Design Specifications & Nutrient Accounting for Riparian Buffer Improvement in Developed Areas

Practice Description and Utility
Purpose: This document addresses the practice of improving riparian buffers in developed areas, provides design criteria and implementation specifications, and provides the nutrient credit assignments used for compliance with Nutrient Management Strategy Rules. ***Applicability:*** This practice has been developed to provide nutrient reduction credits towards compliance with applicable Nutrient Management Strategy rules. The credits described in this document are limited to forested buffer improvement in developed areas to complement the existing design standards and accounting method for buffer improvement in agricultural areas. This practice may also be applicable to new development sites but would require approval by the local government permitting authority as well as the NCDEQ Division of Energy, Mineral and Land Resources Stormwater Permitting Program. This practice was not developed for application to agricultural lands. Consistent with the Buffer Mitigation Rules (15A NCAC 02B .0295), a buffer restoration site is one that is "characterized by an absence of trees and by a lack of dense growth of smaller woody stems (i.e., shrubs or saplings) or sites that are characterized by scattered individual trees such that the tree canopy is less than 25 percent of the cover and by a lack of dense growth of smaller woody stems (i.e., shrubs or saplings)." The practice may be applied adjacent to perennial, intermittent and ephemeral streams or qualifying ditches, with a minimum forested buffer width of 20 feet on a given side, and credit will be awarded for buffers up to a maximum width of 200 feet on a given side. Restoration of buffers along perennial and intermittent streams constitutes a land use change that shall comply with the Buffer Protection Rules (https://deq.nc.gov/riparian-buffer-rules). The Buffer Protection Rules do not apply to ephemeral channels. If a buffer improvement requires use of a level spreader, this device shall be installed in accordance to DWR guidance. ***Method:*** Riparian buffers are natural or constructed low-maintenance vegetated ecosystems adjacent to surface water bodies, where trees, grasses, shrubs, and herbaceous plants function as a filter to remove pollutants from overland stormwater flow, runoff, and shallow groundwater flow prior to discharge to receiving waters (NCDEQ BMP Manual). The proposed credit associated with this practice applies to forested buffers in urban, suburban, and developed rural areas including residential, commercial, industrial, open space, golf courses, and athletic fields. Pollutant removal varies with the width of the buffer and the volume of flow treated by the buffer, either from adjacent upland areas that contribute sheetflow to the buffer or flows that are routed from upstream areas to the buffer as concentrated flow. Buffers receiving concentrated flows require use of a level spreader outside of the required minimum buffer width to provide diffuse flow through the buffer.

Nutrient Credit Overview
This practice is credited by applying percent removal efficiencies that vary by buffer width to project-site nitrogen and phosphorus loading estimates calculated using the latest version of the Jordan Falls Stormwater Nutrient Accounting Tool (JFSNAT) or a subsequent Division-approved

tool. Nutrient reductions are achieved through two mechanisms: land conversion and throughput treatment by the buffer. Using this method, the ranges of estimated nutrient removal for the most likely set of restoration scenarios are: 2.6 lbs/ac/yr to 46.3 lbs/ac/year of the total nitrogen (TN) and 0.8 lbs/ac/yr to 10.3 lbs/acre/year of the total phosphorus (TP). The ranges in reductions provided in this credit document vary, and are based on, the natural drainage area of the buffer. Where catchments are artificially larger through development, the reductions may be greater.
Relative Confidence in Credit Assignments
Credit estimates for buffer improvement in developed areas are considered to have low confidence due to the lack of studies that specifically evaluate riparian buffer improvement in developed environments and the assumptions used in applying gross percent removal efficiencies.

Design Criteria and Recommendations

Buffer improvement projects in developed areas shall meet the design criteria and qualifying conditions and limitations described below in order to be eligible for nutrient reduction credit. The design criteria and recommendations for this practice are drawn from existing buffer protection and mitigation requirements and guidance established in DWR's buffer protection and mitigation rules and mitigation banking instrument which address the establishment, use, operation, and maintenance of buffer improvement projects.

Additional recommendations beyond the scope of existing guidance are informed by information found in literature regarding best practices and consultation with local subject matter experts for this practice.

Qualifying Conditions and Limitations

Area and Location

1. Nutrient credit assignments described in this document apply to buffer restoration in developed areas on perennial, intermittent, and ephemeral streams, qualifying ditches, and perennial waterbodies.
    a. "Perennial" and "intermittent" stream definition is based on the Surface Water Identification Training Course (SWITC) definition; "perennial waterbody" is connected to any perennial or intermittent stream.
    b. "Ephemeral" stream definition is based on the Buffer Mitigation Rule 15A NCAC 02B .0295 (l)(7).
    c. "Ditch" definition is based on the Buffer Mitigation Rule 15A NCAC 02B .0295 (l)(8).
    d. Streams shall be classified by someone who is certified by the State for intermittent and perennial stream identification.

2. Sites qualifying for buffer restoration credit shall meet the definition of "Restoration Site" 15A NCAC 02B .0295 (b)(12): riparian zone sites that are characterized by an absence of trees and by a lack of dense growth of smaller woody stems (i.e., shrubs or saplings) or sites that are characterized by scattered individual trees such that the tree canopy is less than 25 percent of the cover and by a lack of dense growth of smaller woody stems (i.e., shrubs or saplings). "Preservation Site" 15A NCAC 02B .0295 (b)(11) means riparian zone sites that, as determined by a site visit conducted by the Authority, are characterized by a forest consisting of the forest strata and diversity of species appropriate for the location. "Enhancement Site" 15A NCAC 02B .0295 (b)(4) means a riparian zone site characterized by conditions between that of a restoration site and a preservation site such that the establishment of woody stems (i.e., tree or shrub species) will maximize nutrient removal and other buffer functions. Enhanced areas shall not comprise more than 50 percent of the total buffer improvement area.
3. Land uses of areas draining to the buffer may be any form of development.
4. Minimum restored or enhanced buffer width shall be 20 ft on a given side.
5. Maximum buffer width including restored, enhanced, and pre-existing forest is 200 ft on a given side. This does not include space needed for any level spreaders.
6. Improvement can abut pre-existing forest area between 0 and 200 ft, but pre-existing and newly restored forest shall be contiguous with streambanks/edge of waterbody (no breaks). Enhanced areas receive half credit consistent with the Buffer Mitigation Rule 15A NCAC 02B .0295 (m). Pre-existing forest that is not improved is not included in calculations. Where enhancement/restoration occurs landward of pre-existing, fully functional, forested riparian zone, throughput treatment calculations shall credit the incremental increase in efficiency provided by the added buffer width as applied to the remaining catchment area. The incremental increase is calculated as the removal efficiency for the total buffer width minus the removal efficiency for the pre-project buffer width. For sites where the existing buffer is less than 20 feet wide, the existing buffer is assumed an enhanced area which may not exceed 50 percent of the total buffer improvement area.
7. Existing sewer easements within Zone 2 of the buffer are allowed per the requirements specified in the Buffer Mitigation Rule 15A NCAC 02B .0295 (l)(4); sewer easements are not included in credit calculations. As specified in the Buffer Protection Rules, Zone 1 is the inner 30 feet of buffer closest to the waterbody and Zone 2 is the outer portion of the buffer.
8. Buffer width is measured horizontally from top of bank (for streams) and mean high water (for perennial waterbodies).
9. This practice may be used in settings with incised or not-incised streams. Perennial waterbodies are assumed to be not incised unless they experience severe changes in depth over the course of a year, such as from significant and lengthy draw-downs.

Any new development that occurs adjacent to or upstream of the buffer after the buffer has been improved will require separate stormwater treatment measures: new development may not rely solely on the buffer for treatment.

