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PROTECTING RIPARIAN AREAS: FARMLAND MANAGEMENT STRATEGIES

SOIL SYSTEMS GUIDE

Abstract: This publication is designed to help farmers, watershed managers, and environmentalists understand what healthy riparian areas look like, how they operate, and why they are important for the environment and society. It also provides information on the costs and benefits of riparian management and discusses how watershed residents can work together to protect this vital resource. Tables included in the publication are designed to help you evaluate riparian protection strategies from the perspective of your local environment, surrounding land use practices, and land management objectives.

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Introduction

Riparian areas include streams, streambanks, and wetlands adjacent to streams. These areas have a water table high enough to interact with plant roots and affect their growth throughout most of the year. Plant species that thrive in riparian areas are adapted to wet and flooded conditions. They are also adapted to regrow root systems in sediments deposited through soil erosion (Schneider, 1998).

Healthy riparian areas are critically important ecological zones. They provide:

- Water quality protection
- Structural support for streambanks
- Water capture and storage
- Flood control
- Stabilization of water flow in streams and rivers
- Habitat for aquatic and terrestrial wildlife
- Aesthetic and recreational benefits

Unfortunately, various land use practices have degraded riparian areas, resulting in impaired environmental conditions, decreased agronomic production, and a multiplicity of social costs. Both agricultural and non-agricultural land use practices are responsible for the degradation of riparian areas. These degrading land use practices include:

Photo by USDA NRCS

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- Artificial stream widening and straightening
- Road and building construction close to streams
- Replacement of wooded or grassy areas with roads, houses, and parking lots resulting in increased runoff into streams
- Unrestricted grazing or loitering of livestock in or near streams
- Crop production activities including plowing, planting, and fertilizer, manure, and pesticide applications close to streams

This publication is designed to assist farmers, ranchers, watershed managers, homeowners, and community members in understanding the importance of riparian areas and guide them in implementing land management practices to improve riparian health. Tables included provide tools to monitor the conditions of riparian areas during land restoration processes.

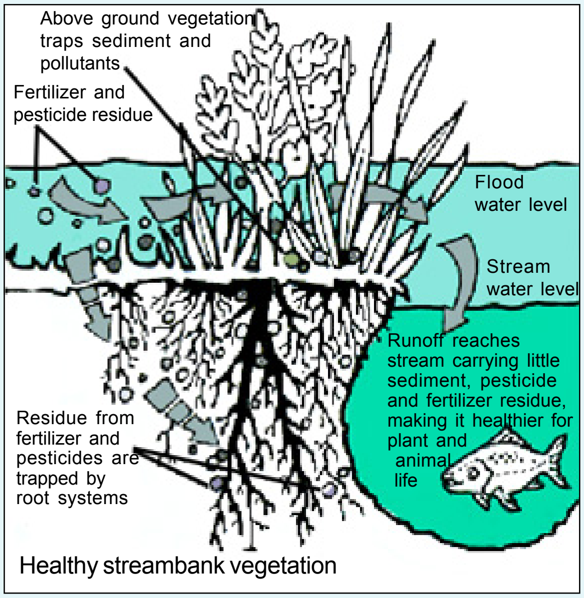
Attached appendices provide detailed information on subjects addressed in this publication.

Upland Land Management and Riparian Health

Water flows from upland areas through riparian areas and eventually into streams. Healthy riparian areas are able to absorb, hold, and use much of the water that flows off from healthy upland areas. Healthy riparian areas are also able to chemically and biologically bind or detoxify many contaminants contained in this water. However, if upland areas are degraded or covered with roads, parking lots, and rooftops that do not allow the water to seep into the soil, even the healthiest riparian area will be unable to absorb and filter large volumes of water, nutrients, and contaminants flowing through it. Therefore, the first step in riparian protection is ensuring that land management practices across the watershed conserve soil and water resources.

Water moves across the landscape in two ways: as groundwater flow and as runoff. *Subsurface* or *groundwater* flow is water that has soaked into the soil and travels underground through pores in the soil. *Runoff* is water that moves over the surface of the soil. When groundwater or runoff water moves, it absorbs nutrients or contaminants and transports them into riparian areas and potentially into streams. Runoff water can also transport eroded soil particles.

Groundwater flow. In most undisturbed watersheds, a majority of the water flows into riparian areas and streams as groundwater rather than as runoff. As rain falls or snow melts, leaves and other plant residues on the soil surface catch this water. Pores created by growing plants, decaying plant roots, and animal burrows help the water seep into the soil (Cohen, 1997). Once it seeps into the soil, the resulting groundwater moves relatively slowly underground through soil particles until it reaches riparian areas and associated streams.



Plants in riparian areas filter ground and surface water moving into streams.

(from Huel, 1998. ©Agriculture and Agri-Food Canada)

Runoff is favored when rain falls faster than the ground can absorb it. Water cannot be effectively absorbed when soils:

- Are compacted at the surface
- Are bare, so that the impact of rain drops on the soil forms a surface crust

- Have pores that have become plugged by eroded sediments
- Have a clay texture that does not allow for rapid water movement into the soil
- Are hydrophobic or have a surface crust, typical of many arid or semi-arid soils (Federal Interagency Stream Restoration Working Group, 2001).

Runoff is also heavy when the soil does not have the capacity to hold additional rainwater or snowmelt entering the soil. This occurs when:

- Soils have been replaced by impermeable surfaces such as roads, parking lots, or rooftops and insufficient natural or artificial wetlands are present to capture water not able to be absorbed by soil
- Soils are rocky or have an impenetrable stony layer close to the surface
- Soils are thin because the topsoil has been eroded off
- Soils have a compacted layer of "pan" within their profile that acts as a barrier to downward water movement
- Groundwater levels are high
- Rain keeps falling on soils that are already saturated

Stream flashing

When runoff is heavy, such as following an intense storm or a rapid snowmelt, stream levels can rise rapidly, often to flood stage. This rise in water levels is often very short term, lasting only a day or two, after which water levels decrease dramatically. The rapid rise and fall of water levels caused by runoff is referred to as stream flashing.

Contaminant movement by water. Runoff water flowing over the soil surface can pick up and *erode* soil sediments. These sediments may carry nutrients, pathogens, pesticides, and other contaminants, depending on the land-use practices in the area they came from. Both runoff water and groundwater can also absorb nutrients or become contaminated with pesticides or pathogens in the soil. Streams are polluted when contaminated water is able to move directly into them.

Impact of runoff and erosion on riparian areas. Under healthy watershed conditions water infiltration across the landscape results in minimal runoff and erosion reaching riparian areas. Healthy riparian areas have a dense growth of vegetation that catches any eroded sediment and prevents it from entering streams. They also have a diversity of plants that facilitate water infiltration and take up many nutrients carried into riparian areas by runoff and groundwater. Riparian areas also have a unique soil environment that provides favorable conditions for the chemical and biological degradation of many soil contaminants.


