# Nutrient Accounting for
# Level Spreader Filter Strips (LSFS) Design Variants

This document addresses the nutrient credit assignments for applications of LSFS design variants used for compliance with Nutrient Management Strategies Stormwater Rules. This credit information supplements the statewide practice design guidance for EVFS found in Chapter 8 of NCDENR's Stormwater BMP Manual found here: http://portal.ncdenr.org/web/lr/bmp-manual

In order to receive this credit, LSFS applications with design variants **must be designed and maintained** as specified by NCDEQ:

- Pursuant to Minimum Design Criteria and related requirements of rules 15A NCAC 2H .1000. (http://portal.ncdenr.org/c/document_library/get_file?uuid=0212634d-9aa9-4301-a481-1d6c57930c44&groupId=38334), and
- Guided by Chapter 8 of the NC BMP Design Manual.
- Minimum width of 10 ft; minimum ratio of length to design flow of 10 ft/cfs.

## Nutrient Credit Overview

LSFS practices are stormwater control measures that achieve nutrient reductions by infiltrating and treating surface runoff. LSFS practices that are installed to meet the nutrient reduction requirements of Nutrient Management Strategy stormwater rules shall be credited using the Jordan Falls Stormwater Accounting Tool (JFSAT).

The tool estimates the following ranges of nutrient benefits for the LSFS practice based on the following design variants: 12 to 85% of the total nitrogen (TN) and 8 to 94% of the total phosphorus (TP). These ranges are for illustrative purposes as the nutrient removal is highly variable and dependent on the width of the LSFS, the ratio of the length of the level spreader to the design flow, and the land uses (and relative event mean concentrations) of the area being treated.

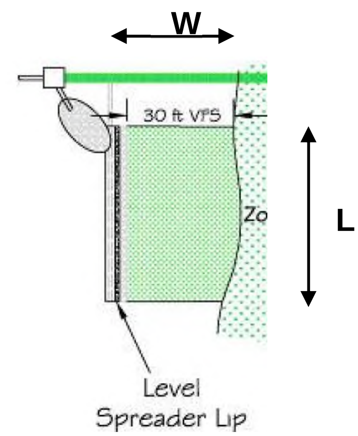
## Relative Confidence in Credit Assignments

Credit estimates for LSFS with design variants are considered to have high confidence based on the well understood methods used to account for the design variants and the historical record of reliable use of LSFS in North Carolina.

# Nutrient Credit Estimation and Relative Confidence

## A. Summary of Nutrient Load Reduction Credit Method

For this practice, the nutrient credit varies based on the width (W) of the filter strip (i.e., flow path; ft) and the ratio of the length (L) of the filter strip (perpendicular to flow; ft) to the design flow (using the Rational Method described in Chapter 3 of the NC BMP Design Manual (Q=CIA); cfs). Credits for LSFS with design variants will be estimated using the latest approved version of the Jordan/Falls Stormwater Accounting Tool (JFSAT) or subsequent Division-approved tool or calculation method.




Modified from Ch 8 of the NCDEQ BMP Manual (Winston and Hunt, 2010)

For designers using JFSAT, after the *Project Information* and *Watershed Characteristic* tabs have been populated for the project, the user will represent a LSFS with design variants by using the following steps to enter parameters on the *BMP Characteristics* tab:

- For *Type of BMP*, select *Other Custom BMP* from the drop-down menu (do not select the standard *Level Spreader Filter Strip* option as the values are fixed and design variants will not apply).
- Select the underlying HSG.
- Enter a description of the Custom BMP for record keeping purposes (e.g., width of level spreader and ratio of length of LS to design flow).
- Leave the Under- or Over-sized Percentage blank (for this practice, the dimensions and design flow are used to vary credits, rather than the under- or over-sized percentage).
- Using the design specifications, look-up the % Volume Reduction from Figure 1.
    - Calculate the *% Treated* as (100% - % Volume Reduction)
    - Set the *Overflow %* to 0% (filter strips are designed to treat the design flow; bypass systems are incorporated into the design to bypass larger storm volumes.)
    - Note that the values entered into the JFSAT for *% Treated* and *Overflow %* will not sum to zero; the balance is equivalent to the % Volume Reduction
- Using the nutrient EMCs for LSFS of 1.09 mg/L for TN and 0.16 mg/L for TP, enter those values into the cells next to *Nutrient Effluent EMC Values*.
- Enter the amount of drainage area that is routed to the LSFS next to the appropriate land use in the cells below the Custom BMP input data.
- Enter the amount of area taken up by the LSFS in the cells below the Custom BMP input data.