Table 1. Site Conditions and Eligible Crediting Mechanisms for Restoration of Buffers in Developed Areas

Fertilizer Use	Only allowed for initial vegetation establishment
Minimum Total Width & Vegetation Type	20 feet forest
Maximum Creditable Total Width	200 feet
Land Conversion Credit	100%, all cases
Treatment Credit Factor	Incised (Perennial or Intermittent) , Ephemeral, or Qualifying Ditch: .5 Nitrogen, 1 Phosphorus
	Non-Incised (Perennial or Intermittent): 1 Nitrogen , 1 Phosphorus
Maximum Slope By Inflow Types	Overland Sheetflow 33%
	Flow Diffused by Level Spreader 8%

General Design Guidance

Projects shall meet the requirements of the applicable buffer protection rules in addition to the following design requirements:

1. Unless concentrated flows are diffused through the use of a level spreader the maximum slope of the buffer area allowed is 33 percent.
2. Pre-existing concentrated flows going through the buffer (that are not associated with a stream and not diffused as part of the improvement project) are allowed to continue crossing the buffer unaltered.
3. Tributary streams crossing the buffer may not be diffused; existing instability problems should be addressed using stream restoration or streambank stabilization, which shall be eligible for credit under those separate practice standards.
4. New concentrated flows (after improvement) through the buffer are prohibited.
5. All <u>very small/minor</u> concentrated flows (e.g., roof drains) daylighting within 10 ft of the improvement area, or inside of the improvement area, shall be diffused with a splash pad or other method of energy dissipation to prevent erosion at least

50 ft away from the stream or waterbody, consistent with the requirements of the Buffer Protection Rules.

Level Spreader Option: Projects with Diffusion of Major concentrated flows:

Projects that are able to diffuse concentrated flows will receive greater credit, but shall be required to meet the following design specifications. A level spreader is required upslope and adjacent to the improved buffer. Level-spreaders, if used, shall be designed and installed according to Minimum Design Criteria for all SCMs and for Level Spreader-Filter Strips (2H .1050 and 2H .1059). Level spreaders shall meet DEMLR Minimum Design Criteria with the following exceptions and requirements:

1. A level spreader shall be designed to the standard of 65 ft of level spreader/peak flow cfs, directly upslope of a forested buffer area with no re-collection of overland flow.
2. Level spreaders may be installed no closer than 50 ft to the stream or waterbody and outside of any restored or enhanced buffer areas. (LS-FS are allowed closer to correct an identified erosional threat to existing infrastructure, but with the LS-FS located as far away from the stream or waterbody as practicable. These installations are not eligible for this credit and must have different credit amounts proposed by the project designer.)
3. Where multiple level spreaders are deployed, level spreaders shall be evenly dispersed along the improvement area to the maximum extent practicable.
4. Flow volumes greater than design specifications, such as for large drainage areas, may be directed to the level spreader but shall have flow split to meet the maximum flow requirements.
5. Overflow conveyances shall use preexisting drainage ditches or swales provided flows do not alter the ditch or swale, or result in the need to alter the conveyance, and are managed to minimize the sediment, nutrients, and other pollution conveyed.
6. Maximum slope of the buffer area and LS is 8 percent.

Identification of Incised Stream Conditions:

All proposed projects shall evaluate the degree of stream incision. The bank height ratio (BHR) is used to determine whether or not a stream is incised (Harman et al. 2012):

BHR = Dtob / Dbf, where

Dtob = the depth from the top of the lowest bank to the thalweg

Dbf = the depth from the bankfull elevation to the thalweg.

Figure 1 shows an example of the Dtob and Dbf terms.

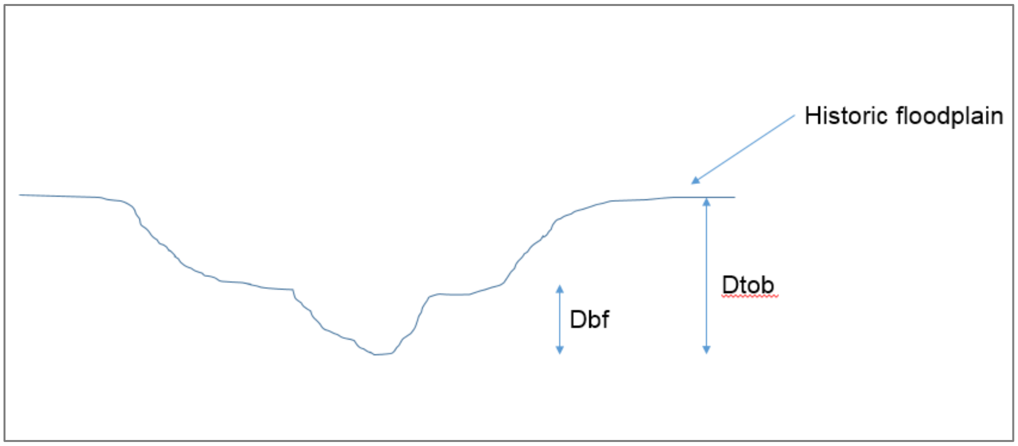

Figure 1. Example of Bank Height Ratio Terms

Streams with a BHR ratio from 1.0 to 1.3 are considered between "stable" and "slightly incised" and use the standard nitrogen removal efficiency values when calculating credit. Streams with BHR greater than 1.3 are considered "moderately" or "severely" incised and use one half the nitrogen removal efficiency when calculating credit.

Implementation Recommendations:

1. In situations with severe stream incision and/or bank erosion, stream restoration or streambank shaping and stabilization should be considered.
2. For ephemeral streams, regenerative stormwater conveyance or bioswales should be used, which may involve some amount of riparian buffer improvement.

Use Limitations in the Buffer

The following constraints apply in addition to those required under the buffer protection rules and apply to the entire restored and enhanced buffer area in both New Development and Existing Development settings:

1. The buffer shall not be disturbed (e.g., cleared, graded, or harvested) unless for specific conservation, restoration, or ecological management purposes; these activities require approval by the approving authority.
2. No activities shall occur in the buffer with the exception of "non-intensive outdoor recreation," existing utility maintenance and management, forestry activities, and buffer inspection and maintenance activities. "Non-intensive outdoor recreation" is defined as dispersed, non-commercial and non-motorized recreational activities that do not generally rely on buildings and have minimal impact on renewable natural resources. Such activities include but are not limited to, hiking, bird watching, camping, picnicking, mountain biking and lawful hunting and fishing, but do not include horseback riding.
3. No impervious surfaces shall be added in the improved buffer. Recreational trails including those suitable for non-motorized vehicles may be installed but shall not exceed 4 feet in width, shall not exceed 10% of the improved area, and installation or use shall not result in removal of trees. Trails shall be designed to minimize erosion

and managed to prevent compaction by users. Trails may be installed along pre-existing utility easements where available.

4. Pre-existing utility easements through the buffer shall be managed to minimize soil erosion and compaction, and minimize transport or dispersal of invasive plant species into the buffer. Improvements to utility crossings of streams are permissible where designed to improve or restore natural stream morphology and reduce erosion.
5. Timber harvesting shall follow the requirements for forestry activities laid out in the applicable Buffer Protection Rule.
6. Fencing and other physical barriers such as tree tubes may be installed to protect trees and shrubs from damage or injury. Installation shall not result in removal of trees.
7. The buffer shall not be used for agricultural use, horticultural use, animal husbandry, or grazing.
8. There shall be no filling, excavation, dredging, mining, or drilling in the buffer.
9. There shall be no storage or dumping of trash, garbage, abandoned vehicles, appliances, or machinery, or other unsightly or offensive material, hazardous substance, or toxic waste.
10. There shall be no changing of the topography through the placing of soil or other substance or material such as land fill or dredging spoils, nor shall activities be conducted in the project area that could cause erosion or siltation.

