious surface area.

*Flow-Bypass*

A flow bypass should be considered in conjunction with level spreader systems. When large storms flow across a level spreader – riparian buffer system that is not designed to route such storms, erosion may take place within the buffer. This erosion will likely worsen until maintenance. Additionally, when level spreaders are discharged into riparian buffers, it may be difficult to determine where stormwater will reconcentrate and discharge into a stream. Thus, the area of the stream that could be impacted by a head cut can not be protected. If stormwater discharge to the buffer is limited to that which can be infiltrated by the buffer (or at least a significant portion can be infiltrated), then the runoff will not reach the buffer with a high (erosive) velocity (if it reaches the stream at all).

During larger storms, which produce more runoff than can be infiltrated by the buffer, excess stormwater can bypass the level spreader and be sent through a protected channel where the location of entry into the stream can be predetermined and protected. This could be achieved by allowing the runoff produced by a rainfall intensity of 1"/ hour (or another moderate intensity) to travel to the level spreader while runoff from higher intensity events is bypassed to the stream. This is given as an alternate solution in the North Carolina design standards, but it is recommended that this become common place.

*Maximum Slope*

The slope thresholds that have been given by the state for wooded and thick ground cover buffers seem appropriate. No sites using multiple level spreaders were analyzed in detail. In cases where slopes exceed 6% for wooded buffers and 8% for buffers containing thick ground cover, it may be advisable to use other BMPs to reduce peak flows and provide water quality improvements. If fill soil is used in the level spreader construction, the slope of the fill soil should not exceed 6%. Fill areas may need to be covered with sod to expedite grass growth.

*Maintenance*

Level spreaders require at least yearly maintenance to remove trees and shrubs that are growing both on the level spreader lip and that are impeding flow just downslope of the level spreader. Any debris and sediment that build up in the level spreader should be removed. The level spreader lip should be examined for possible erosion and channel formation (if an easily eroded lip is used); these issues should be addressed immediately to restore proper function. The riparian buffer should also be examined for signs of erosion and channel formation. If erosion is apparent, it is imperative that corrective action (e.g., installation of erosion control matting) be taken.

*General Guidance and Observations*

Overall, the level spreaders in the sample set were not functioning well. Concentrated flow was noticed at the level spreader lip or in the riparian buffer in all cases. It is highly unlikely that diffuse flow will be achieved on a regular basis using these systems. Riparian buffers are highly variable. Depending on internal buffer topography, water will tend to reconcentrate, almost immediately in some cases.

However, certain level spreader – riparian buffer systems may produce concentrated flow, but still improve water quality and reduce flow peaks. There were a few promising sites in which concrete level spreaders were discharging into well maintained grassed buffers and little erosion was noticed. In one case, the stormwater was recollected at the end of the filter strip and directed to the stream in a non-erosive channel. Systems such as this could provide minimal erosion, high infiltration, and low impact to stream banks.

The overall goal of level spreader – riparian buffer systems is to provide a net water quality benefit. If these systems continue to cause erosion of the riparian buffer, they may be doing more harm than good. Two out of 24 level spreaders in the sample set that were visited showed promise in improving water quality. One was made of well-graded stone and one of concrete. Both systems had a sturdy level lip that was higher than the existing ground on the buffer side. The buffers at each location had either well established grass or thick ground cover immediately downslope of the level spreader followed by a forested buffer. Erosion was noted as the stormwater entered the forested buffer at one of the locations. The buffer slope in both locations was less than 8%.

The purpose of this study was not to evaluate water quality function; it was to determine if level spreaders are able to produce diffuse flow in real world applications. No level spreader – riparian buffer system in the sample set produced diffuse flow from the level spreader throughout the buffer to the stream bank. However, the authors believe that a few systems may be able to improve water quality and reduce peak flows. The authors strongly recommend that the water quantity and quality performance of the entire system be studied.

*Final Conclusions*

Table 4 shows suggested design criteria and site selection criteria based on the results of this study.

Table 4: Level Spreader Design and Site Selection Suggestions

| Item | Suggestion |
|---|---|
| **Level Spreader Lip Material** | A concrete lip should be used in all level spreaders. It is more likely these lips will be constructed level and they show a greater resistance to erosion. The lip should be tied into the soil with an appropriately sized concrete footer. |
| **Level Spreader Lip Dimensions** | The concrete lip should extend 3 - 4" above the existing grade on the buffer side. Just after the lip, a 3 foot wide, 4 inch thick layer of #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 Content** | Level speaders should discharge into buffers containing dense grass or ground cover. Forested areas have varying natural topography that proves too difficult to predict in most circumstances. If a bypass system is used, it may be possible to restrict flow into a forested buffer whereby the majority of the flow will infiltrate. |
| **Buffer Slope** | The current slope restrictions for densely vegetated and forested buffers seem appropriate. If fill soil is used, the slope created by the fill soil should not exceed 6% if the height of the slope is more than 18 inches. |
| **Flow Bypass** | Only the amount of flow associated with a rainfall intensity of 1"/hr 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 form of pre-treatment, should be a part of any level spreader design. The forebay dissipates the energy of the influent stormwater and removes sediment and debris that can build up behind the level spreader lip. The forebay surface area should be no less than 0.2% of the contributing area's impervious surface area. |
| **Maintenance** | Level spreaders should be maintained routinely. Sediment and debris should be removed from the forebay and from behind the level lip. All trees and vegetation that grow in the section of #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 after all events equal to or larger than the 2 year storm. Any erosion that is discovered in the zone 2 buffer should be addressed through re-grading, if necessary, and through the application of erosion control mat. Erosion discovered in the zone 1 buffer should be addressed through the application of erosion control mat. |

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