Runoff from poorly vegetated areas carries eroded sediments into streams

However, when upland watershed conditions are degraded, heavy runoff can flow over or through riparian plants and move directly into river channels. Severe erosion in upland areas can degrade riparian areas by burying plants under sediments. Fine sediments brought in by erosion can degrade stream habitat by filling in stream pools, altering the shape of stream channels, and covering rocky stream bottoms, thereby eliminating important food producing, shelter and spawning areas (Wohl and Caline, 1996). Runoff and erosion also bring in seeds of non-native or non-riparian plant species. Invasive and non water-loving plant species can reduce habitat for native species and lower the water table by crowding out more functional and palatable riparian species. They can also create a fire risk by increasing fuel loads (Allen et al, 2000). As runoff and erosion from upland areas continue to destroy the integrity of riparian areas, streamside areas loose their ability to buffer and protect streams, resulting in damage to aquatic habitat, increased costs for treating drinking water, and loss of aesthetic appeal.

Soil and water conservation practices. Water infiltration is enhanced by land-use practices that provide coverage of the soil surface with vegetation or residues throughout the year. Conservation tillage, contour farming, cover cropping, agroforestry, and rotational grazing are all practices that protect soil quality while promoting water flow into the soil. For more information on these soil and water conservation practices, please see the following ATTRA publications:

Sustainable Soil Management

Conservation Tillage

Pursuing Conservation Tillage for Organic Crop Production

Rye as a Cover Crop

Protecting Water Quality on Organic Farms

Sustainable Pasture Management

Rotational Grazing

Nutrient Cycling in Pastures

What do Riparian Areas Look Like?

Healthy riparian areas. Characteristics of healthy riparian areas differ across the country and across the landscape. In mountainous or hilly areas, streams run through rocky gorges with scattered trees growing out of the thin soil. In prairie landscapes, streams flow through thick, silty soil, with banks covered by reeds, sedges, and willows. Despite these local differences, healthy riparian areas have certain similarities:

- A thick growth of vegetation, representing a diversity of grasses, forbs, shrubs, and trees, covers the streambanks and provides shade over the stream
- Except where streams cut through rocky terrain, land surrounding streambanks remains wet throughout most of the year
- Streambanks are more vertical than flattened out
- Streamflow levels vary only moderately throughout the year
- Stream water is relatively clear but contains leaves, twigs, or logs from streambanks that create pools and other habitat for fish and other aquatic organisms
- A diversity of fish, aquatic life, mammals, and birds live in and around riparian areas

Appendix 1 describes regional differences in the structures and functions of riparian areas.

Degraded riparian areas. In contrast, degraded riparian areas have some or all of the following characteristics:

- Patchy or scrubby plant growth with bare ground showing in many places
- Vegetation dominated by upland plants including noxious weeds
- Soil that is compacted, shows rills or gullies, or has bare trails and pathways along the streambanks
- Streambanks that are eroded, severely undercut, or sloughing
- Streams that flood regularly in the spring and become dry during the summer
- Streamwater that is muddy or murky and may contain toxic levels of various nutrients or contaminants
- Few mammals or birds living or feeding in the area
- Limited numbers and diversity of fish and other aquatic species

These characteristics of degraded riparian areas reflect their inability to protect water quality, stabilize water quantity, and provide critical habitat for both land animals and aquatic species.

Water and Sediment Capture by Riparian Areas

Riparian areas protect water quality by capturing, storing, and treating water that flows through their soils. A thick growth of diverse vegetation, plant residues covering the soil surface, and porous, non-compacted soil facilitate water capture. High streambanks with high water tables provide water storage capacity. Vigorously growing plants take up nutrients transported into riparian areas, while active populations of both aerobic and anaerobic soil organisms degrade many contaminants that flow into these areas. Chemicals in soil minerals and soil organic matter also capture or facilitate biological detoxification of contaminants. Understanding these components of healthy riparian areas can help guide land management practices that protect riparian areas and water quality.

Structure of riparian vegetation. Healthy riparian vegetation captures water and facilitates water infiltration into the soil. Riparian areas that include a diversity of plant species are most effective in slowing the flow of water and storing it for future use. These species are not arranged in a random manner. Rather, they are organized in a natural structure consisting of three roughly parallel ecosystem bands, each consisting of species adapted to survive in the specific moisture regime of that area and able to perform specific ecological functions:

- The first band of vegetation, found at the edge of the water, consists of deep-rooted sedges and rushes.
- The second band of vegetation, found in the wet ground near the edge of the bank, consists of shrubs, trees, moisture loving grasses, and water-tolerant broad-leaved plants (Huel, 1998).
- The drier third band of vegetation, found where the riparian zone merges into the uplands, includes a mixture of riparian and upland plant species (Huel, 1998).

Plants in the first band are water-loving and have deep, strong roots that stabilize streambanks against erosion (Clark, 1998). Plants in the second and third bands catch water and facilitate its absorption. They also take up nutrients transported into the area by runoff and groundwater and provide habitat for terrestrial animals. If land management practices reduce the riparian zones to only one or two of these bands, some or all of the environmental and habitat benefits of these areas will be lost. The first zone is both the most ecologically important and requires the greatest protection against degradation.


Photo by USDA NRCS

Trees, brush, and grasses protect streambanks against erosion and water quality degradation

The dominance of water-loving plant species in the first zone serves as an indicator of riparian health. These plants are critical for promoting water recharge and increasing water table height (Martin and Chambers, 2001). It is not essential for native plant species to dominate in riparian areas for these areas to provide environmental benefits. But water-loving plants that provide functions similar to native species need to be present. However, water-tolerant exotic species — such as leafy spurge, purple loosestrife, or salt cedar —grow very aggressively and overwhelm species that are native to the area and more palatable to wildlife and livestock. In this way, exotic species decrease the ability of riparian areas to maintain high water table levels, retain streambank stability, provide forage to livestock, and support wildlife habitat (Huel, 1998).

The importance of water-loving plants in riparian areas

In the past, land management programs implemented in some arid areas recommended clearing native, water-loving plants from riparian areas in order to reduce water-use competition and encourage the production of agronomic crops or forage grasses. However, the removal of these plants eliminated many of the ecological benefits provided by riparian areas, including stream stabilization, shading, and wildlife habitat (NRC, 2002). As a result, farmers and ranchers along these unprotected streams lost land to streambank erosion and were faced with greater challenges in reducing non-point source pollution.

