BMP 6.7.1: Riparian Buffer Restoration

A riparian buffer is a permanent area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands. Riparian forests are the most beneficial type of buffer for they provide ecological and water quality benefits. Restoration of this ecologically sensitive habitat is a responsive action to past activities that may have eliminated any vegetation.

Key Design Elements

- Reestablish buffer areas along perennial, intermittent, and ephemeral streams
- Plant native, diverse tree and shrub vegetation
- Buffer width is dependant on project preferred function (water quality, habitat creation, etc.)
- Minimum recommended buffer width is 35' from top of stream bank, with 100' preferred.
- Create a short-term maintenance and long-term maintenance plan
- Mature forest as a vegetative target
- Clear, well-marked boundary

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Low/Med.
Water Quality: Med./High

Water Quality Functions

TSS: 65%
TP: 50%
NO3: 50%

Description

The USDA Forest Service estimates that over one-third of the rivers and streams in Pennsylvania have had their riparian areas degraded or altered. This fact is sobering when one considers the important stormwater functions that riparian buffers provide. The non-structural BMP, Riparian Forest Buffer Protection, addresses the importance of protecting the three-zone system of existing riparian buffers.

The values of riparian buffers – economic, environmental, recreational, aesthetic, etc. – are well documented in scientific literature and numerous reports and thus will not be restated here in this BMP sheet. Rather, this BMP serves to provide a starting point for the designer that seeks to restore the riparian buffer. Important reports are cited consistently throughout this section and should be mentioned upfront as sources for additional information to a designer seeking to restore a riparian buffer. The first, the *Chesapeake Bay Riparian Handbook: a Guide for Establishing and Maintaining Riparian Forest Buffers* was prepared by the US Department of Agriculture (USDA) Forest Service for the Chesapeake Bay Program in 1997. The second, the *Pennsylvania Stream ReLeaf Forest Buffer Toolkit* was developed by the Alliance for the Chesapeake Bay specifically for the Pennsylvania streams in 1998. A third and often-referenced report, is the *Riparian Forest Buffers* series written by Robert Tjaden for the Maryland Cooperative Extension Service in 1998.

Riparian buffers are scientifically proven to provide a number of economic and environmental values. Buffers are characterized by high species density, high species diversity, and high bio-productivity as a transition between aquatic and upland environments. Project designers should take into account the benefits or services provided by the buffer and apply these to their project goals. Priorities for riparian buffer use should be established early on in the planning stages. Some important considerations when establishing priorities are:

- **Habitat** – Restoring a buffer for habitat enhancement will require a different restoration strategy than for restoring a buffer for increased water quality.
- **Stream Size** – A majority of Pennsylvania's stream miles is comprised of small streams (first, second, and third order), which may be priority areas to reduce nutrients. Establishing riparian buffers along these headwater streams will reduce the high nutrient loads relative to flow volumes typical of small streams.
- **Continuous Buffers** - Establishing continuous riparian forest buffers in the landscape should be given a higher priority than establishing larger but fragmented buffers. Continuous buffers provide better stream shading and water quality protection, as well as corridors for the movement of wildlife.
- **Degree of Degradation** – Urban streams are usually buried or piped. Streams in areas without forests, such as pastures, may benefit the most from buffer restoration, as sources of headwater streams. Highly urbanized/altered streams may not be able to provide high levels of pollution control.
- **Loading Rates** - The removal of pollutants may be highest where nutrient and sediment loading are the highest.
- **Land Use** – Adjacent land uses will influence Buffer Width and Vegetation types used to establish a riparian buffer. While the three-zone riparian-forested buffers described earlier are the ideal, they may not always be feasible to establish, especially in urban situations.

Preparation of a *Riparian Buffer Restoration Plan* is critical to ensuring long-term success of the project and should be completed before any planting is to occur. It is essential that site conditions are well understood, objectives of the landowner are considered, and the appropriate plants chosen for the site, tasks that are completed in the planning stages. Below is a summary of the nine steps that are recommended for the planning stages of a buffer restoration project.

1. Obtain Landowner Permission and Support

Landowner commitment is essential for the success of the project. Landowners must be aware of all maintenance activities that will occur once buffer is planted.

2. Make Sure Site is Suitable for Restoration

If streambanks are extensively eroded, consider an alternative location. Rapidly eroding streambanks may undermine seedlings. Streambank restoration may need to occur prior to riparian buffer restoration. Obtain professional help in evaluating the need for streambank restoration.

3. Analyze Site's Physical Conditions

The most important physical influence of the site is the soil, which will control plant selection. Evaluate the soil using the County soil survey book to determine important soil characteristics such as flooding potential, seasonal high water table, topography, soil pH, soil moisture, etc. Also, a simple field test can suffice, with direct observation of soil conditions.

4. Analyze Site's Vegetative Features

Existing vegetation present at the restoration site should be examined to determine the strategy for buffer establishment. Strategies will differ for various pre-restoration conditions such as pasture, overgrown abandoned field, mid-succession forest, etc.

