WATER CONSERVATION TECHNICAL BRIEFS

TB11 – Use of conservation riparian buffer to preserve water quality

SAI Platform

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WATER CONSERVATION

TECHNICAL BRIEFS

TB11 - Use of conservation riparian buffer to preserve water quality

Conservation riparian buffers can have a positive impact on agriculture by reducing erosion, improving water quality, increasing biodiversity, and expanding wildlife habitats. Buffers remove sediment from surface runoff and reduce concentrations of nutrients and pesticides. Research demonstrates that buffers can be effective in promoting environmental quality in and beyond agricultural landscapes. This technical brief attempts to give an overview of the benefits of conservation riparian buffers as a way of preserving water quality. Following an overview of the benefits, this brief discusses how to design and maintain a buffer.

The structure of the technical brief is as follows: Sections 1 and 2 describe the conservation of riparian buffers and different types. Section 3 sets out the benefits of the application of buffers at a farm level. Section 4 presents an overview of how water quality is preserved by buffers. Section 5 highlights the obstacles to buffer implementation at farm level. Section 6 explores the steps on how to design a buffer by defining the benefit, the width, the vegetation, diversity and creating an implementation and maintenance plan. Section 7 outlines case studies of buffer implementation in Europe, New Zealand, Japan and China. Finally, Section 8 recommends some further reading.

Contents

SECTION 1: WHAT ARE CONSERVATION BUFFER STRIPS?

A conservation riparian buffer is any piece of land along a water course where there are farming restrictions, that intends to protect the water course. Some of the restrictions can include one of more of the following:

- no use of fertiliser
- no plant protection products applied
- no cultivation
- no livestock grazing allowed
- no farming allowed
- particular plants or types of plant must be grown/allowed to grow

SECTION 2: TYPES OF BUFFERS

Riparian Buffer Strip: A linear band of permanent vegetation adjacent to an aquatic ecosystem intended to maintain or improve water quality by trapping and removing various nonpoint source pollutants from both overland and shallow subsurface flow. Buffer strips occur in a variety of forms, including herbaceous or grassy buffers, grassed waterways, or forested riparian buffer strips. A buffer strip may also provide habitat for a variety of plants and animals.

Buffer strips may function as movement corridors if they provide suitable connections between larger blocks of habitat (see below).

Figure 1: Types of buffers

Riparian Corridor[1] is a strip of vegetation that connects two or more larger patches of vegetation. These landscape features are often referred to as “conservation corridors,” “wildlife corridors,” and “dispersal corridors.” Some scientists have suggested that corridors are a critical tool for reconnecting fragmented habitat “islands.”

Contour buffer strips[2]: strips of vegetation alternated with wider cultivated strips that are farmed on the contour. Buffers are most effective in trapping pesticides when runoff enters uniformly as sheet flow. Contour buffer strips are one of the most effective buffers to trap pesticides. There is less chance for concentrated flow and smaller areas of cultivated field deliver runoff directly to each strip within a relatively short distance compared to some edge-of-field buffers.[a]

Filter strips: areas of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants in runoff and to maintain and/or improve water quality. Filter strips are located between crop fields and water bodies. More pesticides can be removed by encouraging as much flow as possible across the strip and minimising concentrated flow.

SECTION 3: WHAT ARE THE BENEFITS OF CONSERVATION BUFFERS?

Buffers have been used for many years to reduce soil erosion. Soil erosion is a problem because it reduces the depth of fertile topsoil, creates unwanted gullies[b] in the land, and causes sedimentation of streams. As well as reducing pesticides, P, N and suspended solids run-off, buffer strips restore semi-natural habitats with consequent beneficial effects on biodiversity.[3]

Figure 2: Buffer protects water from pollution

Conservation buffers provide a number of benefits. Evidence suggests conservation buffers can be useful for:

- Protecting water from pollution (e.g. fertilisers)
- Improving waterways
- Providing a refuge for wildlife (biodiversity)

[a] See Technical Brief on Integrated Pest Management for more information.
[b] Channel cut by running water

- Enhancing existing biodiversity features by protecting them from spray (e.g. riparian plants)
- Providing a connected network of natural areas (for biodiversity, and climate change adaptation)
- Landscape enhancement e.g. unfarmed areas along water courses
- Reducing topsoil loss
- Improving the ecological health of agro ecosystems
- Reducing sedimentation
- Filtering polluted air, especially from the local sources (e.g., big farm complexes, agro-chemically treated fields)[4]
- Lessening the intensive growth of aquatic macrophytes[c] via shading by canopies
- Improving the microclimate in adjacent fields
- Creating more connectivity in landscapes due to migration corridors and stepping stones
- Filtering chemicals out of runoff before it enters streams or rivers

[c] microalgae are microscopic algae, typically found in freshwater and marine systems

SECTION 4: HOW BUFFERS PROTECT FROM WATER POLLUTION?