Design Requirements Specific to New Development

Since credits for New Development are intended to be perpetual and not renewable, it is required that the improved area will be adequately inspected and maintained and have adequate protections and financial assurances to insure continued health of the forested buffer in perpetuity. Thus, riparian restoration and enhancement projects implemented to generate credits for offsetting new development nutrient reduction requirements, shall set up a Mitigation Banking Instrument to be approved by DWR prior to initiation of the project.

Design Requirements Specific to Existing Development

The following sections address the requirements for vegetation plans and success criteria, inspection and maintenance, and credit award and verification for projects on existing development sites.

Vegetation Plan and Success Criteria

Forest restoration shall follow a DWR approved restoration plan and shall be planted in forest species native to North Carolina only. The initial vegetation plan shall include a minimum of four native tree and shrub species, with a minimum of three hardwood tree species and a maximum of one coniferous/softwood tree species, where no one species is greater than 50 percent of stems. Trees and shrubs shall be planted at a density sufficient to provide 320 stems per acre for the first five years and 260 stems per acre after five years. To achieve this density, approximately 436 (10x10 feet spacing) to 681 (8x8 feet spacing) trees and shrubs per acre should be planted initially. The Division may approve alternative vegetation plans upon consideration of factors, including site wetness and plant availability, to meet the vegetation requirements.

Prior to the establishment of native hardwood trees and shrubs, sites should be stabilized with native grasses, particularly if grading is required to restore hydrologic function; grading is only allowed in Zone 2. Fertilizer may be applied to establish vegetation; subsequent application of fertilizer will require approval.

Success will be defined as the survival of a minimum density of 320 stems per acre for the first five years and 260 stems per acre after five years. If vegetative success criteria are not met, supplemental plantings may be required. Native tree and shrub volunteer species may be included to meet the standard for success, as long as a minimum of three hardwood tree species are present and no species constitutes more than 50 percent of stems.

Inspection and Maintenance

An inspection and maintenance plan shall detail the activities proposed to ensure a final performance standard of 320 stems per acre for the first five years and 260 stems per acre after five years. This plan should describe action levels at which point additional planting will be undertaken to maintain adequate stem density, methods for identifying and removing invasive plant species, and methods to protect young trees from injury by herbivory, foot or vehicular traffic, landscaping activities, etc.

Vegetation surveys shall be conducted to demonstrate that an adequate vegetation density is being maintained. Vegetation surveys shall include permanently-marked 10mx10m plots, with data collected between June 1 and September 1, in which all living stems of trees and shrubs are counted and identified to species. Locations of plots should be documented with GPS coordinates. Each project shall have a minimum of one 10mx10m monitoring plot per acre that is representative of conditions in that area.

During the first five years after planting, the party awarded credit shall ensure that the buffer is inspected at least annually, maintained as necessary, that inspection and maintenance actions are documented by written means, and that the Division will be provided access to the practice with proper notice. In addition to surveying the plotted area, annual inspections should include a visual inspection of the entire site to assess overall health of the vegetation as well as identify areas of disturbance and impacts to planted stems that may require action (e.g., evidence of trees with suppressed growth or death from encroachment by competing vegetation, animal damage, or disease). After five years, inspections, reporting, and remedial actions are required at least every five years.

Credit Award and Verification

Upon submittal and approval of all appropriate documentation by DWR, credits for this practice will become available in accordance with the following credit release schedule. The percentages show below are the proportion of total credit released:

As built approved:	50% of full credit
Year 1:	60% of full credit
Year 2:	70% of full credit
Year 3:	80% of full credit
Year 4:	90% of full credit
Year 5 and beyond:	100% of full credit

For each of the first 5 years in order to release credits, a vegetation survey must be submitted to DWR documenting vegetation density. If the target density is not maintained, the next allotment of credits will not be released until remedial action has been taken.

After the first 5 years, vegetation survivorship surveys, or an alternative approach acceptable to the Division, shall be conducted at least at the end of every 5 year period and submitted to DWR to document calculation of credits applying to that period. If the required vegetation density is not maintained, corrective action should be taken. DWR may adjust credits if vegetation densities are not maintained. Credit may be reduced for that reporting year proportional to the deficiency in tree density. The party shall seek to identify and determine, if possible, when the impacts to the buffer began or occurred, remedy causes for the attrition, and replant as indicated to ensure success criteria are met. The party shall recommence annual inspections and reports on the newly planted stems for a period of no less than 3 years and take appropriate corrective actions considering the identified causes of attrition.

If only one inspection is conducted for a second or later 5-year period, and it is not possible for the party to determine when the impact to the buffer occurred, it shall serve as the sole basis for judging credits for the previous 5 years, and reduced credits may apply to all 5 years. DWR will consider the results of the inspection and other information developed by the party to assist in its determination for any reduction in the credit over the previous 5 years. Documented annual inspections are encouraged to trigger prompt corrective action and to best protect credits. To reduce administrative burden, annual inspection records may be retained and submitted to DWR at least every five years.

At the end of every 5 year period, after notifying DWR of intent, the property owner or entity seeking credit may allow areas outside of Zone 1 of the buffer to be converted to another use with concurrent loss of credit. (This option is not available for credits generated for new development.) Areas within Zone 1 must be maintained as forest to meet requirements of the relevant Buffer Protection Rule.

Nutrient Credit Estimation & Relative Confidence

Summary of Nutrient Load Reduction Credit Method

For this practice, in both new development and existing development settings, the nutrient credit varies based on the width of the completed buffer (measured perpendicular to the stream or waterbody), the width of the pre-project fully functioning buffer, the percent of the project that is restored, the percent of the project that is enhanced, the size of the drainage area treated by the buffer, and the land uses being treated. This practice is credited by applying percent removal efficiencies that vary by buffer width to project-site loading estimates calculated using the latest version of the Jordan Falls Stormwater Accounting Tool (JFSNAT) or a subsequent Division-approved tool.

There are three mechanisms that may contribute to nutrient credits for this practice:

- Land conversion is a change in land use to forest or low maintenance vegetation such as shrubs or grass. The nutrient credit associated with land conversion may be calculated using the latest version of the Jordan Falls Stormwater Accounting Tool (JFSNAT) or a subsequent Division-approved tool. JFSNAT allows the user to input the area of each land use type before and after restoration. The reduction in nutrient export based on land conversion to forest is the nutrient credit for this mechanism. There is no land conversion credit for the portion of the buffer that is "enhanced"; only the area that is "restored" would receive this portion of the credit.
- Buffer treatment may occur by two mechanisms. These mechanisms are represented by the percent mass reductions provided in Table 2.
    - Surface treatment occurs as flows are distributed across the ground surface of the buffer as diffuse flow. Processes that contribute to surface treatment include sedimentation and filtration.
    - Subsurface treatment occurs as water flows beneath the surface of the buffer. Depending on the site characteristics and nutrient being evaluated, loss processes may include infiltration, evapotranspiration, adsorption or, vegetative uptake, and denitrification.
        - Because phosphorus is less affected by the redox state and microbial activity of the soil, this mechanism and crediting method is the same for all buffer improvement projects in developed areas.
        - For nitrogen, subsurface treatment is primarily through denitrification which is maximized when shallow groundwater flows through the active floodplain of the buffer with organic rich soils under anaerobic conditions (Johnson et al. 2013 and Jordan et al. 1993). This interaction is more likely to occur along streams that are not incised and are well connected to the floodplain. Therefore, only buffer improvement projects implemented adjacent to streams or waterbodies that are not incised can use the full percent reduction credit for nitrogen.