- *Identify Desirable Species*: Native tree and shrub species that thrive in riparian habitats in Pennsylvania should be used. These species should be identified in the restoration site and protected for their seed bank potential. Several native vines and shrubs (blackberry, Virginia creeper, and spicebush) can provide an effective ground cover during establishment of the buffer, though they should be selectively controlled to minimize herbaceous competition.
- *Identify Undesirable Species:* Consider utilizing undesirable species such as the black locust for their shade function during buffer establishment. Consider controlling invasive plants prior to buffer planting.
- *Identify Sensitive Species*: Since riparian zones are rich in wildlife habitat and wetland plant species to be aware of any rare, threatened or endangered plant (or animal) species.

5. Draw a Map of the Site (Data collection)

Prepare a sketch of the site that denotes important existing features, including stream width, length, streambank condition, adjacent land uses and stream activities, desired width of buffer, discharge pipes, obstructions, etc.

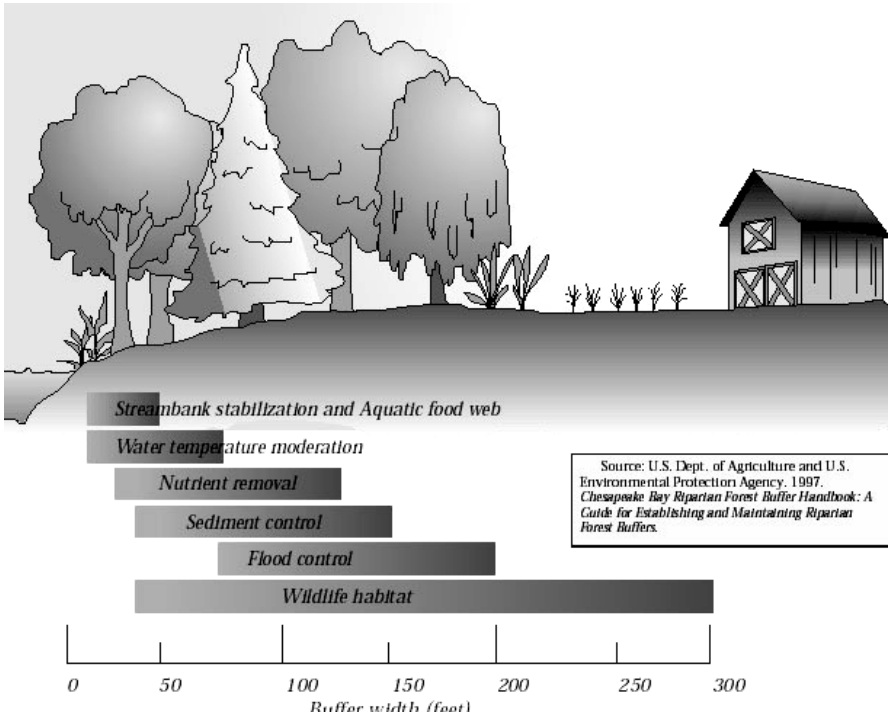
6. Create a Design that Meets Multiple Objectives

Ideally, the three-zone system should be incorporated into the design, in a flexible manner to obtain water quality and landowner objectives.

- *Consider landowner objectives*: Consider the current use of the buffer by the landowner, especially if the buffer will be protected in perpetuity. Consider linking the buffer to an existing (or planned trail system).
- *Buffer width*: Riparian buffer areas do not have a fixed linear boundary, but vary in shape, width, and vegetative type and character. The function of the buffer (habitat, water quality, etc) is the overriding criterion in determining buffer width (Figure 1). Many factors including slope, soil type, adjacent land uses, floodplain, vegetative type, and

water shed condition influence what can be planted. The most commonly approved minimum buffer widths for water quality and habitat maintenance are 35 –100 feet. Buffers less than 35 feet do not protect aquatic resources long term.

Figure 1



- *Consider costs:* The planting design (density, type, mix, etc.) will ultimately be based on the financial constraints of the project. See discussion below for estimating direct costs for planting and maintenance.
- *Choose the appropriate plants:* This manual encourages the use of native plants in stormwater management facilities. Since they are best suited to our local climate, native species have distinct genetic advantages over non-native species. Ultimately using native plants translates into greater survivorship with less replacement and maintenance which is a cost benefit to the landowner. Please refer to the plant list in Appendix B for a comprehensive list of native trees and shrubs available for stormwater management facility planting.

Plant Size: Choice of planting stock (seeds, container seedling, bare-root seedlings, plugs, etc.) is ultimately determined by funding resources. Larger material will generally cost more, although it will usually establish more rapidly.

7. Draw a Planting Plan

Planting Density: Trees should be planted at a density sufficient to provide 320 trees per acre at maturity. To achieve this density, approximately 436 (10 x 10 feet spacing) to 681 (8 x 8 feet spacing) trees per acre should be planted initially. Some rules of thumb for tree spacing and density based on plant size at installation:

Seedlings	6-10 feet spacing (~700 seedlings / acre)
Bare Root Stock	14-16 feet spacing (~200 plants / acre)
Larger & Container	16 – 18 feet spacing (~150 plants/acre)

Formula for Estimating Number of Trees and Shrubs:
Plants = length x width of corridor (ft) / 50 square feet

This formula assumes each tree will occupy an average of 50 sq. ft., random placement of plants approximately 10 feet apart, and mortality rate of up to 40% that can be absorbed by the growing forest system.

Alternatively, the adjacent table can be utilized to estimate the number of trees per acre needed for various methods of spacing.

Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)
2x2	10,890	7x9	691	12x15	242
3x3	4,840	7x10	622	12x18	202
4x4	2,722	7x12	519	12x20	182
4x5	2,178	7x15	415	12x25	145
4x6	1,815	8x8	681	13x13	258
4x7	1,556	8x9	605	13x15	223
4x8	1,361	8x10	544	13x20	168
4x9	1,210	8x12	454	13x25	134
4x10	1,089	8x15	363	14x14	222
5x5	1,742	8x25	218	14x15	207
5x6	1,452	9x9	538	14x20	156
5x7	1,245	9x10	484	14x25	124
5x8	1,089	9x12	403	15x15	194
5x9	968	9x15	323	15x20	145
5x10	871	10x10	436	15x25	116
6x6	1,210	10x12	363	16x16	170
6x7	1,037	10x15	290	16x20	136
6x8	908	10x18	242	16x25	109
6x9	807	11x11	360	18x18	134
6x10	726	11x12	330	18x20	121
6x12	605	11x15	264	18x25	97
6x15	484	11x20	198	20x20	109
7x7	889	11x25	158	20x25	87
7x8	778	12x12	302	25x25	70

Planting Layout: Given planting density and mix, drawing the planting plan is fairly straightforward. The plan can vary from a highly technical drawn to scale plan, or a simple line drawing of the site. Any plan must show the site with areas denoted for trees and shrub species with notes for plant spacing and buffer width.

8. Prepare Site Ahead of Time

Existing site conditions will determine the degree of preparation needed prior to planting. Invasive infestation and vegetative competition are extremely variable, and therefore must be considered in the planning stages. Site preparation should begin in the fall prior to planting. Enlist professional to determine whether use of chemical controls are necessary to prepare site for planting. Eliminate undesired species with either herbicide application (consult a professional) or physical removal. If utilizing a highly designed planting layout, mark site ahead of time with flags, spray paint, or other markers so that the appropriate plant is put in the right place.

9. Determine Maintenance Needs

An effective buffer restoration project should include management and maintenance guidelines, including a description of the allowable uses in the various zones of the buffer. Buffer

boundaries should be well defined with clear signs or markers. Weed control is essential for the survival and rapid growth of trees and shrubs, and can include any of the following:

- Organic mulch
- Weed control fabrics
- Shallow cultivation
- Pre-emergent herbicides
- Mowing

Non-chemical weed control methods are preferred since chemicals can easily enter the water system. If possible, avoid working in the riparian area between April 15 and August 15, the mating and newborn period for local wildlife.