Streambank stabilization. A diversity of plants work together to hold streambank soils in place and protect them from erosion and undercutting by floodwaters, transported woody debris, or ice jams. The deep, penetrating roots of sedges, rushes, grasses, and other herbaceous plants provide structural support for streambanks, while the thicker, harder roots of woody plants protect streambanks against bank scouring by floods and ice jams (Winward, 2000).

Photos by D. Redhege, Kerr Center for Sustainable Agriculture

An eroded streambank that recovered when it was protected from grazing and allowed to become stabilized by vegetation

When riparian areas restore themselves naturally — following a fire, for instance —woody species are often the first plants to become established. These woody plants stabilize stream channels against the forces of erosion while nurturing the growth of water-loving grasses, sedges, rushes, and forbs (Elmore and Beschta, 2000). The herbaceous plants then stabilize streambanks with their thick, deep roots, while their stems trap sediments carried by runoff water and stream-scouring floodwater.

The types of vegetation that naturally dominate in riparian areas differ across locations. Grassy vegetation is more important for holding together streambanks developed from sediments, while trees and shrubs dominate on the steep, rocky banks of more rapidly moving and narrower headwater streams (Sovell et al., 2000). However, water-tolerant or water-loving plants are more effective for holding streambanks in place than are plants more adapted to upland conditions, because they have deeper and stron-

Table 1. Vegetation Indicators for Riparian Areas

Indicator	Healthy Riparian Areas	Moderately Degraded Riparian Areas	Degraded Riparian Areas
Environmental Function of Plants	• effective water infiltration • effective capture of sediments • structural support of streambanks • reduces stream velocity during floods • shade for reducing water loss and moderating temperatures • habitat for wildlife, birds, and aquatic species	• vegetation provides some but not all environmental functions	• vegetation present ineffective in providing most environmental functions of riparian areas
Plant Species Diversity	• predominantly native, water-loving riparian vegetation • combination of sedges, rushes, grasses, herbacous plants, shrubs and trees	• some non-native plant species and noxious weeds • presence of some drought-tolerent vegetation, similar to that in adjacent upland areas	• only non-native species • noxious or invasive weeds present • small number of plant species • trees and shrubs are absent • presence of predominantly drought-tolerent vegetation, similar to that in adjacent upland areas
Diversity of Plant Ages	• both young and mature trees and shrubs are present	• few young trees and shrubs present • some dead or decadent plants present	• reduced plant establishment and survival • all trees are old and in poor health
Plant Vigor and Reproduction	• healthy plant growth and reproduction • plant growth exceeds 80% of potential production	• capability to produce seeds or tillers is somewhat limited • plant growth is 30-80% of potential production	• capability to produce seed or tillers is severely limited • plant growth is poor, less than 30% of potential production
Palatable Vegetation	• diversity of plant species and plant ages provides palatable vegetation throughout the growing season • trees have an open or park-like appearance	• moderate decrease in percentage of palable plant species present • some browsing on palatable tree species	• grazing has removed all of the palatable vegetation • palatable species of shrubs and trees are heavily browsed • willows and other palatable tree species have a “mushroom-like” appearance
Plant and Litter Cover	• full vegetation coverage throughout the year • litter layer present particularly during winter and spring • provides woody debris that serves as shelter for fish and habitat for aquatic insects	• sparse vegetation coverage, especially during the dry season • litter layer thinner than expected for location • reduced amount of woody debris added to stream flow	• bare soil over a large percentage of the soil surface • litter layer largely absent • limited amount of woody debris added to stream flow
Plant Litter Movement and Plant Lodging	• uniform distribution of litter • plants remain standing following heavy rainfalls or snowmelts	• only small size litter is displaced • scattered concentration of litter near obstructions • flattening of grasses in isolated areas	• litter is concentrated around rocks, tree trunks, and other obstructions • plants are flattened by heavy flows of runoff water following rainstorms or snowmelts
Width of Riparian Area	• riparian vegetation at least two channel widths on each side of stream	• natural vegetation extends the width of half the channel on either side of stream	• natural vegetation less than a third of width of the channel on each side of stream

Sources: Belsky et al., 1999; Federal Interagency Stream Restoration Working Group, 2001; Hillard, C. and S. Reedyk. 2000; Naiman et al., 1992; Huel, 1998; Prichard, 1998; Renwick and Eden, 1999; Winward, 2000.

ger root systems. For example, Kentucky bluegrass (*Poa pratensis*) and redtop (*Agrostis stolonifera*) provide good livestock forage, but their root systems are not deep enough to stabilize streambank sediments (Winward, 2000). Thus, these plants often serve as indicators of disturbed or degraded riparian areas. Similarly, trees that are not water tolerant do not develop as extensive root systems in riparian areas as do water tolerant species. As a result, these trees are unable to effectively stabilize streambanks and are likely to be undercut and fall into streams.

For guidelines on how to revegetate degraded riparian areas, please see Appendix 2.

Table 1 provides a list of indicators that compare vegetation characteristics in healthy riparian areas to those in degraded areas.

Water storage within streambanks. Healthy riparian areas that are well-vegetated have highly permeable soils and high stream banks. They have a water table that extends underground and outward from the streambanks and provides a large amount of groundwater storage (Prichard, 1998). In contrast, degraded riparian areas have a low water table, sloping banks, and wide, shallow streams, with limited storage capacity.

A riparian area with a diversity of vegetation is able to trap 80 to 90% of the sediments transported from fields (Naiman and Decamps, 1997). The new sediments, along with lush plant growth, facilitates both water infiltration into riparian soils and increased water storage. As vegetation grows, its stems and roots collect more soil, while its leaves shade the soil and protect it against water loss through evaporation. The seasonal death and decomposition of plants provides additional organic matter to the soil and further facilitates water infiltration and storage. Organic matter holds water like a sponge and stimulates the growth of soil organisms involved in the formation soil aggregates and enhancing soil porosity.

Streambank build-up. Sediment trapping by riparian vegetation increases the height of streambanks, particularly along low-gradient channels (Platts, 1990, Ohmart, 1996). Water tables rise simultaneously in riparian areas as streambanks build up, water absorption is increased, and water loss through evaporation decreases. Under healthy riparian conditions, water tables rise until they reach the height of plants' root zone on the former flood plains (Elmore and Beschta, 2000). These riparian soils remain wet throughout most of the year.

Water recharge. The large water storage capacity of riparian areas buffers the movement of water from upland areas into streams. Instead of allowing water to flow directly into streams following a rainstorm or snowmelt, healthy riparian areas hold and store water. Throughout the year, this water seeps slowly into adjacent streams, providing water recharge and moderating stream flow.

Flood control. The ability of the porous, well-aggregated streambank soils to store vast quantities of water also decreases the potential for flooding. In addition, plants growing in riparian areas control flooding by daily taking up and transpiring thousands of gallons of water per acre (Elmore and Beschta, 2000). If water levels do reach flood stage, streambank vegetation stabilizes streambanks and helps prevent streams from widening or changing course.