Table 2. Percent Mass Reductions Assigned to Full Buffer Restoration (Widths from Top-of-Bank on a Given Side for a Non-Incised, Perennial or Intermittent Channel; No Discount Factors Applied)

Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction	Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction	Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction
20	20.0	81	33.1	142	37.10
21	20.5	82	33.2	143	37.15
22	21.0	83	33.3	144	37.20
23	21.5	84	33.4	145	37.25
24	22.0	85	33.5	146	37.30
25	22.5	86	33.6	147	37.35
26	23.0	87	33.7	148	37.40
27	23.5	88	33.8	149	37.45
28	24.0	89	33.9	150	37.50
29	24.5	90	34.0	151	37.55
30	25.0	91	34.1	152	37.60
31	25.3	92	34.2	153	37.65
32	25.5	93	34.3	154	37.70
33	25.8	94	34.4	155	37.75
34	26.0	95	34.5	156	37.80
35	26.3	96	34.6	157	37.85
36	26.5	97	34.7	158	37.90
37	26.8	98	34.8	159	37.95
38	27.0	99	34.9	160	38.00
39	27.3	100	35.00	161	38.05
40	27.5	101	35.05	162	38.10
41	27.8	102	35.10	163	38.15
42	28.0	103	35.15	164	38.20
43	28.3	104	35.20	165	38.25
44	28.5	105	35.25	166	38.30
45	28.8	106	35.30	167	38.35
46	29.0	107	35.35	168	38.40
47	29.3	108	35.40	169	38.45
48	29.5	109	35.45	170	38.50
49	29.8	110	35.50	171	38.55
50	30.0	111	35.55	172	38.60
51	30.1	112	35.60	173	38.65
52	30.2	113	35.65	174	38.70
53	30.3	114	35.70	175	38.75
54	30.4	115	35.75	176	38.80
55	30.5	116	35.80	177	38.85
56	30.6	117	35.85	178	38.90

Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction	Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction	Buffer Width from Top-of-Bank (feet)	Percent Nitrogen & Phosphorus Reduction
57	30.7	118	35.90	179	38.95
58	30.8	119	35.95	180	39.00
59	30.9	120	36.00	181	39.05
60	31.0	121	36.05	182	39.10
61	31.1	122	36.10	183	39.15
62	31.2	123	36.15	184	39.20
63	31.3	124	36.20	185	39.25
64	31.4	125	36.25	186	39.30
65	31.5	126	36.30	187	39.35
66	31.6	127	36.35	188	39.40
67	31.7	128	36.40	189	39.45
68	31.8	129	36.45	190	39.50
69	31.9	130	36.50	191	39.55
70	32.0	131	36.55	192	39.60
71	32.1	132	36.60	193	39.65
72	32.2	133	36.65	194	39.70
73	32.3	134	36.70	195	39.75
74	32.4	135	36.75	196	39.80
75	32.5	136	36.80	197	39.85
76	32.6	137	36.85	198	39.90
77	32.7	138	36.90	199	39.95
78	32.8	139	36.95	200	40.00
79	32.9	140	37.00		
80	33.0	141	37.05		

There are several project characteristics that affect the nutrient credits for this practice. To get the final load reduction, multiply the initial calculation of nutrient load removed by the composite discount:

Composite discount = (nitrogen removal discount) * (enhancement discount) * (credit release discount) * (insufficient survivorship discount)

If a specific factor is not applicable, such as the nitrogen removal discount for a phosphorus calculation, use the value 100% (i.e., no discount):

- Improved areas adjacent to streams that are incised, ephemeral, or qualifying ditches receive one-half of the nitrogen credit and the full phosphorus credit.
- Areas that are restored receive full credit; areas that are enhanced receive half credit for both nitrogen and phosphorus. Areas undergoing enhancement are assumed forest in both the pre- and post-project state and do not receive land conversion credit. Utility

easements are assumed managed pervious for their entire width in both the pre- and post-project state, whether they are cleared to that width or not, because they can be cut back at any time. The enhancement discount may be calculated as

Enhancement discount (calculate composite based on relative proportions):

[1 * (proportion of restored area)] + [0.5 * (proportion of enhanced area)]

- During the first five years after planting, credits are released as follows if vegetation density requirements are met:
    - Year 1 50% of full credit
    - Year 2 60% of full credit
    - Year 3 75% of full credit
    - Year 4 90% of full credit
    - Year 5 and beyond 100% of full credit
- Areas that are improved adjacent to an existing, fully functioning riparian buffer that is at least 20 feet wide are credited assuming an incremental percent removal efficiency calculated as

  Removal Efficiency = Removal efficiency for post-project buffer width – Removal efficiency for the pre-project, fully functioning buffer width
- An additional discount factor may be applied by DWR if the vegetation density requirements are not met during the post 5-year period.

Reductions Obtained with Practice

Example ranges for this practice are provided in Table 3 for illustrative purposes, and individual site designs may result in different values depending on the combination of land use classes, drainage area treated, etc. Because buffer improvement has different treatment mechanisms depending on site conditions, the percent reductions will depend on whether or not the adjacent stream is incised, the amount of built upon area, the event mean concentrations of the land use draining to the practice, etc. The nutrient reductions (or credits) are provided in the table as pounds per acre per year (lbs/ac/yr) for a given site condition. For these examples, a six acre residential site was used with built upon areas ranging between 10 percent and 50 percent. The ranges in reductions provided in Table 3 assume the stream channel is not incised and a drainage area size of 6 acres. Where catchments are artificially larger through development, the reductions may be greater.

Table 3. Example Load Reductions per Acre of Buffer Restoration for a Non-Incised Channel

Buffer Width from Top-of-Bank (feet)	Percent N & P Reduction (from Table 2)	Nitrogen Reductions Per Acre of Buffer (lbs/Buffer ac/yr)	Phosphorus Reductions Per Acre of Buffer (lbs/Buffer ac/yr)
20	20	13.7 – 46.3	3.9 – 10.3
30	25	11.0 - 30.0	3.1 – 8.3
50	30	7.9 – 21.5	1.6 – 6.0
100	35	4.6 – 12.6	1.4 – 3.5
200	40	2.6 – 7.4	0.8 – 2.0

Buffer Restoration – Credit Calculation Examples

Example #1 – Basic Buffer Restoration Example

The following is an example of how to calculate the nutrient load reduction credits for restoring a 30′ wide buffer along 500′ of a perennial stream for a six-acre residential drainage area. This example includes calculating the credit achieved by both land conversion and treatment by the restored buffer.

For this example, assume the project site has the following characteristics:

- Site is existing residential development with 20% Built Upon Area
- Entire Site is 6 acres (261,360 sq.ft.)
- Roof makes up 10 percent (26,136 sq.ft.)
- Roadway makes up 10 percent (26,136 sq.ft.)
- Managed Pervious Grass Area takes up 80 percent (209, 088 sq.ft.)
- Year 6 of credit release schedule

JFSNAT allows the user to input the area of each land use type before and after restoration (the "project"). The reduction in nutrient export based on land conversion to forest is the nutrient credit for this mechanism.

Land Conversion Credit Data Entry

1. Enter all the relevant information on the Project Info and Watershed Characteristics pages
    a. In the Pre-development column enter the roof, roadway and managed pervious grass area.
    b. In the Post-Development column enter the roof and roadway area. Enter the footprint of the buffer area as Forest. This footprint comes out of the managed pervious footprint. In this example the 209,088 sq.ft. Pre-Development Managed Pervious Grass would convert to 194,088 sq.ft. of Post-Development Managed Grass and 15,000 sq.ft. of forested (buffer area) in the post development condition.