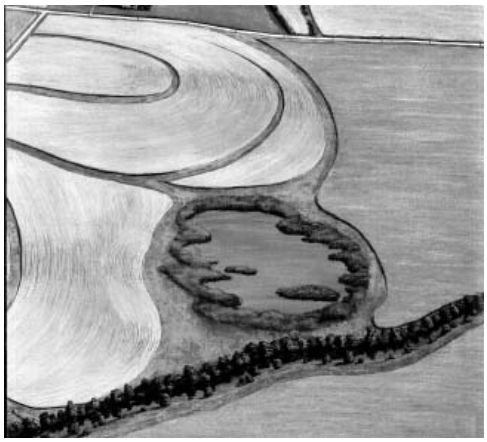
Variations

See Applications

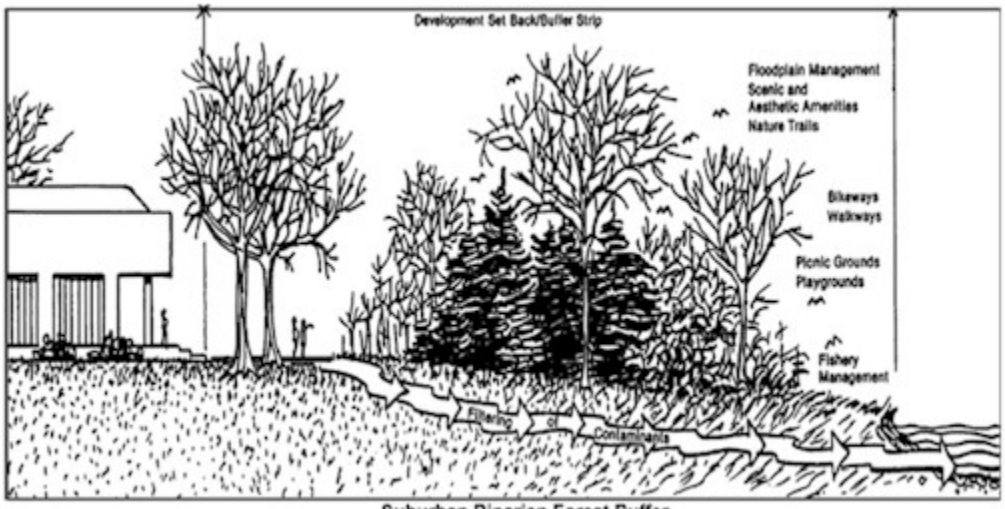
Applications

- **Forested Landscape**

- **Agricultural Landscape**

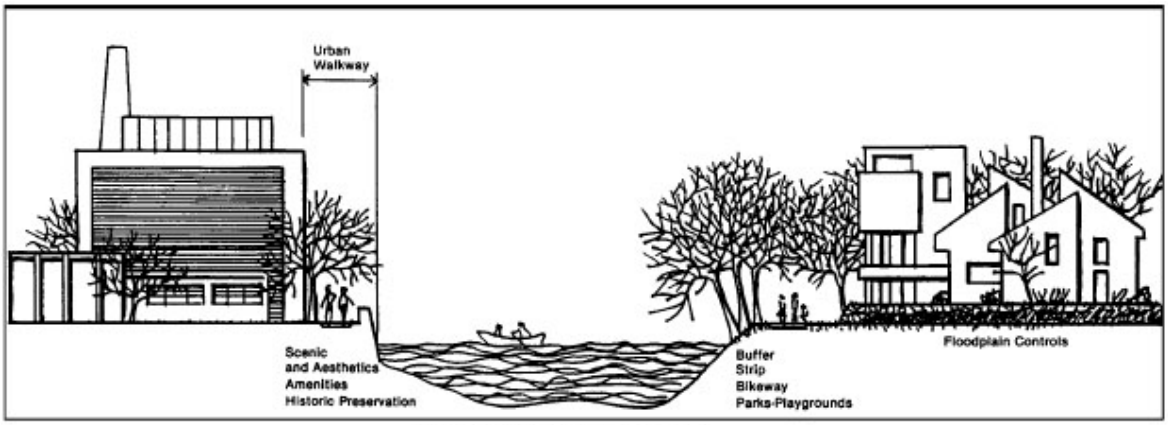


- **Suburban / Developing Landscape**



Suburban Riparian Forest Buffer

- **Urban Landscape**



Urban Riparian Forest Buffer

Design Considerations

The considerations listed below should all be taken into account during the planning stage. There are many potential threats to the long-term viability of riparian plant establishment and with proper foresight, these problems can be eliminated or addressed.

1. Deer Control

    a. Look for signs of high deer densities, including an overgrazed understory with a browse line 5-6 feet above the ground.

2. Tree Shelters

    a. Recommended for riparian plantings where deer predation or human intrusion may be a problem.
    b. Plastic tubes that fit over newly planted trees that are extremely successful in protecting seedlings.
    c. Protect trees from accidental strikes from mowing or trimming
    d. Create favorable microclimate for seedlings
    e. Secure with wooden stake and place netting over top of tree tube
    f. Remove tree shelters 2 to 3 years after plants emerge

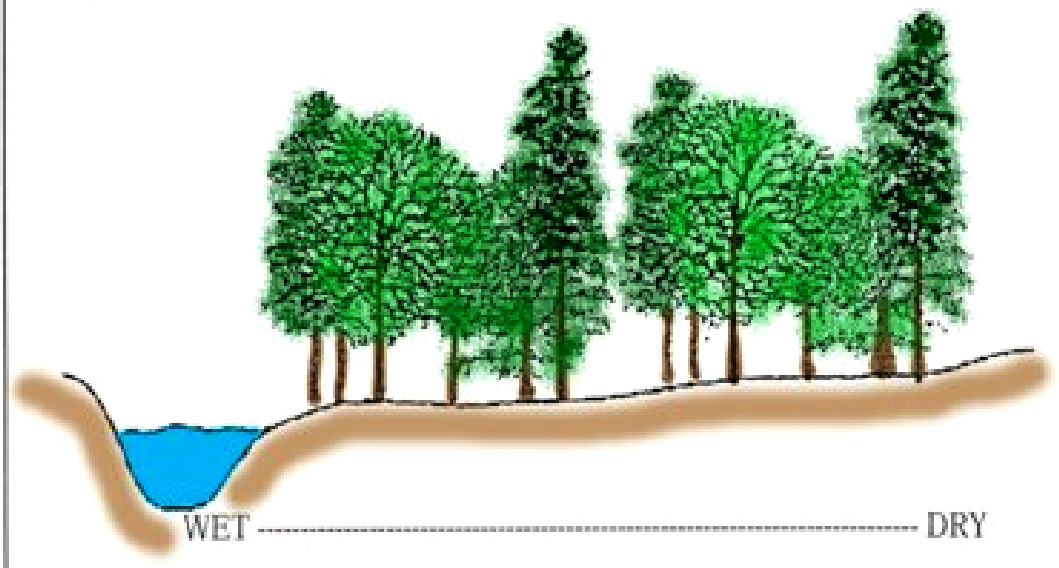
3. Stream Buffer Fencing

    a. Deer can jump fences up to 10 feet high, preferring to go under barriers.
    b. Farm animals cause greatest damage to stream banks – consider permanent fencing like high-tensile smooth wire fencing or barbed fencing.
    c. The least expensive is 8 foot plastic fencing, which are effective against deer and easily repaired.

4. Vegetation

    a. Consider using plants that are able to survive frequent or prolonged flooding conditions. Plant trees that can withstand high water table conditions. Figure 5 shows tree species that fit into the moisture conditions of a streamside area.
    b. Soil disturbance can result in unanticipated infestation by invasive plants.