Table 2 (next page) compares streambank and channel conditions in healthy and degraded riparian areas.

Water Decontamination by Riparian Soils

Riparian areas contain a combination of wet and dry soil zones that facilitate a variety of biological and chemical reactions. These reactions reduce the availability of some nutrients and decrease the toxicity of some contaminants (Edwards, 2000). The presence of slowly decomposing plant residues in these wet soils further facilitates water purification processes. Some organic matter particles have a high ability to chemically capture and hold many potential contaminants, while others serve as sources of food and energy for soil organisms involved in contaminant detoxification (Cohen, 1997).

Table 2. Soil Indicators for Riparian Areas

Indicator	Healthy Riparian Areas	Moderately Degraded Riparian Areas	Degraded Riparian Areas
Organic matter	• soil covered by growing plants and plant residues throughout the year • organic matter has accumulated in the soil profile • high soil biological activity • topsoils are deep • soils are well aggregated	• soil organic matter content somewhat reduced • some loss of topsoil • moderate levels of soil biological activity • soil patches bare of vegetation • relatively high removal of residues from soil system • moderate to poor soil aggregation	• low soil fertility and low concentration of organic matter • soil is bare in many areas • limited topsoil • limited soil biological activity • limited return of plant residues to the soil system • soils are sticky or grainy, not well aggregated
Diverse microbial community structure	• organic matter decomposes rapidly • effective loss of nitrogen through denitrification • good soil aggregation by microbial slimes	• moderate decomposition of organic matter	• peat builds up in riparian areas because area is too wet or organic matter remains undecomposed because areas are too dry • ineffective denitrification • poor soil aggregation
Minimal compaction	• soil is soft, high organic matter content • good water infiltration • good soil aggregation • healthy plant growth	• soil is somewhat hard, especially during the dry season • water infiltration is limited in some areas • plants have difficulty getting water and nutrients from the soil	• soil is hard • little or no soil oggregation • little or no water infitration
Good infiltration	• vegetation coverage over the soil surface • good soil aggregation • relatively thick topsoil	• some loss of vegetation coverage • some runoff, erosion, or ponding of water observed • soil compaction on surface or within profile	• numerous areas bare of vegetation • loss of soil aggregation • soil is compacted • runoff and erosion observed even following light to moderate storms
Limited runoff	• good water infiltration • deep topsoil with good water holding capacity • high amount of organic matter in soil and good soil aggregation	• infiltration is somewhat restricted • water holding capacity of soil is somewhat limited • some soil compaction or relatively high water table	• infiltration is restricted • high soil surface compaction • limited water holding capacity of soil
Limited erosion	• complete vegetation cover over the soil surface • no indication of soil movement • stream is not muddied by runoff water	• some small rills present • water becomes muddy only after heavy rains	• rills and gullies present • soil is scoured where water flows over the surface • soil build up behind rocks • stream is muddied by runoff water

Sources: Belsky et al., 1999; Federal Interagency Stream Restoration Working Group, 2001; Naiman et al., 1992; Prichard, 1998; Renwick and Eden, 1999; Winward, 2000.

The hyporheic zone. Healthy riparian soils have a unique ecological zone composed of water-saturated oxygen-poor soils adjacent to soils that are drier and oxygen-rich. Referred to as the *hyporheic zone*, this transition area between aerobic and anaerobic conditions promotes biological transformations, such as denitrification and pesticide detoxification, and chemical transformations that influence the availability of phosphorus and iron (Cohen, 1997).

Denitrification occurs when soil organisms that grow under aerobic conditions transform organic nitrogen into nitrate, followed by the transformation of nitrate into atmospheric nitrogen by bacteria that thrive under anaerobic conditions. This process is important environmentally when the amount of nitrogen moving across the watershed into riparian areas is greater than the amount that can be used for riparian plant growth. The overapplication of nitrogen-containing fertilizers and manure on agricultural and residential landscapes is the primary source of nitrogen pollution of waterways. The amount of nitrogen entering streams is reduced when riparian areas are able to capture and remove nitrogen from runoff water. Natural riparian forests can denitrify and release 25 to 35 pounds of nitrogen per acre per year (Cole, 1981).

Phosphorus availability. Overapplication of fertilizer and manure can also overload the soil with phosphorus. Iron, aluminum, and calcium in the soil can bind excess phosphorus. In flooded soils, iron binds less phosphorus than it does in drier, aerobic soils. This decreased binding ability increases the availability of phosphorus both for plant uptake and for movement into surface water (Green and Kaufman, 1989). Since riparian areas have a limited ability to hold excess phosphorus, they are relatively ineffective in protecting streams against poor phosphorus management practices on upland areas. Thus, good upland management is necessary to protect against phosphorus pollution.

For additional information on the ability of riparian areas to control phosphorus movement into streams, please see Appendix 3.

Detoxification of contaminants. Riparian soils have a high concentration of peat, a partially decomposed organic material formed under primarily anaerobic conditions. Under wet, anaerobic conditions organic materials decompose more slowly than under aerobic conditions, since many more decomposing soil organisms require oxygen than thrive without it. Peat is a highly reactive material that has the ability to capture and hold many chemicals—nutrients, pesticides, heavy metals, and other contaminants—that flow off the uplands and into riparian areas (Cohen, 1997).

Other microorganisms found in the aerobic and anaerobic areas of the riparian zone are able to degrade toxic contaminants such as pesticides. Habitat competition by other soil microorganisms decreases populations of human and animal pathogens, such as *E. coli*, *cryptosporidium*, or *giardia*, that may be transported into streams from septic systems or manure piles (Stehman et al., 1996).

Table 3 (next page) compares soil characteristics in healthy riparian areas to those in degraded areas.

Riparian Areas and Habitat Preservation

Riparian areas provide food and habitat for a diversity of soil, aquatic, and terrestrial organisms. A multistoried plant canopy of annual and perennial grasses and forbs, as well as juvenile and mature shrubs and trees, provides a varied aboveground habitat for birds and wildlife and a belowground habitat for burrowing animals and soil organisms. Exposed roots and irregular streambanks provide breeding areas for many aquatic species, as well as habitat for algae and macroinvertebrates that are used as food by fish and other aquatic life. In addition, overhanging branches of riparian trees and sloughed off residues of riparian plants provide aquatic life with shade and habitat.