<u>Interpreting Results</u>
On the *Overall Summary* page, the *Total Nitrogen* & *Phosphorus Loading* (lbs/yr) should show the following values for Pre-Development Conditions:

Total Nitrogen Loading (lbs/yr) = 21.10
Total Phosphorus Loading (lbs/yr) = 5.81

For Post-Development Conditions w/BMPs, the values are

Total Nitrogen Loading (lbs/yr) = 20.89
Total Phosphorus Loading (lbs/yr) = 5.72

The user then completes the remaining steps by hand to calculate the credits (reductions in loading) achieved via land conversion. Compute the nutrient reductions in pounds per year:

Nitrogen -> 21.10 - 20.89 = 0.21 lbs/yr
Phosphorus -> 5.81 – 5.72= 0.9 lbs/yr

Note: Discount factors do not apply to land conversion credit.

Treatment of Runoff through the Buffer

The bulk of the nutrient reduction credit for buffer restoration is achieved by the surface and subsurface treatment of the runoff through the buffer. To calculate this part of the credit:

1. Use the JFSNAT to calculate the nitrogen and phosphorus load shed by the watershed draining to the buffer area, but excluding the buffer area itself. If concentrated flow is diffused outside of the buffer, the drainage area for the concentrated flow may be included in the watershed area. Otherwise exclude any areas drained to/across the buffer as concentrated flow.
2. Calculate an average buffer width based on multiple measurements of the project width for projects that are not uniform in width (30 feet for this example).
3. Determine the percent reduction to apply to the nitrogen and phosphorus loads using the values in Table 2 for the average buffer width (25 percent reduction for this example). If there is any pre-existing forest or utility easement mixed in the restored/enhanced buffer area, you will need to calculate the incremental percent reduction.
4. Calculate the initial load reduction by multiplying the nitrogen and phosphorus loads by the percent reduction.
5. Apply a composite discount to the initial load reduction based on whether the stream is incised/ephemeral, whether part of the project was enhanced, if you are in the first 5 years and have partial credit release, or if your vegetation survival was less than required for full credit. Instructions to determine discounts are in the methods section.

Data Entry for Treatment of Runoff through Restored Buffer on Perennial Stream

1. Enter all the relevant information on the Project Info and Land Use Characteristics page.
    a. In the Pre-development column enter the roof, roadway and managed pervious area (but do not include the managed pervious area that was converted to buffer).
    b. In this example the 209,088 sq.ft. Pre-Development Managed Pervious Grass was converted to 194,088 sq.ft. of Post-Development Managed Grass and 15,000 sq./ft. of forested (buffer area) in the post development condition. So 15,000 sq.ft. of Managed Pervious Area would not be included resulting in a

project site area of 246,360 square feet instead of the original 261,360 square feet.

c. The following land use areas would be entered into the watershed characteristics tab:
   i. Roof area = 26,136 sq.ft.
   ii. Roadway =26,136 sq.ft.
   iii. Managed Pervious Area takes = 194,088 sq.ft.

<u>Interpreting Results</u>
On the *Overall Summary* page, the *Total Nitrogen* & *Phosphorus Loading* (lbs/yr) should show the following values for Pre-Development Conditions:

Total Nitrogen Loading (lbs/yr) = 20.63

Total Phosphorus Loading (lbs/yr) = 5.67

The user then completes the remaining steps by hand to calculate the credits for throughput treatment by applying the appropriate percent removal efficiency value from Table 2. In this case with a 30′ buffer along a stream that is not incised, the removal efficiency is 25% for both nitrogen and phosphors resulting in the following reductions:

Nitrogen Reduction = 20.63 lbs/yr * 25% = 5.16 lbs/yr

Phosphorus Reductions = 5.67 lbs/yr *25% = 1.42 lbs/yr

Combine Land Conversion Credit and Runoff Treatment Credit
The total reduction credit in this example is the sum of the land conversion credit and runoff treatment credit:

Total Nitrogen Reduction = 0.21 lbs/yr + 5.16 lbs/yr = **5.4 lbs/yr**

Total Phosphorus Reduction = 0.09 lbs/yr + 1.42 = **1.51 lbs/yr**

Example #2: Applying Discounts to Buffer Restoration Projects

For this example, we assume the project site is similar to the one in example #1 and has the following characteristics:

- Site is existing residential development with 20% Built Upon Area
- Entire Site is 6 acres (261,360 sq.ft.)
- Roof makes up 10 percent (26,136 sq.ft.)
- Roadway makes up 10 percent (26,136 sq.ft.)
- Managed Pervious Grass Area takes up 80 percent (209, 088 sq.ft.)

In this case however, the buffer restoration was done on an incised stream the project is only in year 1 of the credit release schedule so the following discount factors apply:

- Incised Stream (50% Nitrogen Discount Factor)
- Year 1 of the credit release schedule (50% Discount Factor for both N & P)

Data Entry for Land Conversion Credit

Discount factors only apply to treatment through the buffer so the land conversion credit will be the same as calculated in example #1.

Data Entry for Treatment of Runoff through the Buffer

The initial calculation for treatment through the 30′ restored buffer would be calculated following the same steps and reduction efficiency (25%) as described in example #1. This results in the following initial reductions before the discount factors are applied.

Nitrogen Reduction = 20.63 lbs/yr * 25% = 5.16 lbs/yr
Phosphorus Reductions = 5.67 lbs/yr *25% = 1.42 lbs/yr

Applying Composite Discount Factor

In this example a 50% nitrogen removal discount applies because the restoration takes place along an incised stream and an additional 50% discount applies to both the nitrogen and phosphorous reductions because the restoration project is in the first year of the credit release schedule. The composite discounts are calculated separately for nitrogen and phosphorus using the following formula:

Composite discount = (nitrogen removal discount) * (enhancement discount) * (credit release discount) * (insufficient survivorship discount)

For nitrogen and phosphorus, the composite discount factors are

Nitrogen Composite Discount = (50%)*(1)*(50%)*(1) = 25%
Phosphorous Composite Discount = (1)*(1)*(50%)*(1) = 50%

The user then completes the remaining steps by hand to calculate the adjusted throughput treatment credit by applying the discount factors.

Nitrogen Reduction = 5.16 lbs/yr * 25% = 1.29 lbs/yr
Phosphorus Reductions = 1.42 *50% = 0.71 lbs/yr

Combine Land Conversion Credit and Discounted Runoff Treatment Credit

The total reduction credit in this example is the sum of the land conversion credit and discounted runoff treatment credit:

Total Nitrogen Reduction = 0.21 lbs/yr + 1.29 lbs/yr = **1.5 lbs/yr**
Total Phosphorus Reduction = 0.09 lbs/yr + 0.71 = **0.8 lbs/yr**

Example #3: Net Percent Reduction Example - Project with Pre-Existing Forest

The following is an example of how to calculate the nutrient load reduction credits for restoring a 30′ wide buffer abutting 20′ of existing forest along 500′ of a perennial stream for a six-acre residential drainage area.

For this example, assume the project site has the following characteristics:

- Site is existing residential development with 20% Built Upon Area
- Entire Site is 6 acres (261,360 sq.ft.)
- There is 20′ of pre-existing forested buffer along a perennial stream (10,000 sq.ft.)
- Roof makes up 10 percent (26,136 sq.ft.)
- Roadway makes up 10 percent (26,136 sq.ft.)
- Managed Pervious Grass Area takes up 80 percent (199, 088 sq.ft.)
- Year 6 of credit release schedule

Land Conversion Credit Data Entry

1. Enter all the relevant information on the Project Info and Watershed Characteristics pages
    a. In the Pre-development column enter the roof, roadway, pre-existing forest, and managed pervious grass area.
    b. In the Post-Development column enter the roof and roadway area. Enter the footprint of the additional 30′ buffer area (15,000 sq.ft) as Forest by adding it to the pre-existing forest area (10,000 sq.ft). The 30′ buffer footprint comes out of the managed pervious footprint. In this example the 199,088 sq.ft. Pre-Development Managed Pervious Grass would convert to 184,088 sq.ft. of Post-Development Managed Grass and 25,000 sq.ft. of forested (combined pre-existing and restored buffer area) in the post development condition.