Figure 1 provides the % Volume Reduction percentages to calculate the JFSAT Input Parameter values required for the LSFS BMP. The user must know the width of the filter strip and the ratio of the filter strip length to the design flow.

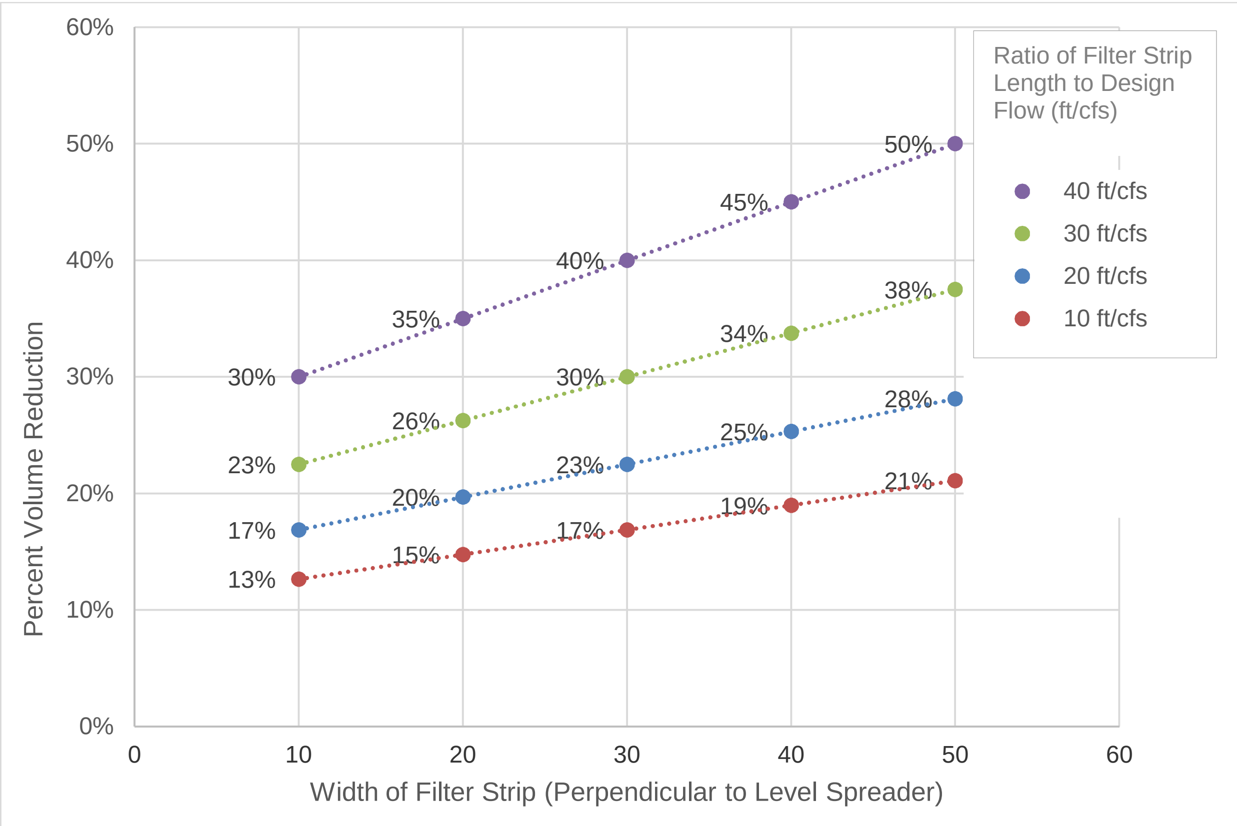



**Figure 1. Runoff Reduction Based on Two Design Variants: 1) Ratio of Filter Strip Length to Design Flow (ft/cfs) and 2) Filter Strip Width**