Conservation buffers are important for protecting water quality. Riparian zones help to prevent sediment, nitrogen, phosphorus, pesticides and other pollutants from reaching a stream. Many studies have demonstrated the effectiveness of buffers in reducing the concentration of nitrates, phosphorous, and a host of pesticide compounds from water running off cultivated fields.

The root systems of trees, shrubs and plants stabilise the soil, preventing sediments and pollutants from entering the water body. Twigs and leaves from trees slow and trap sediments in storm water runoff, allowing the nutrients they carry to infiltrate into the ground where they may be stored or removed through natural processes. Nutrients are stored in leaves, limbs and roots instead of polluting the waterway.[5]

- **Nitrogen**: Nitrogen, a harmful pollutant in many water sources[d], is trapped and assimilated by the plants located in buffers. According with literature from US, the concentration of nitrate (N) can be reduced from between 40 and 94%[e] in a buffer or wetland before entering a stream.
  Results from a study in US shows changes in the concentration of nitrates in groundwater. Evidence suggests that vegetated riparian buffers may yield water quality benefits in groundwater within a few years.[6] See figure 3.

- **Phosphorus**: Phosphorus runoff is reduced in vegetated buffer strips, but removal rates vary greatly[f] (depending on the percentage of soil-bound versus soluble phosphorus,

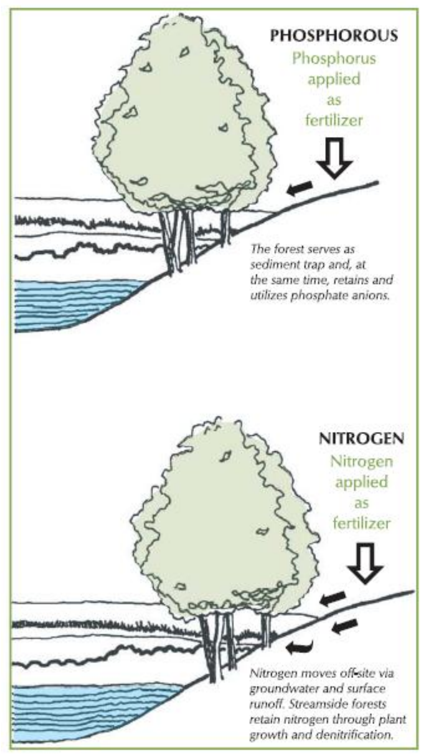

Figure 3: Buffers trap phosphorous and nitrogen. See http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf

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[d] See Technical Brief on Water Pollution for more detail on pollutants

[e] These rates depend on a series of characteristics described further down on the technical brief.

[f] Phosphorus can vary from 25 to 95% according with experience in the US

length of buffer strip, plant cover, and hydrologic condition).

Buffers can also become saturated, which reduces their effectiveness in removing phosphorus[g]: It has been suggested that after a long period of time the soils in the buffer strip may become saturated with P and no longer retain it effectively but, at the moment, this appears to be a prediction based on the behaviour of some soils rather than an observed phenomenon.[7]

- **Pesticides**: Buffers can be effective in removing pesticides tightly bound to the soil, but effectiveness is variable. The ability of buffers to retain pesticides is variable because each pesticide has unique mobility and soil binding properties. Indications are that grass buffers may reduce herbicide losses by more than 50%.[8]
- **Sediments**: Slowing floodwaters allows the riparian zone to function as a site of sediment deposition, trapping sediments that build stream banks and would otherwise degrade water courses. Extensive root systems of perennial plants hold soil in place, allow greater infiltration of water, and trap the sediment entering from cultivated areas. Windbreaks containing woody plants also help minimise soil loss from fields by reducing wind current. When properly maintained, buffers can remove up to 97% of soil sediment before it enters a stream.