<u>Interpreting Results</u>

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

Total Nitrogen Loading (lbs/yr) = 20.96
Total Phosphorus Loading (lbs/yr) = 5.75

For Post-Development Conditions w/BMPs, the values are

Total Nitrogen Loading (lbs/yr) = 20.74
Total Phosphorus Loading (lbs/yr) = 5.66

The user then completes the remaining steps by hand to calculate the credits (reductions in loading) achieved via land conversion. Compute the nutrient reductions in pounds per year:

Nitrogen -> 20.96- - 20.74 = 0.21 lbs/yr
Phosphorus -> 5.75 – 5.66= 0.09 lbs/yr

Note: Discount factors do not apply to land conversion credit.

Data Entry for Treatment of Runoff through Restored Buffer Projects with Pre-Existing Forest

1. Enter all the relevant information on the Project Info and Land Use Characteristics page.
    a. In the Pre-development column enter the roof, roadway and managed pervious area (but do not include the managed pervious area that was converted to buffer).
    b. In this example the 199,088 sq.ft. Pre-Development Managed Pervious Grass was converted to 184,088 sq.ft. of Post-Development Managed Grass and 25,000 sq./ft. of forested (pre-existing + restored buffer area) in the post development condition. So 15,000 sq.ft. of Managed Pervious Area would not be included resulting in a project site area of 236,360 square feet instead of the original 261,360 square feet.
    c. The Following land use areas would be entered into the watershed characteristics tab:
        iv. Roof area = 26,136 sq.ft.
        v. Roadway =26,136 sq.ft.
        vi. Managed Pervious Area takes = 184,088 sq.ft.

<u>Interpreting Results</u>
On the *Overall Summary* page, the *Total Nitrogen* & *Phosphorus Loading* (lbs/yr) should show the following values for Pre-Development Conditions:

Total Nitrogen Loading (lbs/yr) = 20.31
Total Phosphorus Loading (lbs/yr) = 5.59

The user then completes the remaining steps by hand to calculate the credits for throughput treatment by applying the appropriate net percent removal efficiency value. In this case, adding a 30 foot buffer to an existing 20 foot buffer along a stream that is not incised, the net removal efficiency is 10% for both nitrogen and phosphors resulting in the following reductions:

Nitrogen Reduction = 20.63 lbs/yr * 10% = 2.03 lbs/yr
Phosphorus Reductions = 5.59 lbs/yr *10% = 0.56 lbs/yr

Combine Land Conversion Credit and Runoff Treatment Credit
The total reduction credit in this example is the sum of the land conversion credit and runoff treatment credit:

Total Nitrogen Reduction = 0.21 lbs/yr + 2.03 lbs/yr = **2.24 lbs/yr**
Total Phosphorus Reduction = 0.09 lbs/yr + 1.42 = **1.51 lbs/yr**

Table 4 provides examples of the nutrient reduction credit that would be generated using the approach described in Example 1 in residential areas for buffers of various widths on projects sites ranging from 10 percent to 50 percent built upon area (BUA). These reduction credits were calculated assuming a 6 acre project site located in Wake County.

Table 4. Example Nutrient Credits for 500′ of Full Buffer Restoration on a Non-Incised Perennial or Intermittent Channel in a Developed Area

Buffer Width from Top-of-Bank (feet)	Buffer Length (feet)	Built Upon Area	Percent Reduction (from Table 2)	Nitrogen Load Reduction (lbs/Buffer ac/yr)	Percent Phosphorus Reduction (from Table 2)	Phosphorus Load Reduction (lbs/Buffer ac/yr)
20	500	10%	20%	13.7	20%	3.9
30	500	10%	25%	11.0	25%	3.1
50	500	10%	30%	7.9	30%	1.6
100	500	10%	35%	4.6	35%	1.4
200	500	10%	40%	2.62	40%	0.80
20	500	20%	20%	19.0	20%	5.2
30	500	20%	25%	15.8	25%	4.4
50	500	20%	30%	11.3	30%	3.2
100	500	20%	35%	6.6	35%	1.9
200	500	20%	40%	3.7	40%	1.1
20	500	50%	20%	46.3	20%	10.3
30	500	50%	25%	30.0	25%	8.3
50	500	50%	30%	21.5	30%	6.0
100	500	50%	35%	12.6	35%	3.5
200	500	20%	40%	7.4	40%	2.0

Relative Confidence in Reduction Estimates

Overall, relative confidence in the reductions estimated for this practice is low. While there are numerous studies that evaluate the effectiveness of buffers in agricultural settings there is a general lack of studies that specifically evaluate riparian buffer improvement in urban environments. The credit calculation for this practice uses gross percent removal efficiencies as a substitute for specific published data on buffer improvement practices in developed areas.

Co-Benefits

In the case of buffer improvement, additional benefits may include further reducing other pollutants including Total Suspended Solids (TSS), metals, and bacteria; reducing flooding; improving habitat; sequestering carbon; reducing streambank erosion in downstream reaches; and providing stream shading that reduces light available for algal and periphyton growth in streams and reduces stream water temperatures.

Supporting Technical Information

This supporting technical information is provided for the buffer improvement in developed areas nutrient crediting document and includes a description of the studies that were evaluated during the process to establish the credits 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
- North Carolina Department of Environmental Quality Division of Mitigation Services: Katie Merrit and Karen Higgins
- North Carolina State University Biological & Agricultural Engineering Stormwater Engineering Group: 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

Summary of studies

Twenty two publications were used to populate the riparian buffer database for this practice, but eight were excluded for inclusion in this analysis for the following reasons:

- Five of the studies were review papers that summarized and analyzed existing literature on riparian forest buffers (Klapproth and Johnson 2013; Castelle et al. 1994; Mayer et al. 2006; Mayer et al. 2007; Sweeney and Newbold 2014). Although they were excluded from the crediting analysis, they are referenced below where appropriate as they provide insight into the water quality benefits and design specifications for riparian buffers that are useful when considering the development of a credit as described in the Proposed Crediting section below.
- Orzetti et al. (2010) collected samples from within the stream only and not from the surface or subsurface flow across the studied buffers.
- Ice et al. (2004) presented a GIS approach to estimate the extent of alternative riparian area management schemes and the economic consequences.
- NCSU (2013) provided guidance on the rehabilitation and maintenance of riparian vegetation, but did not include information on appropriate buffer widths or nutrient removal.

Fourteen publications were selected for inclusion in the analysis. Many of these studies were conducted in rural/agricultural areas in the coastal plain, as is the case with much of the available literature on riparian buffers. Nine publications included monitoring studies or summarized crediting programs outside of the coastal plain.