Aquatic habitat. Healthy riparian areas protect fish habitat by minimizing the movement of eroded sediments into streams. Heavy silt loads disrupt reproductive behavior and destroy feeding and spawing areas for many aquatic species (Thompson, 1984). For example, trout require gravel for reproduction and egg laying, while various gamefish need relatively clear

Table 3. Streambank and Channel Indicators

Indicator	Healthy Riparian Areas	Moderately Degraded Riparian Areas	Degraded Riparian Areas
Streambank Stability	• banks are at elevation of active flood plain • little or no streambank erosion • many strong, fine roots hold streambank in place	• some streambank erosion • some deep rooted riparian plants replaced by more shallow rooted or woody plant species	• streambanks are high • bends eroded by flowing water • plant roots either not present or uable to hold banks against scouring • trees are falling into stream
Stream Channel Shape	• channel is relatively narrow • banks are relatively straight with deep undercut that provides shade for aquatic species • stream has pools and meanders	• channel is wider than under natural conditions • banks are broken down in isolated areas • some loss of pools and meanders	• channel is shallow and wide • banks are laid back • banks are trampled where livestock enter the water to drink or cross the stream • loss of pools and meanders
Frequency of Riffles	• relatively frequent occurrence of riffles • distance between riffles is no more than 7 times the measurement of the width of the stream	• occassional riffles • bottom contours provide some aquatic habitat • distance between riffles is no more than 20 times the measurement of the width of the stream	• water is generally flat • if riffles are present, they are shallow and provide poor aquatic habitat • distance between riffles is greater than 20 times the measurement of the width of the stream
Riparian Water Table	• water table remains high and stable throughout the year • water loving vegetation predominates • riparian area provides an interface between wet and dry environments	• water table is not at bankful level • soil surface may dry out during the dry season • some drought tolerent upland plants present in the riparian zone	• water table is low or varies greatly throughout the year • drought tolerant or upland vegetation has replaced riparian vegetation • water table is too low to facilitate chemical and biological interactions between wet and dry conditions
Channel Alternation	• stream has not been subject to channelization, stream alteration, or dredging	• some channelization present, usually in areas of bridges or in urban areas • evidence of dredging or channelization having occurred over 20 years ago • drainage outlets from agricultural lands	• extensive channelization, especially in urban areas • banks shored with gabion or cement • instream habitat greatly altered or removed entirely

Sources: Belsky et al., 1999; Federal Interagency Stream Restoration Working Group, 2001; Huel, 1998; Naiman et al., 1992; Prichard, 1998; Renwick and Eden, 1999; Winward, 2000.

water to see prey and detect visual clues used in their social and reproductive behavior (Cohen, 1997).

The ability of riparian areas to stabilize stream flow levels throughout the year is also critical to the survival of many fish and other aquatic species. Fish need enough water in streams to navigate and find food. If a stream becomes polluted, decreasing water levels may concentrate pollutants to levels that are too toxic for fish. High water levels caused by stream flashing can rapidly increase water temperatures, which can be fatal to some fish and other aquatic organisms. Stable water levels provide the moderate water temperatures required for the growth of fish and the aquatic organisms that they use for food (Wenger, 1999; Cohen, 1997).

Large woody debris that falls into streams traps sediments and creates pools that provide protected, shaded habitats for aquatic species (Stuart et al., 1994). For trout, vegetation cover provides food and places to hide from predators (Burgess, 1985). For many aquatic organisms, leaves, twigs, and insects falling from overhanging trees are an important food source (Hillard and Reedyk, 2000). In naturally forested areas, retaining at least 50% of the tree canopy is critical for providing moderated temperatures required for good fish habitat (Whitaker-Hoagland, 1998).

Terrestrial wildlife habitat. Riparian areas are the main source of moisture for plants and wildlife within watersheds, especially in arid regions or during the dry season in more temperate climates. Riparian areas with a high density and diversity of foliage, both vertically and horizontally, can provide habitat and food for a diversity of birds and other terrestrial wildlife, including many endangered and threatened species (NRCS/RCA, 1996). Many animals also use these moist areas as travel corridors between feeding areas (Henry et al., 1999).

Many bird species depend on riparian areas for food, shelter, and nesting sites. Some bird species require riparian areas for nesting, although they may forage for food outside of these areas. Other bird species prefer nesting in riparian areas even if they can nest elsewhere. However, degradation of riparian areas reduces populations of these species (Bureau of Land Management and Partners in Flight, 2000).


Photo by USDA NRCS

Appendix 4 provides guidelines for adequate buffer widths to meet various environmental objectives.

Riparian vegetation growth, soil fertility and porosity, water quality, and stream flow conditions all affect the ability of fish and wildlife to thrive in streams and their associated riparian areas. Table 4 compares habitat conditions provided by healthy riparian areas to those of degraded areas.

Land Management Practices to Protect Riparian Areas

Key components of riparian protection are maintaining good soil and water conservation practices across the landscape and preserving, as much as possible, the integrity of the three natural riparian zones. Specific land management practices that protect riparian areas include:

- Maintaining a vegetative cover over the soil throughout the year
- Minimizing animal trampling or vehicle traffic on wet soils
- Avoiding overuse of fertilizers or manure that may be transported into riparian areas
- Avoiding applying or disposing of toxic chemicals on soils
- Protecting against loss of plant diversity and vitality in riparian areas
- Protecting against the establishment of exotic or non water-loving species in riparian areas
- Avoiding practices that artificially alter stream flow

Table 4. Indicators of Aquatic and Riparian Wildlife

Indicator	Healthy Riparian Areas	Moderately Degraded Riparian Areas	Degraded Riparian Areas
Water quality and quantity	• adequate water supply and quantity throughout the year • presence of macroinvertebrate indicators of good water quality such as caddis flies and mayflies • water contains few contaminant such as pesticides, heavy metals, or excess nutrients	• water tables fluctuate throughout the year • some contaminants present in the water	• streams dry up during the dry season • presence of mancroinvertebrate indicators of poor water quality • water contains toxic levels of sediments, pesticides, heavy metals, or nutrients • excessive aquatic weed growth in streams
Water Temperature	• streamside vegetation cools streams • undercut streambanks provide shade • presence of aquatic species used for fish food	• some reduction in streamside vegetation • decrease in the availability of aquatic species used for food	• stream temperatures are high • lack of streamside vegetation • low dissoloved oxygen levels • cool water aquatic species replaced by warm water species • lack of aquatic species to provide food for fish
Stream Pools	• numerous both deep and shallow stream pools • woody debris present to form pools • complex channel structures	• decrease in stream pools • woody vegetation replaced by herbaceous vegetation	• loss of stream pools • low amounts of woody debris due to loss of trees • channel straightening or modification to simplify channel structure
Sediment Load	• low amount of sediments in streams • water is clear or tea colored	• sediment levels in streams increasing	• stream muddy looking because of sediment load • floating algal mats or scum may be present
Nutrient and Pathogen Concentration	• natural concentrations of nutrients and pathogens from wildlife in area • little or no evidence of livestock access to streams	• nutrient and pathogen levels somewhat elevated • manure present but not concentrated on or near streambanks	• high concentrations of nutriets and pathogens in water • extensive amounts of manure on banks and in streams
Waterfowl Habitat	• native plant communities are dominant vegetation • land use delayed until chicks have left the nest • land is rested for several years to allow for homing, larger clutches, and earlier nesting • sufficient blocks of land are protected to provide corridors of movement and foraging	• some non-native species are present • land is used for grazing or other agricultural uses each year • land is insufficiently rested to provide vegetation cover for nesting	• non-native species are dominant vegetation • land is grazed or mowed while waterfowl are nesting • vegetation regrowth does not provide sufficient cover for nesting

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Table 4. Indicators of Aquatic and Riparian Wildlife (cont'd.)