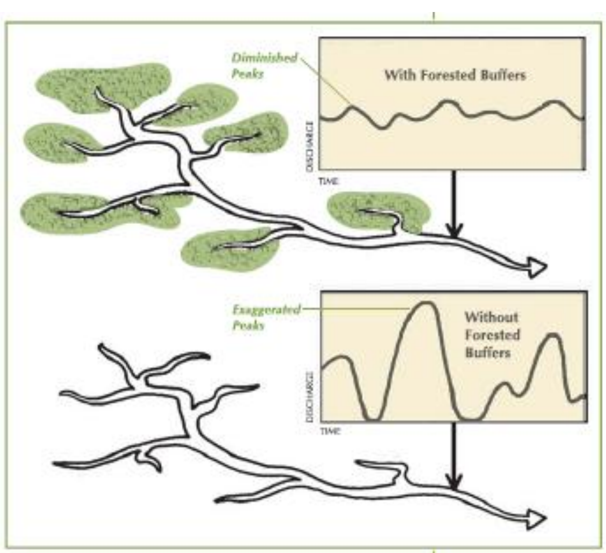


Figure 4: Riparian buffers slow runoff, increases infiltration and reduce floods peaks. Source: el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf

[g] De-nitrification does not occur if the soils become aerobic

- **Groundwater recharge**: By slowing down floodwaters and rainwater runoff, the riparian vegetation allows water to soak into the ground and recharge groundwater.

- **Biodiversity**: Buffers also provide indirect environmental benefits such as increasing the biodiversity of flora and fauna and providing habitats for wildlife. Vegetation in riparian areas can help regulate light and temperatures, allowing wildlife access to food and water and creating a wide variety of habitats—all contributing to ecological diversity. Riparian buffers, particularly those containing trees, can also contribute to the health of aquatic species by cooling stream waters, providing food and habitat, and increasing the dissolved oxygen in water.

- **Flooding**: Buffers can reduce the severity of flooding by slowing water flow, increasing infiltration of water into soils, and in the case of wetlands, providing a holding area for flood water. See figure 4 above.

Section 5: What are the obstacles to the implementation of conservation buffers?

There are a variety of social and economic factors that can curb the adoption of riparian buffers. These include: a lack of buffer incentives programmes, poorly defined goals, lack of maintenance, and private ownership of land.[9]

Some of the obstacles to optimise buffer effectiveness and adoption can be related to:

- the structure and function of government incentive programmes
- Poorly defined goals. For example, In the US incentive programmes place greater emphasis on the development of new buffer areas rather than preserving existing natural riparian buffers or wetlands that often provide greater environmental benefits and plant diversity
- lack of information regarding buffer management

SECTION 6: HOW DO YOU DESIGN A RIPARIAN BUFFER?

Unfortunately, there is no "one-size-fits-all" description of an ideal riparian buffer strip. Most of the focus on buffer design is the required width, but the vegetation assemblage, layout, and length are also key design parameters. The following diagram shows a 5 step process to achieving an adequate design level for a riparian buffer. In Step 1 the primary objectives of a buffer strip should be determined. Step 2 and 3 present the selection of the vegetation and diversity, Step 4 determines the buffer width and Step 5 set up a maintenance and installation plan.