Figure 5. Sample Planting Recommendations According to Moisture Conditions



TREES

- Silver Maple
- Box Elder
- Persimmon →
- Black Ash
- Red Ash
- Pawpaw →
- Sweet-bay Magnolia
- Sycamore →
- Cottonwood
- Swamp White Oak
- Oak,Willow →
- Willow, Sandbar & Black

SMALL TREES/SHRUBS

- River Birch
- Smooth Alder
- Chokeberry, Red
- Chokeberry, Black →
- Groundselbush
- Dogwood, Red Osier & Silky
- Summersweet →
- Winterberry →
- Inkberry →
- Swamp Rose
- Swamp Azalea
- Meadowsweet →
- Highbush Blueberry →
- Witherod →
- N. Arrowwood

TREES

- ← Maple, Red →
- Bitternut Hickory →
- ← Redbud →
- Hackberry →
- American Beech →
- ← Ash, White →
- ← Honey Locust →
- Kentucky Coffee Tree →
- ← Sweet-gum
- Tuliptree →
- Black-gum →
- ← Large-toothed Aspen →
- ← Oak, Pin →

SMALL TREES/SHRUBS

- ← Black/Sweet Birch →
- Mountain Laurel →
- ← Hornbeam →
- Yellow Birch →
- ← Shadbush (A.arborea & canadensis) →
- ← Dogwood, Gray & Flowering →
- Fringe Tree →
- American Hazelnut →
- ← Black Huckleberry
- ← Common Spicebush →
- ← Rosebay Rhododendron
- ← Southern Arrowwood
- ← Ninebark
- ← American Elder →
- Bayberry →
- ← Highbush Cranberry →
- Red Elm

TREES

- White Pine
- Black Cherry
- Sassafras
- Canada Hemlock
- Oak, White
- ← Oak, Red
- Oak, Chestnut
- Hickory, Shagbark
- Maple, Sugar
- Black Walnut

SMALL TREES/ SHRUBS

- Hop-hornbeam
- Witchhazel
- Staghorn Sumac
- Nannyberry
- Blackhaw

Arrows denote that certain species can tolerate either a wetter or drier environment.

Construction Sequence

The PA Stream ReLeaf project provides a checklist that can substitute for a construction sequence for riparian buffer restoration. A slightly modified version follows:

1. SELECT SITE

    - Confirm site is suitable for restoration
    - Obtain landowner permission

2. ANALYSE SITE

    - Evaluate site's physical conditions (soil attributes, geology, terrain)
    - Evaluate site's vegetative features (desirable and undesirable species, native species, sensitive habitats)
    - Sketch or map site feature

3. DESIGN BUFFER

    - Consider landowner objectives in creating buffer design
    - Determine desired functions of buffer in determining buffer width
    - Match plant species to site conditions (hardiness zone, moisture, soil pH)
    - Match plant Species to objectives of buffer functions (water quality, wildlife, recreation, etc.)
    - Match plant sizes to meet budget limitations
    - Develop sketch of planting plan

4. PREPARE SITE

    - Eliminate undesirable species ahead of planting date
    - Mark planting layout at the site
    - Purchase plants and planting materials (mulch, tree shelters)

5. SITE PLAN SHOULD INCLUDE:

    - Site map with marked planting zones
    - Plant species list
    - Planting directions (spacing, pattern of planting)
    - Equipment/tool list
    - Site preparation directions
    - Maintenance schedule

6. PLANTING DAY

    - Keep plants moist and shaded
    - Provide adequate number of tools
    - Document with photos of site during planting

7. SITE MAINTENANCE (additional information below)

    - Assign responsibilities watering, weeding, mowing, and maintenance
    - Monitor site regularly for growth and potential problems

Maintenance Issues

The riparian buffer is subject to many threats, including:

- Browsing
- Invasion by exotic species
- Competition for nutrients by adjacent herbaceous vegetation
- Human disturbance

Proper awareness of these issues is critical to ensure the long-term effectiveness of a restored riparian buffer.

The most critical period during buffer establishment is maintenance of the newly planted trees during canopy closure, typically the first 3 to 5 years. Ongoing maintenance practices are necessary for both small seedlings and larger plant materials. Maintenance and monitoring plans should be prepared for the specific site and caretakers need to be advised of required duties during the regular maintenance period.

Maintenance measures that should be performed regularly:

Watering

- Plantings need deep regular watering during the first growing season, either natural watering via rainfall, or planned watering, via caretaker.
- Planting in the fall increases the likelihood of sufficient rain during planting establishment.

Mulching

- Mulch will assist in moisture retention in the root zone of plantings, moderate soil temperature, provide some weed suppression, and retard evaporation
- Use coarse, organic mulch that is slow to decompose in order minimize repeat application
- Apply 2-4 inch layer, leaving air space around tree trunk to prevent fungus growth.
- Use combination of woodchips, leaves, and twigs that are stockpiled for six months to a year.

Weed control

- Weed competition limits buffer growth and survival, therefore weeds should be controlled by either herbicides, mowing, or weed mats:

    Herbicides

    This is a short-term maintenance technique (2-3 years) that is generally considered less expensive and more flexible than mowing, and will result in a quicker establishment of the buffer. Herbicide use is regulated by the PA Department of Agriculture. Proper care should be taken to ensure that proximity to water features is considered.