In addition to infiltration of water, filter strips also treat surface runoff through processes including filtration, sedimentation, and plant uptake. The event mean concentrations for nitrogen and phosphorus for filter strips are 1.09 mg/L and 0.16 mg/L, respectively, which are lower than many event mean concentrations for land uses. These values are changes from the Jordan Falls Stormwater Loading Accounting Tool (JFSAT) User Guide (Version 1.1) and have been incorporated in the latest version of JFSAT.

## B. Reductions Obtained with Practice

The ranges listed in Table 1 are estimated using the JFSAT Version 3.0 in the Jordan and Falls watershed for various land use types. These example ranges are for illustrative purposes, and individual site designs may result in different values depending on the combination of various land use classes, drainage area treated, etc. Because LSFS design variants includes a volume reduction and a treated effluent component, the percent reductions will depend on the event mean concentrations of the land use draining to the practice. The nutrient reductions (or credits) are provided in the table as pounds per acre per year (lbs/ac/yr); for a given site condition, the LSFS may be designed to treat a much smaller area than one acre, and this would be reflected in the JFSAT output.

**Table 1. Example Mass Load Reductions and Percent Load Reductions Achieved with LSFS Design Variants (Ranges reflect different design configurations)**

| Land Use | Range of TN Reduction (lb/ac/yr) | Range of TN Percent Load Reduction | Range of TP Reduction (lb/ac/yr) | Range of TP Percent Load Reduction |
|---|---|---|---|---|
| Commercial / industrial (parking lots and roof tops) | 1.4 - 9.1 | 12 - 62 | 0.1 - 3.1 | 8 - 79 |
| Transportation | 1.9 - 32 | 17 - 85 | 2.9 - 11 | 68 - 93 |
| Pervious areas including residential lawn | 0.9 - 1.6 | 61 - 84 | 0.3 - 0.8 | 79 - 94 |
| Residential areas (not lawn) | 1.4 - 8.7 | 12 - 61 | 0.1 - 11 | 8 - 93 |

**C. LSFS Design Variants Example**

The following is an example of how to represent the nutrient load reduction credits in the JFSAT for adding a 200 s. f. filter strip to an existing commercial parking lot using a LSFS design variants. The site has the following characteristics:

- Commercial Parking Lot
- *Parking lot* = **22,800** s.f. parking lot that drains to a LSFS that takes up **200** s.f. (total developed area is **23,000** s.f.)
- The LSFS has a level spreader length of 10 feet, a filter strip width of 20 feet, and a design flow of 0.5 cfs; the ratio of LS length to design flow is 10 ft/0.5 cfs = 20 ft/cfs.

To estimate the nutrient load reductions from this scenario, take the following steps:

<u>Data Entry</u>

1. Enter all the relevant information on the *Project Info* and *Watershed Characteristics* pages:
    a) In the *Pre-Development* column, enter 23,000 s.f. of *Commercial parking lot*
    b) In the *Post-Development* column, enter 22,800 s.f. of *Commercial parking lot* and 200 s.f. as land taken up by BMPs.