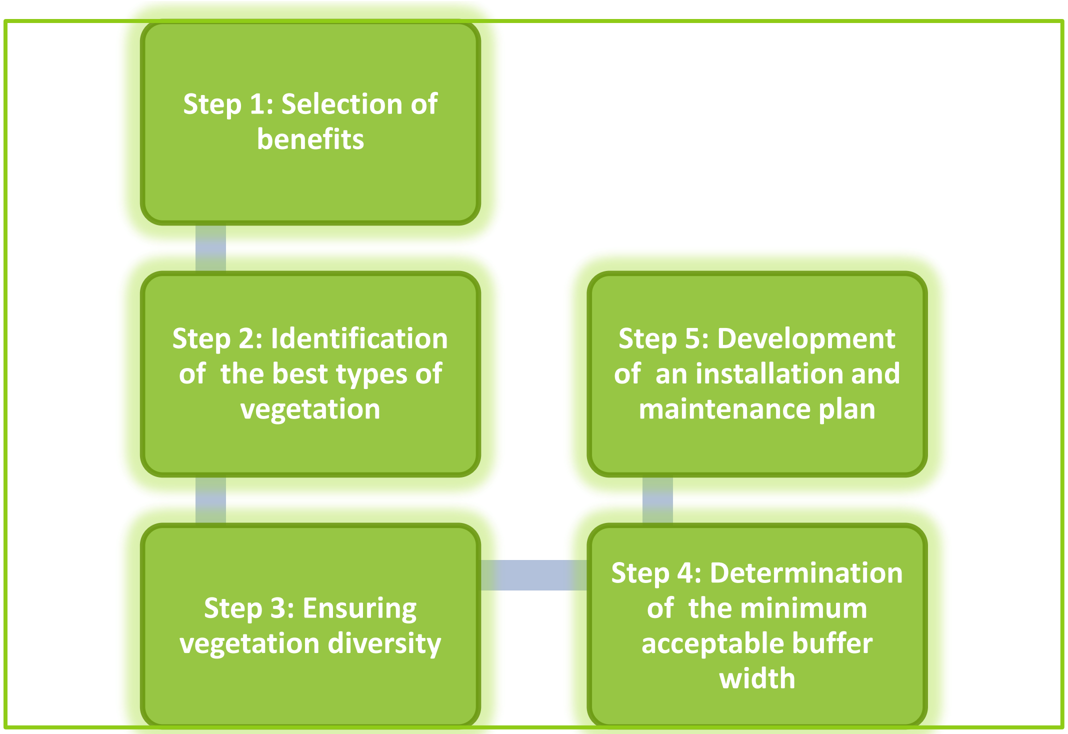


Figure 5: Framework to design a buffer strip

Step 1: Selection of benefits

Riparian buffers can have a multitude of benefits as described in section 3. These might include protection of water quality, stabilization of bank erosion, avoiding algae blooms or excessively turbid water, enhancing biodiversity, improving visual diversity, ensuring flood protection, downstream flood attenuation, or provision of wildlife habitat or movement corridors. In general, the ability of buffer strips to meet specific objectives is a function of their position within the watershed, the composition and density of vegetation species present, buffer width and length, and slope. Some benefits can be obtained for buffers as narrow as a few metres while others require wider widths.

Step 2: Identification of the best types of vegetation for providing the required benefits

Different types of vegetation can provide certain benefits better than others. Riparian buffers can be most effective at improving water quality when they include a native grass or herbaceous filter strip along with deep rooted trees and shrubs along the stream.

Plantings trees can improve stream habitat by providing shade, woody debris, leaf litter, and tree roots that can stabilise stream banks. Shade can reduce nuisance in-stream plant growth and reduce water temperatures, which are typically too high for a number of sensitive aquatic species in pasture streams, and may contribute to declines in aquatic biodiversity in developed catchments. Planting native trees also enhances landscape values and terrestrial biodiversity.[10]

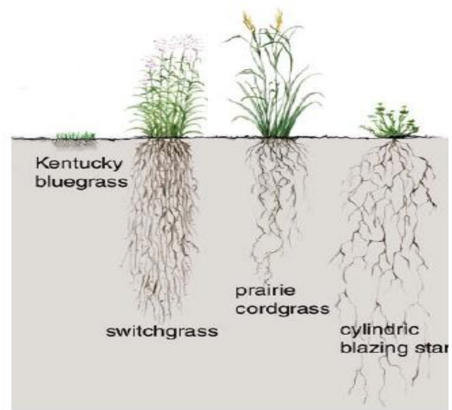
Generally speaking, vegetation used for buffer projects should consist of a mix of trees, shrubs, and herbaceous plants that are native to the region and well-adapted to the climactic, soil, and hydrologic conditions of the farm. The relative effectiveness of different vegetation types at meeting specific objectives within a buffer strip are listed in the table below.

Table 1: Relative efficiency of different vegetations types to provide specific benefits. Modified from USDA, 1997[11]

	Vegetation Type		
Benefit	Grass	Shrub	Tree
Stabilise bank erosion	low	high	high
Filter sediment	high	low	low
Filter nutrients, pesticides, microbes (sediment-bound)	**high**	**low**	**low**
Filter nutrients, pesticides, microbes (soluble)	medium	low	medium
Aquatic habitat	low	medium	high
Enhance wildlife (pastures)	high	medium	low
Enhance wildlife (forest)	low	medium	high

Economic products	medium	low	medium
Visual diversity	low	medium	high
Flood protection	low	medium	high

It is recommended to consult a local flora specialist to select species most likely to meet project objectives, as well as ensuring that plants are placed in the proper zone in the floodplain (e.g., those that thrive with frequent inundation at the edge of the stream versus those less tolerant of flooding further from the stream). For example, in Minnesota native species such as switchgrass, prairie cordgrass and cylindrical blazing star were applied on riparian buffers. This native grasses which have long roots were used to filter pesticides, to encourage infiltration, minimise erosion, and stabilise stream banks.[12] See figure on the right.