Mowing

Mowing controls the height of the existing grasses, yet increases nutrient uptake, therefore competition for nutrients will persist until the canopy closure shades out lower layers. A planting layout similar to a grid format will facilitate ease of mowing yet yield an unnaturally spaced community. Mowing may result in strikes on the trunk unless protective measures are utilized. Mowing should occur twice each growing season. Mower height should be set between 8 –12 inches.

Weed Mats

Weed mats are geo-textile fabrics that are used to suppress weed growth around newly planted vegetation by providing shade and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds.

Deer damage

- Deer will browse all vegetation within reach, generally between 5-6 feet above the ground
- Approaches to minimize damage include: 1) selecting plants that deer do not prefer (ex. Paper Birch, Beech, Ash, Common Elderberry) 2) homemade deer repellants 3) tree shelters

Tree shelters

- Repair broken stakes
- Tighten stake lines
- Straighten leaning tubes
- Clean debris from tube
- Remove netting as tree grows
- Remove when tree is approximately 2 inches wide

Invasive Plants

- Monitor restoration sight regularly for any signs of invasive plants.
- Appendix B contains common invasive plants found in Pennsylvania.
- Choice of control method is based on a variety of considerations, but falls into three general categories:
    - Mechanical
    - Mechanical with application of herbicide
    - Herbicide

Special Maintenance Considerations

Riparian buffer restoration sites should be monitored to maximize wildlife habitat and water quality benefits, and to discover emerging threats to the project. During the first four years, the new buffer should be monitored four times annually (February, May, August, and November are recommended) and inspected after any severe storm. Repairs should be made as soon as possible.
Depending on restoration site size, the buffer area should be sampled to approximate survival rate. Data derived should consider survival of the planted material and natural regeneration to determine if in-fill planting should occur to supplement plant density.

Survival rates of at least 70% are deemed to be successful. Calculate percent survival by the following equation:

(# of live plants / # of installed plants) 100 = % survival

Cost Issues

Establishment and maintenance costs should be considered up front in the riparian buffer plan design. Installing a forest riparian buffer involves site preparation, tree planting, second year reinforcement planting, and additional maintenance. Both the USDA Riparian Handbook and the PADEP/PADCNR Stream ReLeaf Forest Buffer Toolkit utilize a basic outline for estimating costs for establishment and maintenance:

Costs may fluctuate based on numerous variables including whether or not volunteer labor is utilized, whether plantings and other supplies are donated or provided at a reduced cost.

Specifications

The USDA Forest Service developed a riparian forest buffer specification, which outlines three distinct zones and establishes the minimally acceptable requirements for reforestation by landowners.

Definition

An area of trees and other vegetation located in areas adjoining and upgradient from surface water bodies and designed to intercept surface runoff, wastewater, subsurface flow, and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and ground water recharge areas.

Scope

This specification establishes the minimally acceptable requirements for the reforestation of open lands, and renovation of existing forest to be managed as Riparian Forest Buffers for the purposes stated.

Purpose

To remove nutrients, sediment, animal-derived organic matter, and some pesticides from surface runoff, subsurface flow, and near root zone groundwater by deposition, absorption, adsorption, plant uptake, denitrification, and other processes, thereby reducing pollution and protecting surface water and groundwater quality.

Conditions Where Practice Applies

Subsurface nutrient buffering processes, such as denitrification, can take place in the soil wherever carbon energy, bacteria, oxygen, temperature, and soil moisture is adequate. Nutrient uptake by plants occurs where the water table is within the root zone. Surficial filtration occurs anywhere surface vegetation and forest litter are adequate.

The riparian forest buffer will be most effective when used as a component of a sound land management system including nutrient management and runoff, and sediment and erosion control practices. Use of this practice without other nutrient and runoff, sediment and erosion control practices can result in adverse impacts on buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting, and the carrying of excess nutrients and sediment through the buffer by concentrated flows.

This practice applies on lands:

1. adjacent to permanent or intermittent streams which occur at the lower edge of upslope cropland, grassland or pasture;

2. at the margins of lakes or ponds which occur at the lower edge of upslope cropland, grassland or pasture;

3. at the margin of any intermittent or permanently flooded, environmentally sensitive, open water wetlands which occur at the lower edge of upslope cropland, grassland or pasture;

4. on karst formations at the margin of sinkholes and other small groundwater recharge areas occurring on cropland, grassland, or pasture.

Note: In high sediment production areas (8-20 in./100 yrs.), severe sheet, rill, and gully erosion must be brought under control on upslope areas for this practice to function correctly.

Riparian Buffer Installation Costs - Estimation per Acre

			Cost, ea.	Number	Cost, Total
Phase 1: Establishment					
Preparation					
	Light site preparation (mow, disking)		-	-	$ 12.00
Planting					
	Tree Seedlings (12" - 18" Hardwoods)		$ 1.15	430	$ 494.50
	Tree Shelters	(optional)	$ 5.00	430	$ 2,150.00
	Fencing (1 ac = 282 ft)	(optional)			$ 564.00
		Subtotal			**$ 3,220.50**
Phase 2: Maintenance					
Reinforcement Planting					
	Tree Seedlings in Year 2		$ 1.15	50	$ 57.50
	Herbicide Treatment	(optional)			$ 54.00
	Mowing	(optional)			$ 12.00
		Subtotal			**$ 123.50**
Total Costs, no options					**$ 564.00**
Total Costs, with options					**$ 3,344.00**

Design Criteria

Riparian Forest Buffers

Riparian forest buffers will consist of three distinct zones and be designed to filter surface runoff as sheet flow and downslope subsurface flow, which occurs as shallow groundwater. For the purposes of these buffer strips, shallow groundwater is defined as: saturated conditions which occur near or within the root zone of trees, and other woody vegetation and at relatively shallow depths where bacteria, oxygen, and soil temperature contribute to denitrification. Streamside Forest Buffers will be designed to encourage sheet flow and infiltration and impede concentrated flow.