2. On the *BMP Characteristics* page, select the *Other Custom BMP* as the type of BMP.
3. Select the predominant hydrologic soil group (HSG) for the location of the BMP. This can be determined by an NRCS soil survey map or an on-site infiltration test. For this example, select a HSG of *C,* but for this practice the HSG is considered in the design and this parameter does not affect the output.
4. Enter LSFS, width 20 ft, ratio 20 ft/cfs next to *Description of Custom BMPs*.
5. Use Figure 1 to determine the % Volume Reduction for a LSFS that has a level spreader width of 20 and a ratio of level spreader length to design flow of 20. Enter the *Overflow %* and *% Treated* for the LSFS.
    - The % Volume Reduction for the practice based on the design specifications is 20 %.
    - The *Overflow %* should be entered as *0* for any LSFS (these are designed to treat the entire design flow).
    - The *% Treated* is calculated as 100 % minus % Volume Reduction, or 80% for this example.
6. Enter the nutrient EMC values for LSFS:
    a) TN EMC (mg/L) =**1.09**
    b) TP EMC (mg/L) = **0.16**
7. In the rows under the *Area Treated by BMP*, enter in the *Parking Lot* area that is being treated (**22,800** s.f.) and the *Land Taken up by BMP* (**200** s.f.).

<u>Interpreting Results</u>

On the *Overall Summary* page, the *Total Nitrogen* & *Phosphorus Loading* (lbs/yr) should show the following values:

a) *Pre-Development Conditions*
    - *Total Nitrogen Loading (lbs/yr)* = 7.69
    - *Total Phosphorus Loading (lbs/yr)* = 0.85

*b) Post-Development Conditions w/BMPs*
    - *Total Nitrogen Loading (lbs/yr)* = 4.65
    - *Total Phosphorus Loading (lbs/yr)* = 0.68

These values are information that the tool outputs in pounds per year. The user completes the remaining steps by hand to calculate the credits (reductions in loading):

8. Compute the nutrient reductions in pounds per year, which would be used towards compliance with *Existing* Development Rule requirements:
    a) Compute the reduction in loads
        - Nitrogen -> 7.69-4.65=3.04 lbs/yr
        - Phosphorus -> 0.85-0.68= 0.17 lbs/yr

## D. Tier Assignment and Basis

LSFS design variants have been designated Tier II based on the fact that LSFS have applicable, published research data and the results were used to develop credits. Tier II measures receive the currently established credit at the time of installation for their functioning lifetime. Any credit refinements based on additional research would apply only to installations done subsequent to those refinements.

To evaluate relative confidence in the measure's estimated reduction, Division staff considered a range of factors outlined in the document "*DWR Approval Framework For Nutrient Load-Reducing Measures.*"

### 1. Supporting Research

Based on the following factors and the historical record of reliable function of LSFS in North Carolina, there is high confidence in the crediting estimate methods for these devices.

<u>Data Scope</u>
Four studies were used to quantify credits associated with this practice, however, each study reported different parameters (e.g. runoff volume, concentration, pollutant load). The study period for all studies ranged from 9 to 18 months, with 13-30 sampling events for each study. The designs of the filter strips evaluated included a blind swale with level spreader, width, drainage area, and percent imperviousness. Based on the available scientific data for TSS, TN, and TP, percent volume reduction and previously published EMCs for filter strips appear to be the preferred crediting method for the design variants.

A critical assumption of this crediting method is that the LSFS is properly designed and installed. In order to receive this credit, LSFS must be designed and maintained as specified by NCDEQ pursuant to Minimum Design Criteria and related requirements of rules 15A NCAC 2H .1000. (http://portal.ncdenr.org/c/document_library/get_file?uuid=0212634d-9aa9-4301-a481-1d6c57930c44&groupId=38334), and guided by Chapter 8 of the NC BMP Design Manual.

<u>Applicability</u>
All four studies analyzed were conducted in North Carolina in either the Piedmont or Coastal Plain geologic provinces and they all used natural stormwater runoff in their monitoring, thus this crediting is directly applicable to Jordan and Falls watersheds. The key design factors are accounted for in the crediting method and are fully applicable, and thus uncertainty based on applicability is negligible.

Data Quality
The quality of data and the assumptions used in the analysis result in a high degree of confidence in the nutrient credits. Each study in this analysis was located in North Carolina and conducted on multiple storm events with a minimum of 13 samples. Each was published in a peer-reviewed journal, with sound conclusions and supporting statistics.