Step 3: Ensuring vegetation diversity

It is recommended to grow diverse vegetation ensuring sufficient environmental tolerances to fluctuations in various conditions over time, such as water level, temperature fluctuations, and predators.

Vegetation diversity in a buffer area can be increased in a number of ways by:

- Planting an array of different species in different amounts.
- Planting a variety of growth forms such as herbaceous ground cover, shrubs, saplings and tree species.
- Planting species with a variety of life histories (e.g., annuals, short-lived or long-lived perennials).
- Providing a range of site conditions (e.g., through elevation changes and the creation of habitats with varying aspects/orientations) to support a diverse range of plant species.

The availability of plants of the appropriate species, size, and quality can be a limiting factor in the final selection and plant acquisition process. Thus plans for acquiring plants must be made in advance of the project implementation (sometimes 1 to 2 years). Some native plant species are very difficult to propagate and many desirable species are not commonly available through commercial suppliers. As a general rule, it is advisable to specify as many species as possible and require the use of some minimum number of these species.

Step 4: Determine the minimum acceptable buffer width

There is no definitive width for these buffers, although there is little evidence that strips less than 5 m width have any effect.[13] In general terms the minimum acceptable width is determined by the specific location and the benefit needed that requires the greatest width. The minimum acceptable width is one that provides acceptable levels of all required benefits.

Literature recommends different widths ranging from 5 to 60 metres depending on the benefits required. The following table depicts some recommended widths for buffer areas.

Protection of water quality is often the most common consideration during buffer strip design recommendations. Although many buffer strip width recommendations tend to be arbitrary or based on anecdotal information, there is a range of scientific literature with recommendations for maintaining or improving water quality in a variety of different settings (e.g., various soil types and different slopes) (See Table below).

Table 2. Recommended width for buffer areas. Modified from http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf

Author	Width	Type of buffer	Benefit
Madison et al. (1992)	≥5m	Grass filter strip	Trapped approximately 90% of nitrates and phosphates
Dillaha et al. (1989)	≥7m	Vegetated buffer strip	Removed an average of 84% of suspended solids, 79% of phosphorus, and 73% of nitrogen
Lowrance et al. (1992)	≥7m		Nitrate concentrations almost completely reduced due to microbial de-nitrification and plant uptake
Ghaffarzadeh, Robinson, and Cruse (1992)	>9m	Grass filter strip	Removed 85% of sediment on 7% and 12% slopes

Woodard and Rock (1995)	>15m	Hardwood buffer	The effectiveness of natural buffer strips is highly variable, but in most cases, a 15m natural, undisturbed buffer was effective in reducing phosphorus concentrations adjacent to single family homes
Nichols et al. (1998)	≥18m	Grass filter strip	Reduced estradiol (estrogen hormone responsible for development of the female reproductive tract) concentrations in runoff into surface water by 98%.
Shisler, Jordan, and Wargo (1987)	≥19m	forested riparian buffers	Removed as much as 80% of excess phosphorus and 89% of excess nitrogen
Young et al. (1980)	>25m	Vegetated buffer	25m buffer reduced the suspended sediment in feedlot runoff was reduced by 92%
Lynch, Corbett, and Mussalem (1985)	>30m		30-m buffer between logging activity and wetlands and streams removed an average of 75 to 80% of suspended sediment in storm water; reduced nutrients to acceptable levels; and maintained water temperatures within 1BC of their former mean temperature.
Horner and Mar (1982)	>61m	Grass filter and vegetated buffer strip	Removed 80% of suspended sediment in storm water

Source: Modified from http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf

Appropriate design for species conservation depends on several factors, including type of stream and taxon of concern. In general terms, recommended widths for ecological concerns in buffer strips typically are much wider than those recommended for water quality concerns.[h]

Step 5: Development of an installation and maintenance plan

Once vegetation types and width are determined, an installation and maintenance plan is necessary to successfully establish the buffer and achieve the potential long-term benefits. A few general considerations are listed below.