Coastal Plain Studies:

- Four of the studies were completed in the coastal plain portion of the Tar Pamlico River Basin in North Carolina (Johnson et al. 2013; Messer et al. 2012; Tilak et al. 2014; Wiseman et al. 2014). One of the studies (Tilak et al. 2014) was used to support a 33 year modeling projection using information from the field sampling study (Messer et al. 2012).
- The other studies were from the Delmarva Peninsula, Maryland (Jordan et al. 1993) and Goldsboro, North Carolina (Wu et al. 2012).
- Due to the location of the studies within the coastal plain, sandy soils and high water tables made infiltration and denitrification a main focus. This limits their direct application to the Piedmont region; however, these processes remain relevant to the function of nitrate removal from forested buffers and are therefore included for review. All of the studies focused on subsurface nitrate removal, with the exception of Tilak et al. (2014) that also included a modeled estimate of surface TN removal.
- Subsurface nitrate removal was reported as a percent reduction in nitrate concentration, with only two studies (Messer et al. 2012; Tilak et al. 2014) also reporting a percent reduction in nitrate load.
- In terms of subsurface nitrate removal, authors found that landscape position is a more important defining variable for buffer site selection than buffer width – removal is higher in areas with greater denitrification potential.
    - Johnson et al. (2013) found that water quality improvement did not occur until groundwater flow passed into an existing hardwood buffer situated within the active floodplain of the stream.
    - Jordan et al. (1993) found that most of the change in nitrate occurs in the riparian buffer where the hillslope ends and the floodplain begins - groundwater comes in contact with tree roots and organic-rich surface soils become water-logged, producing low redox conditions favoring denitrification.
- Even when denitrification conditions are favorable, low incoming groundwater nitrate concentrations may limit the potential for nitrate removal (Messer et al. 2012).
- The addition of organic matter to riparian soil was found to be effective at promoting nitrate loss (Wu et al. 2012).
- Jordan et al. (1993) observed high phosphate concentrations near the streambank. The authors hypothesize that the highly reducing conditions suitable for denitrification near the streambank also favor reduction of iron oxyhydroxides, which can release bound phosphorus and increase the phosphate that is exported from the buffer.
- Wiseman et al. (2014) studied a 150 ft buffer in the NC Coastal Plain. Subsurface nitrate concentrations were measured at three locations in the buffer, and reductions ranged from 76 percent to 92 percent. However, the authors determined that much of the apparent reduction was likely due to dilution as concentrations of a conservative tracer were reduced by 48 percent to 65 percent.

Non-Coastal Plain Publications (Piedmont (Pennsylvania and Chesapeake Bay) and Flint Hills, KS):

- Weller et al. (2011) developed statistical models to predict stream nitrate concentration and evaluate buffer effects from 113 tributaries in the piedmont and 111 tributaries in the coastal plain of the Chesapeake Bay watershed. The models were based on water quality samples taken at the watershed outlets and the results are presented as an average of all watersheds aggregated based on physiographic region. On average, buffers in coastal plain watersheds had a higher relative nitrate removal potential (95% of inputs from cropland) than piedmont buffers (35% of inputs). Buffers in the piedmont had a median width of 34 m (110 ft). Aggregate nitrate removal by riparian buffers was less than suggested by many studies of field-to-stream transects and may be due to transect studies providing an idealized view of buffer removal under optimal conditions. The authors hypothesized that the piedmont buffers were found to remove lower percentages of their inputs than coastal plain buffers due to existing buffers being bypassed or dysfunctional in some piedmont settings.

- In comparison, to Weller et al. (2011), Sweeney and Newbold (2014) found that subsurface nitrate removal varied proportionally with buffer width, and sites with water flux >50 l/m/day had a median removal efficiency of 55% for buffers <40 m (130 ft) wide and 89% for buffers >40 m (130 ft) wide. The observed 35% efficiency reported by Weller et al. (2011) would correspond to a water flux of 215 l/m/day.
- Newbold et al. (2009) found that a 35-m wide 3-zone riparian forest buffer system (USDA Forest Service specification that consists of a 5 m wide permanent woody vegetation for habitat protection, 18-20 m of reforested hardwoods, and a 6-10 m grass filter strip with a level spreader) removed 26% of the subsurface nitrate and 43% of the suspended sediments delivered from upslope. The influence of tree growth on nitrate removal became apparent approximately ten years after planting. The grass filter strip functioned effectively to remove sediment. Low subsurface nitrate removal was hypothesized to be a function of averaging the removal that occurred prior to the influence of reforestation (i.e., mostly grass buffer) together with the higher rate once reforestation occurred. It could also be due to flow that was preferentially constrained to the shallow saprolite with significant flow through the underlying bedrock.
- Properly designed and maintained buffers with widths less than those typically recommended (NRCS guidelines in KS require a minimum average buffer width of 23 m to a maximum of 46 m) may be adequate for water-quality improvement. Mankin et al. (2007) found that vegetation type, rather than width, was the fixed effect that was shown to influence mass removal of TP and TN. Grass-shrub riparian buffer plots (natural selection grasses, natural selection/plum shrub, and native grasses/plum shrub) were evaluated and all were found to provide excellent mass reductions of outflow runoff (>77%), sediment (>99%), TP (>85%), and TN (>85%). Infiltration was found to be the primary mechanism for pollutant removal.
- Belt et al. (2014) summarize the recommendations of the expert panel on the removal rates for riparian forest buffers. Buffers that are at least 35 feet in width are eligible for crediting, but the expert panel indicates that buffers that are 50 feet to 100 feet in width offer more consistent water quality benefits. In the Piedmont, forested buffers that are at least 35 feet wide earn TN credits of 46 percent and 56 percent for schist/gneiss and sandstone soils, respectively; TP credits for these soils range from 36 percent to 42 percent.
- Halley (2002) summarizes buffer literature as part of his thesis on Watershed Management and Riparian Buffer Analyses Using Remotely Sensed Data. His literature review indicates that width strongly affects TSS and nitrogen removal, and that buffers that the first 60 feet of a buffer may remove 70 to 90 percent of subsurface total nitrogen loads.

- Gregory (2008) presented information during a 2008 presentation that included a table of buffer widths and reported reductions in runoff concentrations of sediment, nitrogen, and phosphorus. Wider buffers consistently reduced runoff concentrations compared to narrow buffers over the range of data summarized (15 ft to 92.5 ft) and noted that the maximum removal of dissolved nutrients occurred subsurface.
- Mayer et al. (2007) summarized the buffer literature to assess the effect of width on nitrogen removal rates. Studies included vegetated filter strips and riparian buffers. The authors concluded that wider buffers showed more consistent nitrogen reductions than more narrow buffers. The summary suggests that 13 ft buffers may achieve 50 percent nitrogen removal, 160 ft buffers achieve 75 percent nitrogen removal, and 490 ft buffers achieve 90 percent nitrogen removal. The authors note the large variability associated with these predictive efficiencies attributed to additional factors other than width also affect nitrogen removal including soil type, subsurface hydrology, and subsurface biogeochemistry; vegetation type was not found to significantly affect nitrogen reductions.

Review of NC Existing Crediting Systems for Riparian Buffers

North Carolina has several existing programs that apply to buffer improvement whether that is a single approved design for stormwater credits, nutrient offset and mitigation, or agriculture accounting. These existing programs are described below.

NCBMP Design Manual

The NCBMP design manual currently offers load reduction credits for TSS of 60%, TN of 30%, and TP of 35% for riparian buffers that have a minimum width of at least 50 ft (30 ft forested buffer + 20 ft grass). Width still appears to be the most practical metric for assigning a riparian buffer credit as it remains to be supported in the scientific literature as the main proxy for pollutant removal, with the exception of nitrate which is also affected by denitrification. Buffer width is important for trapping particulates and filtering nutrients that are particulate-bound and for infiltrating and storing water in the soils.

Nutrient Offset and Riparian Buffer Mitigation Program

The NC Division of Water Resources (DWR) nutrient offset and riparian buffer mitigation program provides for the use of nutrient offset payments in the Neuse and Tar Pamlico basins, along with the Falls and Jordan watersheds as an option to meet nutrient reduction requirements for new development and redevelopment. The predominant practice used by those seeking to generate nutrient reduction credits for sale is the establishment of riparian forested buffers where none exists due to their cost effectiveness. The credit calculation for riparian buffers is currently based on a formula developed in 1997 by the Division of Water Quality that assumed the restoration of riparian wetland area to calculate nutrient reductions based on three elements: 1) nutrient reductions from upslope drainage (limited to 10.8 acres of upslope area for every 1 acre of buffer restored), 2) deposition of nitrogen from overbank flooding, and 3) land use change to forest. Buffers that are at least 50 feet wide and adjacent to agricultural lands are eligible for these credits: 75.77 lb-N/ac/yr and 4.88 lb-P/ac/yr.