Indicator	Healthy Riparian Areas	Moderately Degraded Riparian Areas	Degraded Riparian Areas
Fish Habitat	• fish cover provided by woody debris, overhanging vegetation, bank cobbles, pools, riffles, and undercut banks • water temperatures moderated by vegetation cover • minimal soil loss and pollution • good supply of aquatic insect species for fish to eat	• decrease in the types of fish cover available • some soil loss and pollution • water levels are unstable	• little or no fish cover provided • water contaminated by sediments and pollution • streams are ephemeral
Insect and Invertebrate Habitat	• habitat provided by woody fine debris, submerged logs, leaf packs, undercut banks and cobbles	• decrease in the amount of habitat sites available	• few or no habitat sites present
Mammal Diversity	• trails, tracks, feeding areas, and resting areas are present		
Macro-invertebrate Diversity	• predominately pollution intolerent species such as caddisflies, mayflies, stoneflies and riffle beetles	• predominantly moderately tolerent species such as damsel flies, dragonflies, aquatic sowbugs, blackfish and crayfish	• if macroinvertebrates are present, predominantly pollution tolerant species such as midges, craneflies, horseflies, leeches, aquatic earthworms, and tubificid worms
Bird Diversity	• presence of bird nests • species that are obligate dependent on riparian areas are present, for example Common Yellowthrout, Song Sparrow, and Willow Flycatcher	• decreasing presence of obligate bird species • presence of riparian dependent bird species such as goldfinch, bank swallow, grosbeak, or red-headed woodpecker	• lack of bird nest • if birds are present, species are similar to upland areas
Fish Diversity	• predominance of native species • pollution intolerent species, such as trout, small mouth bass and sunfish are present		• native species are not present • pollution tolerent species such as carp predominate

Sources: Belsky et al., 1999; Bureau of Land Management and Partners in Flight, 2000; Federal Interagency Stream Restoration Working Group, 2001; Huel, 1998; Mosley et al., 1998; Prichard, 1998; Sovell et al., 2000; Winward, 2000.

Community Watershed Collaboration to Protect Riparian Areas

> *Watershed councils lay the cultural foundations for a lasting way of life. They establish the tradition of responsible speech, of civil democracy, and of making decisions based on factual information and well-articulated values. They embody the long-term perspective of sustainability, seeking not quick fixes but deeper understanding and new alternatives.*
>
> Alan T. During (quoted in Wood et al.,1997)

Farmers, ranchers, and conservationists often become embroiled in debates over the use of riparian areas. If you are a farmer or rancher, you may be concerned about the loss of access to grazing land and watering areas as well as costs associated with management practices, such as the installation and maintenance of fences. If you are a conservationist or environmentalist, you may be concerned about the loss of habitat for birds, wildlife, and aquatic species that depend on this diverse and fragile ecosystem. If you are a downstream water user, you are no doubt concerned about the contamination of drinking and recreational waters with nutrients, pathogens, and pesticides.

Pinpointing sources and causes of riparian degradation and the associated degradation of water quality is very contentious. Farmers and ranchers often assert that livestock grazing in riparian areas cause less damage than construction activities, septic tanks, and industrial discharges. Conservationists often counter this assertion by contending that agriculture is the primary source of nonpoint pollution in many areas, and they maintain that excluding agricultural practices from riparian areas is the best method for protecting wildlife habitat and water quality.

To work together in restoring riparian areas, community members need to understand that riparian areas are only protected if all land users across the watershed work together. Getting this cooperation is often difficult since watershed users can easily blame others for causing water pollution and riparian degradation. Meanwhile, those involved in implementing good watershed and riparian management practices often go unnoticed and under-compensated.

Why is this so? Most watershed and riparian degradation is non-point source pollution, which by definition means that it is difficult to identify specific land use practices responsible for this pollution. Secondly, good upland and riparian grazing management practices in one part of the watershed cannot, in most cases, compensate for poor land management practices in other parts of the watershed. Thirdly, and possibly most importantly, land users who implement soil and water conservation practices often are asked to bear the costs of implementing changes while obtaining few of the benefits. This disparity between those who pay and those who benefit often discourages farmers and other landowners from implementing soil conservation and riparian management practices.

For more information on the economic costs and benefits of riparian buffer protection, please see Appendix 5.

The Bureau of Land Management, the U.S. Forest Service, and the Natural Resources Conservation Service understand that programs designed to promote soil and water conservation practices are often contentious. In their joint letter announcing the initiation of a program to help restore riparian areas (PLF, 2002), the agencies state that riparian restoration:

> *will not happen by regulation, changes in the law, more money, or any of the normal bureaucratic approaches. It will only occur through the integration of ecological, economic, and social factors and participation of affected interests.*

For watershed and riparian management programs to be effective, they should include the following elements (Wood et al., 1997):

- Active involvement by community members from across the watershed who represent a broad array of perspectives and problems
- Collaborative identification of program objectives, such as protecting high value resources and solving problems that most threaten the sustainability of the watershed
- Education and outreach

- Community access to and sharing of factual information on watershed economic, environmental, and social conditions
- Willingness to discuss and address critical but often contentious resource issues such as population growth, overconsumption, endangered species, and pollution
- Willingness to examine and implement long-term ecological solutions to watershed problems rather than look to "technological quick-fixes"
- Willingness of landowners and land managers to work together to develop a watershed or regional level coordinated approach to watershed management that will address upstream-downstream concerns and the need for management practices to be coordinated throughout the watershed to protect aquatic environments and provide continuous corridors for wildlife movement
- Baseline assessments and on-going monitoring of watershed and riparian conditions
- A combination of positive incentives (economic, personal values, prestige) **and** disincentives (regulations and policies) motivate involvement more than either one or the other alone (Alexander, 1993).