Zone 1

Location
Zone 1 will begin at the top of the streambank and occupy a strip of land with a fixed width of fifteen feet measured horizontally on a line perpendicular to the streambank.

Purpose
The purpose of Zone 1 is to create a stable ecosystem adjacent to the water's edge, provide soil/water contact area to facilitate nutrient buffering processes, provide shade to moderate and stabilize water temperature encouraging the production of beneficial algal forms, and to contribute necessary detritus and large woody debris to the stream ecosystem.

Requirements
Runoff and wastewater to be buffered or filtered by Zone 1 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 1. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipes or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Dominant vegetation will be composed of a variety of native riparian tree and shrub species and such plantings as necessary for streambank stabilization during the establishment period. A mix of species will provide the prolonged stable leaf fall and variety of leaves necessary to meet the energy and pupation needs of aquatic insects.

Large overmature trees are valued for their detritus and large woody debris. Zone 1 will be limited to bank stabilization and removal of potential problem vegetation. Occasional removal of extreme high value trees may be permitted where water quality values are not compromised. Logging and other overland equipment shall be excluded except for stream crossings and stabilization work.

Livestock will be excluded from Zone 1 except for designed stream crossings.

Zone 2

Location
Zone 2 will begin at the edge of Zone 1 and occupy an additional strip of land with a minimum width of 60 feet measured horizontally on a line perpendicular to the streambank. Total minimum width of Zones 1 & 2 is therefore 75 feet. Note that this is the minimum width of Zone 2 and that the width of Zone 2 may have to be increased as described in the section "Determining the Total Width of Buffer" to create a greater combined width for Zones 1 & 2.

Purpose
The purpose of Zone 2 is to provide necessary contact time and carbon energy source for buffering processes to take place, and to provide for long term sequestering of nutrients in the form of forest trees. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipe or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Requirements
Runoff and wastewater to be buffered or filtered by Zone 2 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 2.

Predominant vegetation will be composed of riparian trees and shrubs suitable to the site, with emphasis on native species, and such plantings as necessary to stabilize soil during the establishment period. Nitrogen-fixing species should be discouraged where nitrogen removal or buffering is desired. Species suitability information should be developed in consultation with state and federal forestry agencies, Natural Resources Conservation Service, and USDI Fish and Wildlife Service.

Specifications should include periodic harvesting and timber stand improvement (TSI) to maintain vigorous growth and leaf litter replacement, and to remove nutrients and pollutants sequestered in the form of wood in tree boles and large branches. Management for wildlife habitat, aesthetics, and timber are not incompatible with riparian forest buffer objectives as long as shade levels and production of leaf litter, detritus, and large woody debris are maintained. Appropriate logging equipment recommendations shall be determined in consultation with the state and federal forestry agencies.

Livestock shall be excluded from Zone 2 except for necessary designed stream crossings.

Zone 3

Location
Zone 3 will begin at the outer edge of Zone 2 and have a minimum width of 20 feet. Additional width may be desirable to accommodate land-shaping and mowing machinery. Grazed or ungrazed grassland meeting the purpose and requirements stated below may serve as Zone 3.

Purpose
The purpose of Zone 3 is to provide sediment filtering, nutrient uptake, and the space necessary to convert concentrated flow to uniform, shallow, sheet flow through the use of techniques such as grading and shaping, and devices such as diversions, basins, and level lip spreaders.

Requirements
Vegetation will be composed of dense grasses and forbs for structure stabilization, sediment control, and nutrient uptake. Mowing and removal of clippings are necessary to recycle sequestered nutrients, promote vigorous sod, and control weed growth.

Vegetation must be maintained in a vigorous condition. The vegetative growth must be hayed, grazed, or otherwise removed from Zone 3. Maintaining vigorous growth of Zone 3 vegetation must take precedence and may not be consistent with wildlife needs.

Zone 3 may be used for controlled intensive grazing when conditions are such that earthen water control structures will not be damaged.

Zone 3 may require periodic reshaping of earth structures, removal or grading of accumulated sediment, and reestablishment of vegetation to maintain effectiveness of the riparian buffer.

Determining Need For Protection
Buffers should be used to protect any body of water which will not be:

- treated by routing through a natural or artificial wetland determined to be adequate treatment;

- treated by converting the flow to sheet flow and routing it through a forest buffer at a point lower in the watershed.

Determining Total Width of the Buffer
Note that while not specifically addressed, slope and soil permeability are components of the following buffer width criteria.

Each of the following criteria is based on methods developed, or used by persons conducting research on riparian forests.

Streamside Buffers

The minimum width of streamside buffer areas can be determined by any number of methods suitable to the geographic area.

1. Based on soil hydrologic groups as shown in the county soil survey report, the width of Zone 2 will be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C which are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 & 2 may be limited to the 75 foot minimum.