Agricultural Accounting

Agricultural areas in nutrient strategy watersheds shallshall track and report estimated nutrient losses from farms annually. To do this agricultural technicians utilize the Nutrient Loss Evaluation Worksheet (NLEW), an accounting tool used to estimate nitrogen loss from agriculture lands. This tool was developed by a team of researchers and policy makers (Osmond et al., 2007). NLEW uses nutrient inputs, soils, cropping data and management practice information to estimate nutrient losses from farms. Best management practices, such as the implementation of forest buffers, are assigned nitrogen reduction efficiencies and can be implemented and tracked with NLEW to account for reductions in nutrient losses from agricultural lands.

NLEW reduction efficiencies for forest buffers are set by the NLEW committee. Current buffer efficiencies are provided in Table 5. These efficiencies were established after a review of net nitrogen removal rates by the committee upon review of a number of North Carolina research (Osmond et al., 2011). These efficiencies represent a reduction of 10 to 20% over the prior version of NLEW and are based on buffer gross reduction efficiencies. In its reduction accounting, NLEW applies these reductions to a composite agriculture loading based on the county data at a ratio of 1:1 (i.e., one acre of buffer reduces the nitrogen load from 1 acre of land). NLEW does not estimate reductions to Phosphorus.

Table 5. NLEW Net N Reduction Efficiencies

Buffer Width (ft)	NLEW v5.53b % N Reduction
20	20%
30	25%
50	30%
100	35%

References

Belt, K., Groffman, P., Newbold, D., Hession, C., Noe, G., Okay, J., Southerland, M., Speiran, G., Staver, K., Hairston-Strang, A., Weller, D., and Wise, D. (2014). Recommendations of the expert panel to reassess removal rates for riparian forest and grass buffers best management practices. Chesapeake Bay Program.

Castelle, A., Johnson, A., and Conolly, C. (1994). Wetland and stream buffer size requirements - a review. Journal of Environmental Quality, 23, 878-882.

Clausen, J.C., K. Guillard, C.M. Sigmund and K.M. Dors. 2000. Water quality changes from riparian buffer restoration in Connecticut. Journal of Environmental Quality. 29:1751-1761.

Gregory, J.D. 2008. Riparian Zones Definition and Functions. February 2008.

Halley, J. (2002). Watershed management and riparian buffer analyses using remotely sensed data. A thesis submitted to the graduate faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C. EPA 843-K-12-006.

Ice, G., Skaugset, A., and Simmons, A. (2004). Calculating the area and cost of riparian management zones. Proceedings of the American Water Resources Association Summer Specialty Conference: riparian ecosystems and buffers: multi-scale structure, function and management: Olympic Valley, CA. June 28-30th 2004. American Water Resources Association technical publications series; TPS-04-2.

Jacobs, T.C. and J. W. Gilliam. 1983. Nitrate loss from agricultural drainage waters: implications for nonpoint source pollution control. Water Resources Research Institute University of North Carolina. Report No. 209. Raleigh, NC.

Johnson, S., Burchell, M., Evans, R., Osmond, D., and Gilliam, J. (2013). Riparian buffer located in an upland landscape position does not enhance nitrate-nitrogen removal. Ecological Engineering, 52, 252-261.

Jordan, T., Correll, D., and Weller, D. (1993). Nutrient interception by a riparian forest receiving inputs from adjacent cropland. Journal of Environmental Quality, 22(3), 467-473.

King, S.E., D.L. Osmond, J.W. Gilliam, and R.O Evans. 2006. Riparian Buffer Effectiveness in Removing Groundwater Nitrate as Influenced by Vegetative Type (paper under review).

Klapproth, J., and Johnson, J. (2009). Understanding the science behind riparian forest buffers: effects on water quality. Virginia Cooperative Extension, Virginia Tech.

Lowrance, R. 1992. Groundwater nitrate and denitrification in a Coastal Plain riparian forest. Journal of Environmental Quality. 21:401-405.

Lowrance, R., G. Vellidis, and R.K. Hubbard. 1995. Denitrification in a Restored Riparian Forest Wetland. Journal of Environmental Quality. 24:808-815.

Lowrance, R., and 12 others. (1997). Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. Environmental Management 21(5):687-712.

Mankin, K., Ngandu, D., Barden, C., Hutchinson, S., and Geyer, W. (2007). Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff. Journal of the American Water Resources Association, 43(5), 1108-1116.

Mayer, P., Reynolds, S., Canfield, T., and McCutchen, M. (2006). Riparian buffer width, vegetated cover, and nitrogen removal effectiveness: a review of current science and regulations. U.S. Environmental Protection Agency, EPA/600/R-05/118.

Mayer, P., Reynolds, S., McCutchen, M., and Canfield, T. (2007). Meta-analysis of nitrogen removal in riparian buffers. Journal of Environmental Quality, 36, 1172-1180.

Messer, T., Burchell, M., Grabow, G., and Osmond, D. (2012). Groundwater nitrate reductions within upstream and downstream sections of a riparian buffer. Ecological Engineering, 47, 297-307.

Newbold, D., Herbert, S., Sweeney, B., and Kiry, P. (2009). Water quality functions of a 15-year-old riparian forest buffer system. NWQEP Notes, the NCSU Water Quality Group Newsletter. NC State University, A&T State University Cooperative Extension.

North Carolina State University (NCSU). (2013). A guide for the installation, establishment, and maintenance of riparian vegetation in restoration projects in North Carolina. NC State University, A&T State University Cooperative Extension.

Orzetti, L., Jones, R., and Murphy, R. (2010). Stream condition in piedmont streams with restored riparian buffers in the Chesapeake Bay watershed. Journal of the American Water Resources Association, 46(3), 473-485.

Smith, T.A., D.L. Osmond, and J. W. Gilliam. 2006. Riparian Buffer Width and Nitrate Removal in a Lagoon-Effluent Irrigated Agricultural Area. J. Soil and Water Conser. 31:273-281.

Sweeney, B., and Newbold, D. (2014). Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. Journal of the American Water Resources Association, 50(3), 560-584.

Tilak, A., Burchell, M., Youssef, M., Lowrance, R., and Williams, R. (2014). Field testing the riparian ecosystem management model on a riparian buffer in the North Carolina coastal plain. Journal of the American Water Resources Association, 50(3), 665-682.

Wafer, C.C. 2004. Effect of Shrub Buffers, Tillage and Cropping Systems on Shallow Groundwater Nitrate-N in Eastern North Carolina. MS Thesis, NC State University, Raleigh, NC.

Weller, D., Baker, M., and Jordan, T. (2011). Effect of riparian buffers on nitrate concentrations in watershed discharges: new models and management implications. Ecological Applications, 21(5), 1679-1695.

Wenger, S. (1999). A review of the scientific literature on the riparian buffer width, extent and vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia.

Wiseman, J. Burchell, M., Grabow, G., Osmond, D., and Messer, T. (2014). Groundwater nitrate concentration reductions in a riparian buffer enrolled in the NC Conservation Reserve Enhancement Program. Journal of the American Water Resources Association, 50(3), 653-664.

Wu, L., Osmond, D., Graves, A., Burchell, M., and Duckworth, O. (2012). Relationships between Nitrogen transformation rates and gene abundance in a riparian buffer soil. Environmental Management, 50(5), 861-875.