Summary

There is much scientific literature to document the importance of watershed and riparian management practices to the preservation of water quality, riparian vegetation, and the wildlife of riparian and aquatic areas. However, for farmers to be willing *and able* to adequately protect these vulnerable environments, these environmental benefits need to be balanced with economic benefits that farmers, ranchers, and other landowners may obtain from changing their land management practices. Downstream water users—including people who drink, cook, and bathe with water, people who use lakes and streams to boat, swim, and fish, and people who gain property value from the proximity of their home to a lake or river—also need to be willing to place a value on clean water and protected riparian habitats. As all community members become aware of the multiple benefits provided by good watershed management, they can work together to develop a consensus on a set of sustainable land management objectives.

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PDF
http://www.attra.ncat.org/attra-pub/PDF/riparian.pdf

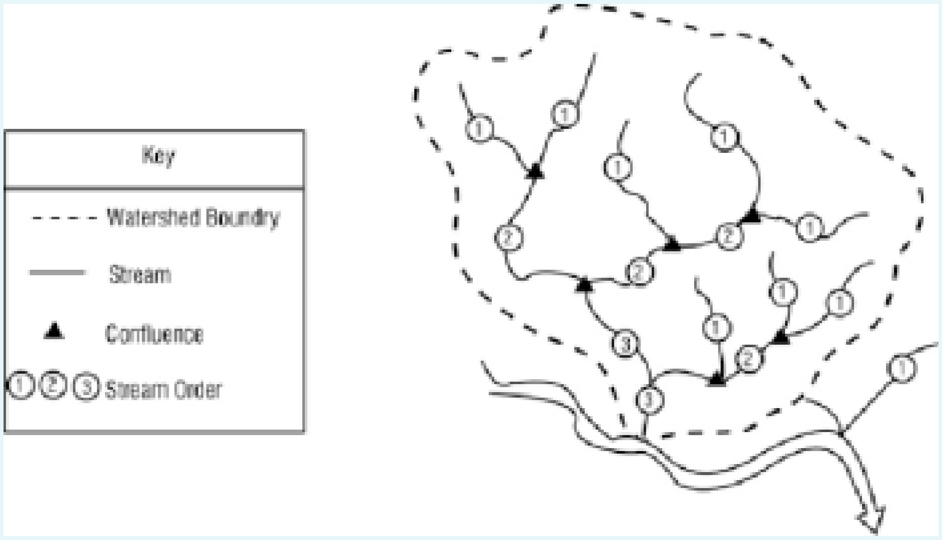
Appendix 1: Impacts of Local Ecology on Riparian Characteristics

Differences in Local Ecology

> *…different riparian areas have their own unique attributes and can and do function quite differently. As a result, most areas need to be evaluated against their own capability and potential. Even for similar areas, human influence may have introduced components that have changed the area's capability and potential. Assessments, to be correct, must consider these factors and the uniqueness of each area.* **(***Prichard, 1998***)**

Streams and their adjacent riparian areas exhibit differences in their hydrology, geology, and biology, not only on a regional basis but also as a stream moves from its headwaters to its outlet (Renwick and Eden, 1999). These differences are important to understand when choosing appropriate vegetation and land management practices for riparian restoration or when monitoring the conditions of streambanks and their surrounding riparian areas.

Stream order refers to changes in stream shape and flow from its origin as a headwater, or first order stream, to where it flows into a lake or ocean as a higher order stream.



Stream order designations. Lower numbers refer to headwaters and tributaries while higher numbers refer to larger downstream rivers.

Schueler, T. - No additional reference, as used on the web page of the Chester County Water Resource Authority, West Chester, PA. <http://www.chesco.org/water/Resource_Library/1st_order.html>.

The effects of stream order on riparian geology and vegetation are examined in Table A.1.

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Table A.1. Effect of Stream Order on Natural Riparian Characteristics

	Stream Order		
	Headwater or low order streams	**Transition or mid-order streams**	**Outlet or high-order streams**
Stream Characteristics			
Stream slope	• steep slopes	• moderate to steep gradient (between 1 to 6 degrees)	• shallow bank slopes
Riparian terrain	• hilly to mountainous terrain	• hilly	• rolling
Streambanks	• impermeable gravelly or rocky soils	• sandy or silty soils on banks • boulders and gravel on stream bottom	• deep soils with fine sediments
Stream shape and flow	• relatively narrow • rapidly flowing • cool water	• some meanders present	• slow moving • uniform width and depth • continuously changing meanders • wide basins
Hydrology	• predominantly runoff flows • flooding common	• combination of runoff and groundwater flows	• predominantly groundwater flows • stream flow levels are moderated
Streambank erosion	• occurs as infrequent, mass wasting processes		• occurs more frequently, but each incident tends to cause incremental changes • wider streams are better able to contain floodwaters
Stream structure debris	• boulders and large woody debris	• large amounts of woody debris	• sand bars, pools and riffles
Vegetation	• moisture-loving woody species	• combination of trees and grasses	• sedges, rushes, and grasses

Sources: Naiman et al., 1992; Undersander and Pillsbury, 1999; Federal Interagency Stream Restoration Working Group, 2001; Sovell et al, 2000; Gebhardt et al., 1989; Moseley et al., 1998

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Regional differences in climate have a large impact both on riparian characteristics and how wildlife and grazing animals use these areas. The Table A.2 examines how regional differences in rainfall and temperature affect the structure and function of riparian areas.

Table A.2. Effect of Rainfall and Temperature on Riparian Characteristics

Rainfall		
	Arid	**Moist**
Vegetation	• riparian vegetation is much more diverse than upland vegetation • woody vegetation is shrubby and relatively sparse • microbial soil crusts are an important component of soil vegetation cover	• riparian vegetation is relatively similar to upland vegetation • combination of trees, shrubs, grasses, and herbaceous plants
Soil characteristics	• alkaline	• neutral to acid pH
Seasonality	• short, distinct wet or monsoon season and long dry season	• relatively moist throughout the year
Streamflow	• distinct changes in stream height based on rainfall	• stream levels relatively stable throughout the year
Animal use	• animals dependent on lush vegetation except during the short, wet period	• animals feed more evenly between riparian and upland areas
Temperature		
	Mild Winter	**Cold Winter**
Seasonality	• ground does not freeze completely or throughout the winter • water infiltration can occur throughout the year	• ground freezes throughout the winter • distinct snow melt period common with accompanying ground saturation and runoff
Streamflow	• streamflow moderated by on-going water infiltration	• flooding common following snowmelt
Animal use	• animals less dependent on riparian vegetation during winter • animal trampling can compact moist, unfrozen soil	• animals more dependent on riparian vegetation during winter • frozen soil can withstand impact of animal trampling

Sources: Naiman et al., 1992; Huel, 1998; Prichard, 1998; Winward, 2000.