[h] To see recommended width for enhancing biodiversity, please see http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf.

Installation:

• Use local knowledge to select the best plant species for each situation. Emphasise easily obtainable species yielding quick establishment and good growth on the site.

• Incorporate existing perennial vegetation into the buffer design, if possible, since some benefits, such as shade and bank stabilization from trees, are maximised only after vegetation matures. Using existing vegetation also reduces installation costs and risk of total planting failure.

• The site may require tillage or herbicide application prior to planting.

• Bare soil in areas where trees and shrubs are to be planted may also need to be planted with less-competitive grasses and forbs to hold soil in place and discourage weeds until trees and shrubs become established.

- The location of filter strips is critical to ensuring that during heavy runoff or erosion, a flushing effect through the filter area does not exacerbate potential pollution. Buffer strips are most effective when they combine conservation practices, such as conservation tillage techniques and measures to enhance soil organic matter. They are effective when flow is kept slow and shallow.[14]

- All buffers can provide some protection of water bodies if they are sited between pesticide-treated fields and water. Physical separation of spraying operations and water reduces the chances for direct application to water where spray booms overhang water when turning at field ends. It can also reduce spray drift into water. However, to trap the pesticides in runoff and drift, buffers must be sited so that water runs over, or wind passes through, the buffer area.15

Maintenance:

Grass buffer strips should be inspected periodically so that eroded areas are identified, repaired, and reseeded.

- Weed control by mowing and prescribed burning may be needed in the buffer until native vegetation is well established.

- Fertilisers, pesticides, or animal wastes should not be applied to the buffers.

- Ensuring that the strip does not become compacted and that there are no breaks, gateways, tracks or "grips" (temporary channels) through the strip is necessary as these will channel water and undo the benefits.[16]

Section 6: Case Study

Case study A: Buffer applications around the world

In the European Union, NItrogen COntrol by LAndscape Structures in agricultural environments (NICOLAS), was founded in 1998 with the goal of evaluating the natural performance of riparian zones to buffer agricultural nitrogen pollution of aquatic environments in France, England, Switzerland, Romania, Spain, Poland and the Netherlands. A key conclusion of the project was that riparian buffer zones are important measures for protecting water quality from diffuse pollution in agricultural environments and for preventing eutrophication of aquatic ecosystems.[17]

These findings have been replicated in New Zealand where nine riparian buffer zone schemes were compared to unbuffered control reaches. The results demonstrated that streams within buffer zones showed rapid improvements in visual water clarity and channel stability.

Similar studies have also been carried out in Japan, Estonia, and Australia. Thus, the concern over re-developing riparian buffers is an issue not only in the Mid-west US, but also in many places across the world.

In North China many natural or artificial buffer/detention sink landscapes (field edges, road borders, abandoned fishponds, depressions, etc.) have been created as a result of human alterations and natural events. Results shows that buffer structures - stone dams, a vegetated filter strip, dry ponds and a riparian buffer zone- compose a sink structure system for the control of the transport process of sediment and N pollutants. Significant amounts of sediment and N can be retained from surface runoff as a result of the purification by this system. Vegetated filter strip and riparian buffer zones are very effective for dissolved N forms. The system constituted by buffer structures has a good capacity for the reduction of sediment and the flow of both forms of N. These landscape buffer structures decrease the kinetic energy of runoff and, as the result of the prolonged detention time, provide good conditions for the retention and transformation of sediment and N.[18]

Section 7: References and further reading

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http://www.in.nrcs.usda.gov/technical/agronomy/newconbuf.pdf
An extensive review of buffers and their potential for reducing pesticide contamination. United States Department of Agriculture, Natural Resources Conservation Service, 2000

Vegetation Buffer Strips in Agricultural Areas- 2007
http://files.dnr.state.mn.us/publications/waters/buffer_strips.pdf

USDA Forest Service - National Agro forestry Centre
How to Design a Riparian Buffer for Agricultural Land
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1002&context=agroforestnotes

National Conservation Practice Standards – NHCP
http://www.nrcs.usda.gov/technical/standards/nhcp.html
The conservation practice standard contains information on why and where the practice is applied, and sets forth the minimum quality criteria that must be met during the application of that practice in order for it to achieve its intended purpose(s).

Design Recommendations for Riparian Corridors and Vegetated Buffer Strips
http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf
Montgomery County, Pennsylvania

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