**2. Measure Design & Operation Specification**

Confidence in sustained load reductions is reasonably good given that the practice is relatively simple in design, and it has been used and permitted in the State of NC using the current minimum design standards since 2010. A longer record of use will further improve this confidence.

**3. Load Reduction Estimation Methods**
LSFS with design variants is a relatively simple practice, and the nutrient removal processes and assumptions used in the Jordan/Falls Tool are known and straightforward, so the practice and the credit method are well matched and do not introduce significant uncertainties.

## Co-Benefits

In the case of LSFS design variants, additional benefits may include further reducing other pollutants including Total Suspended Solids (TSS), metals, and bacteria. Historically, the original design intent of filter strips was the reduction in suspended sediment, while improvements to design specifications promote added value of infiltration and treatment. Because of the reductions of runoff volume associated with LSFS, the practice may also help to alleviate drainage issues and reduce flooding.

## References & Resources

**Hunt, W.F., J.M. Hathaway, R.J. Winston, and S.J. Jadlocki. 2010.** *Runoff Volume Reduction by a Level Spreader - Vegetated Filter Strip System in Suburban Charlotte, NC.* Journal of Hydrologic Engineering, 15(6): 399-503. One LS-VFS system with a 19.4 meter level spreader and 900 $m^2$ vegetated filter strip was monitored over a 14-month period with 23 monitored storm events. Receiving runoff from a 2.15 acre water shed only produced outflow from the LS-VFS system in three storm events that were all greater than 1.6 inches. Total volume reduction over the monitoring period was 85 percent.

**Knight, E.M.P, W.F. Hunt, and R.J. Winston. 2013.** *Side-by-side evaluation of four level spreader–vegetated filter strips and a swale in eastern North Carolina.* Journal of Soil and Water Conservation. Two LS-VFS pairs and a swale in eastern North Carolina were evaluated for pollutant concentrations (N, P, and, TSS) and hydrologic performance. Two of the LS-VFSs were amended with sand and a phosphorus sorptive aggregate. Length of LS-VFS system was also evaluated. Runoff volumes were reduced by 36–59 percent. The systems consistently reduced the nitrogen and particulate pollution, while all systems increased total phosphorus.

**Line, D.E. and W.F. Hunt. 2009.** *Performance of a Bioretention Area and a Level Spreader-Grass Filter Strip at Two Highway Sites in North Carolina*. Journal of Irrigation and Drainage Engineering, 135(2): 217-224. One LS-VFS and a bioretention area along the North Carolina highway system were evaluated for pollutant and volume reduction. The LS-VFS was found to have 49 percent total volume reduction over the 13 storm events monitored.

**Winston, R.J., W.F. Hunt, D.L. Osmond; W.G. Lord; and M.D. Woodward. 2011.** *Field Evaluation of Four Level Spreader–Vegetative Filter Strips to Improve Urban Storm-Water Quality*. Journal of Irrigation and Drainage Engineering 137(3):170-182. Two level spreader-vegetated filter strip pairs were tested in Louisburg and Apex, NC. The LS-VFS systems reliably removed particulate pollution from all locations. Runoff volumes were reduced by 40-50 percent. A minimum width of 25 feet appeared sufficient to achieve most observed benefits.

## Supporting Technical Information

This supporting technical information is provided for the LSFS design variants nutrient crediting document and includes a description of the studies that were evaluated to establish the credits associated with design variants for this practice.

Development of the nutrient credit document for this practice was a collaborative effort that included representatives from the following organizations who comprised the technical workgroup referenced below:

- North Carolina Department of Environmental Quality Division of Water Resources: Rich Gannon, MEM, CPM; John Huisman; Trish D'Arconte; and Amin Davis, PWD
- North Carolina Department of Environmental Quality Division of Energy, Mineral and Land Resources: Annette Lucas, PE and Bradley Bennett
- North Carolina State University Biological & Agricultural Engineering Stormwater Engineering Group: Andrew Anderson, PE; Erin Carey, MS; and Bill Hunt, Ph D, PE
- Upper Neuse River Basin Association: Forrest Westall, PE
- The Center for Watershed Protection, Inc.: Neely Law, Ph D
- Cardno: Alix Matos, PE