2. Based on area, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 equal to one third of the slope distance from the streambank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream which occupies approximately one third of the source area.

3. Based on the Land Capability Class of the buffer site as shown in the county soil survey, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 as shown below.

Capability Class	Buffer Width
Cap. I, II e/s, V	75'
Cap. III e/s, IV e/s	100'
Cap. VI e/s, VII e/s	150'

Pond and Lake-Side Buffer Strips
The area of pond or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic Group and Capability Class methods of determining width remain the same as for streamside buffers. Minimum widths apply in all cases.

Environmentally Sensitive Wetlands
Some wetlands function as nutrient sinks. When they occur in fields or at field margins, they can be used for renovation of agricultural surface runoff and/or drainage. However, most wetlands adjoining open water are subject to periodic flushing of nutrient-laden sediments and, therefore, require riparian buffers to protect water quality.

Where open water wetlands are roughly ellipsoid in shape, they should receive the same protection as ponds.

Where open water wetlands exist in fields as seeps along hillslopes, buffers should consist of Zones 1, 2 & 3 on sides receiving runoff and Zones 1 & 3 on the remaining sides. Livestock must be excluded from Zones 1 & 2 at all times and controlled in Zone 3. Where Zones 1 & 3 only are used, livestock must be excluded from both zones at all times, but hay removal is desirable in Zone 3.

Vegetation Selection
Zone 1 & 2 vegetation will consist of native streamside tree species on soils of Hydrologic Groups D and C and native upland tree species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter which drives bacterial processes that remove nitrogen, as well as, the sequestering of nutrients in the growth processes. In warmer climates, evergreens are also important due to the potential for nutrient uptake during the winter months. In both cases, a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs.

Species recommendations for vegetated buffer areas depend on the geographic location of the buffer. Suggested species lists should be developed in collaboration with appropriate state and federal forestry agencies, the Natural Resources Conservation Service, and the USDI Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, forbs, as well as site preparation techniques. Fertilizer and lime, helpful in establishing buffer vegetation, must be used with caution and are not recommended in Zone 1.

Maintenance Guidelines

General
Buffers must be inspected annually and immediately following severe storms for evidence of sediment deposit, and erosion, or concentrated flow channels. Prompt corrective action must be taken to stop erosion and restore sheet flow.

The following should be avoided within the buffer areas: excess use of fertilizers, pesticides, or other chemicals; vehicular traffic or excessive pedestrian traffic; and removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives.

Zone 1 vegetation should remain undisturbed except for removal of individual trees of extremely high value or trees presenting unusual hazards such as potentially blocking culverts.

Zone 2 vegetation, undergrowth, forest floor, duff layer, and leaf litter shall remain undisturbed except for periodic cutting of trees to remove sequestered nutrients; to maintain an efficient filter by fostering vigorous growth; and for spot site preparation for regeneration purposes. Controlled burning for site preparation, consistent with good forest management practices, could also be used in Zone 2.

Zone 3 vegetation should be mowed and the clippings removed as necessary to remove sequestered nutrients and promote dense growth for optimum soil stabilization. Hay or pasture uses can be made compatible with the objectives of Zone 3.

Zone 3 vegetation should be inspected twice annually, and remedial measures taken as necessary to maintain vegetation density and remove problem sediment accumulations.

Stable Debris
As Zone 1 reaches 60 years of age, it will begin to produce large stable debris. Large debris, such as logs, create small dams which trap and hold detritus for processing by aquatic insects, thus adding energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Wherever possible, stable debris should be conserved.

Where debris dams must be removed, try to retain useful, stable portions which provide detritus storage.

Deposit removed material a sufficient distance from the stream so that it will not be refloated by high water.

Planning Considerations

1. Evaluate the type and quantity of potential pollutants that will be derived from the drainage area.

2. Select species adapted to the zones based on soil, site factors, and possible commercial goals such as timber and forage.

3. Plan to establish trees early in the dormant season for maximum viability.

4. Be aware of visual aspects and plan for wildlife habitat improvement if desired.

5. Consider provisions for mowing and removing vegetation from Zone 3. Controlled grazing may be satisfactory in Zone 3 when the filter area is dry and firm.

References

Natural Resources Conservation Service. 1997. USDA Natural Resources Conservation Practice Standard Riparian Forest Buffer. USDA Natural Resources Conservation Service.

Palone, R.S. and A.H. Todd (editors.) 1997. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. USDA Forest Service. NA-TP-02-97. Radnor, PA. http://www.chesapeakebay.net/pubs/subcommittee/nsc/forest or *order from: U.S. EPA Chesapeake Bay Program. 410 Severn Ave. Suite 109. Annapolis, MD. 1-800-968-7229*.

PA Department of Environmental Protection. 1998. *Pennsylvania Stream ReLeaf – Forest Buffer Toolkit*, http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/StreamReLeaf/default.htm

Tjaden, R.L. and G.M. Weber. 1997. An Introduction to the Riparian Forest Buffer. Maryland Cooperative Extension Fact Sheet 724. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS724.pdf.

Tjaden, R.L. and G.M. Weber. 1997. Riparian Buffer Systems. Maryland Cooperative Extension Fact Sheet 733. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS733.pdf.