Stormwater runoff that is infiltrated into the ground as a result of volume reducing practices is assumed "lost" from the system, and the nutrient loads associated with the "water lost" are available for nutrient crediting. This assumption is consistent with a memorandum issued by NCDEQ on May 13, 2014: Procedure for Meeting the Requirements of the Nutrient Sensitive Waters Stormwater Programs by Implementing Low Impact Development. To estimate the annual volume of "water lost" for LSFS, the volume reduction data available in the literature (Table 2) were analyzed, and the designs of the field studies were compared to the Minimum Design Criteria specified by NCDEQ pursuant to Minimum Design Criteria and related requirements of rules 15A NCAC 2H .1000.
(http://portal.ncdenr.org/c/document_library/get_file?uuid=0212634d-9aa9-4301-a481-1d6c57930c44&groupId=38334).

**Table 2. Volume Reductions Reported in the Literature for Level Spreader Filter Strips**

| Study | Drainage area (ac) (A) | Percent Imperviousness (PI) | Computed (C) [(PI*0.95+ (1-PI)*0.2] | Design Flow (cfs) [CIA, where I=1in/hr storm)] | Length of Level Spreader (ft) | Width of Filter Strip (ft) | Ratio of Filter Strip Length to Design Flow (ft/cfs) | Percent Volume Reduction |
|---|---|---|---|---|---|---|---|---|
| Line and Hunt, 2009 | 0.86 | 49% | 0.57 | 0.49 | 24 | 56 | 49 | 49% |
| Hunt et al., 2010 | 2.15 | 45% | 0.54 | 1.16 | 63.5 | 158 | 55 | 85% |
| Winston, 2011 | 0.49 | 73% | 0.75 | 0.37 | 13 | 25 | 35 | 48% |
| Winston, 2011 | 0.49 | 73% | 0.75 | 0.37 | 13 | 51 | 35 | 41% |
| Knight et al, 2013 | 0.27 | 56% | 0.62 | 0.17 | 26 | 20 | 155 | 36% |
| Knight et al, 2013 | 0.36 | 56% | 0.62 | 0.22 | 66 | 20 | 296 | 59% |
| Knight et al, 2013 | 0.38 | 56% | 0.62 | 0.24 | 26 | 20 | 110 | 42% |
| Knight et al, 2013 | 0.57 | 56% | 0.62 | 0.35 | 66 | 20 | 187 | 57% |

Four studies were used to quantify credits associated with this practice, however, each study reported different parameters (e.g. runoff volume, concentration, pollutant load) (Table 2). The study period for all studies ranged from 9 to 18 months, with 13-30 sampling events for each study. The designs of the filter strips evaluated included a blind swale with level spreader, width, drainage area, and percent imperviousness. Based on the available scientific data to estimate load reductions for TSS, TN, and TP, percent volume reduction and previously published EMCs for filter strips appear to be the preferred crediting method for the design variants.

The technical workgroup determined the volumes reductions associated with two design variants using a combination of the data in the literature and best professional judgment (Figure 1). The four studies analyzed were conducted in North Carolina in either the Piedmont or Coastal Plain geologic provinces and they all used field-based monitoring of stormwater runoff with a minimum of 13 samples per study. The available studies tended to have relatively high ratios of length of level spreader to design flow, and are more representative of the 40 ft/cfs values shown on Figure 1. Best professional judgment exercised by staff at NC DWR and NC DEMLR were used to extrapolate the research to designs with lower ratios (e.g., 10 ft/cfs) by assuming that every 10 foot per cfs decrease in the ratio resulted in a 25 percent reduction in the annual volume reduction relative to the published studies.

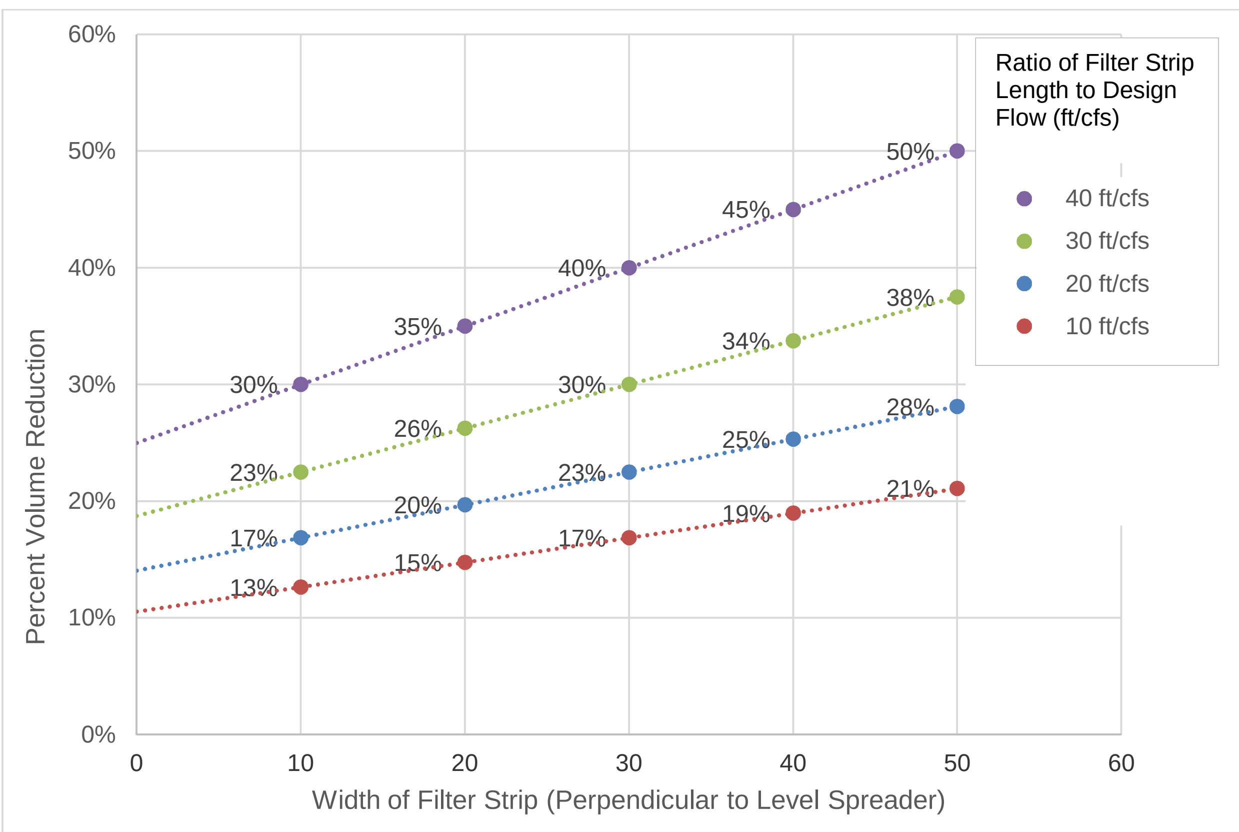



**Figure 1. Runoff Reduction Based on Two Design Variants: 1) Ratio of Filter Strip Length to Design Flow (ft/cfs) and 2) Filter Strip Width**

In addition to infiltration of water, filter strips also treat surface runoff through processes including filtration, sedimentation, and plant uptake. Based on NCDWR consultation with staff from the North Carolina State University Biological & Agricultural Engineering Stormwater Engineering Group in October 2014, the event mean concentrations for nitrogen and phosphorus for filter strips are 1.09 mg/L and 0.16 mg/L, respectively, which are lower than many event mean concentrations for land uses. These values are changes from the Jordan Falls Stormwater Loading Accounting Tool (JFSAT) User Guide (Version 1.1) and have been incorporated in the latest version of JFSAT.