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Appendix 1, continued from page 24

Riparian Management in the Context of Local Conditions

Understanding how characteristics of riparian areas differ depending on local or regional conditions is important in the management, monitoring, and regeneration of riparian areas. Unfortunately, several examples exist of agencies or landowners who inadvertently harmed riparian conditions by using practices that were not appropriate for their locations.

Case 1. Soil conservation practices implemented in the 1930s did not take into account the ecological role of native vegetation and sought to protect streams by planting fast-growing trees, such as box elder, along streambanks. Unfortunately, the dense, woody vegetation did not permit the growth of understory vegetation. Without a deep-rooted grass cover, the streambanks in these riparian areas were severely undercut. In the absence of grasses and forbs covering the riparian soil surface, runoff water did not infiltrate into the soil where soil chemicals and organisms could filter out or transform contaminants. Instead, water running off the surrounding watersheds flowed directly into streams, forming rills and gullies and picking up additional sediments as it moved between trees planted in the riparian zones (Sovell et al., 2000).

This situation may have provided the context for results obtained from a Sustainable Agriculture Research and Education (SARE) funded project in Minnesota (Lentz, 1998) that monitored three areas along a stream.

> *This area was entirely fenced free of livestock in 1967. In 1988 the area was divided into three sections: the upper section was grazed three days per month, the middle section was grazed heavily once a year in early summer, and the lower section was never grazed.*
>
> *Ten years later, both the upper and middle sections, where grazing was allowed, have developed into prime trout habitat with the return of many native grasses and forbs, while the ungrazed lower section is heavily wooded and grass free, with broad shallow water and extreme bank erosion.*

These results appear to portray riparian grazing as better for the environment than natural wooded systems. However, other riparian grazing research, conducted in similar ecosystems, reported a high species richness in woody buffer strips (Paine and Ribic, 2001). Thus, non-native, fast-growing tree species that restricted understory growth probably dominated the lower section of the streambank in the Minnesota research.

Case 2. Streambanks in the Pacific Northwest were originally dominated by willows and other shrubs (Elmore, 1992). To restore these areas, a three-paddock rotation system was implemented. Each paddock in this system was subject to spring grazing one year, fall grazing the next year, and total rest the following year. This system of livestock grazing favored the growth of forage grasses but did not provide sufficient rest for woody plants to become established. Livestock access to mature trees during times when they were setting shoots and budding hindered the ability of the trees to grow and reproduce. Livestock ate or trampled the shoots of young trees. The lack of native woody species caused streamflows to become erratic, decreased water infiltration and water filtering, and increased streambank erosion.

Case 3. In other areas of the Pacific Northwest, some restoration projects recommended adding pieces of wood to streams to provide fish and wildlife habitat. Unfortunately, this "restoration" activity was used in some streams that historically flowed through meadows

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and did not previously contain much wood debris. In previously forested areas, where trees have been removed, these restoration projects added wood debris without considering restoring the riparian forest (NRC, 2002). This practice provides aquatic habitat on a short-term basis, but it does not address more fundamental riparian concerns, such as streambank erosion, stream shading, habitat for terrestrial species, and food for aquatic species.

These examples raise questions that you may want to ask when choosing or evaluating a riparian management practice:

- Does the practice favor the growth of either native vegetation or vegetation that grows under similar conditions and serves similar roles to native vegetation? For example, are you using practices that favor the growth of grasses and other herbaceous plants on meadowland, or are you planting riparian forests on land that under natural conditions did not support trees?
- Does the riparian management practice provide long-term solutions to environmental concerns, or is it just designed to provide short-term relief?
- If a new practice protects riparian areas better than an existing practice, do you know whether the existing practice is natural or introduced? Also, do you know whether the new practice is appropriate for the local conditions? For example, the intensive rotational grazing practices described by the SARE-funded project in Minnesota may provide significant watershed protection benefits. But the woody treatment was probably the remnant of an inappropriately designed "restoration" project rather than a natural "control."

Appendix 2: Guidelines for Riparian Area Revegetation

Often practices that protect riparian areas from grazing, plowing, trampling or other direct impacts will allow riparian vegetation to regrow and healthy riparian conditions to become reestablished. However, if riparian areas have become seriously degraded because of poor upland management practices, removal of riparian vegetation, or aggressive growth of invasive plant species, these areas may need to be revegetated.

Revegetation and restoration of riparian areas is particularly difficult in areas where invasive species have become prominent. By understanding the ecology of invasive species, farmers, ranchers, and conservationists can manipulate farming, grazing, and other land management practices to produce environmental conditions unfavorable for the growth of these species. For example, herbicides or inundation for 36 months can kill salt cedar (*Tamarix spp.*). Cutting is not effective, since this tree is able to resprout from its roots. This exotic tree is an aggressive colonizer of riparian areas in the arid west, often displacing native willows and cottonwoods and drying up springs and marshy areas because of its high water consumption (Washington State Dept. of Ecology, 2002a). Similarly, herbicides can control the aggressively growing purple loosestrife (*Lythrum salicaria*), which also cannnot be controlled by cutting, since it grows back from stems and adventitious roots. No native herbivores or pathogens are known to suppress this plant. Mulching with black plastic or organic mulches can provide some control (Washington State Dept. of Ecology, 2002b). While herbicides may be effective in killing existing noxious plant species, the die-back of these plants may open up bare ground to invasion by other noxious species. Herbicides also can degrade water quality and kill riparian and aquatic species.

Managed grazing can be used to control the spread of some noxious plants. Grazing invasive species when they are producing seed or spreading vegetatively can limit their spread. Sheep, goats, and certain species of cattle (e.g., Scottish Highland) can be used to control noxious brush species (Shepard, R. 2001; Luginbuhl et al., 2000).

In areas where invasive weeds can be controlled, the following guidelines can assist you in developing restoration and revegetation methods that are consistent with the ecological conditions of the area:

- Determine the natural environmental conditions and native vegetation of upland and riparian zones in the area.
- If seed sources for native plants are still present in the area, allow these plants to reestablish naturally for one year.
- Exclude riparian areas from cropping, grazing, or other invasive land-use practices, especially if these areas are highly degraded (see indicators in Tables 1, 2, 3, and 4).
- If riparian areas are only moderately degraded, you may be able to integrate grazing and other land use practices with riparian restoration practices. Select land use practices that favor the growth and reproduction of critical native species.
- Be aware that weed growth will surge for some time after riparian areas are allowed to naturally regenerate. If seed sources for native plants are present and invasive plants are not present in significant numbers, native plants will be able to compete with weeds as soil conditions improve and the water table rises.
- If riparian areas are unable to reestablish functional vegetation on their own, revegetate these areas using native species and proper land preparation practices.

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- Understand how vegetation species change naturally over time (local natural succession processes) and plant riparian areas with species naturally found in areas just recovering from a flood or a fire (early succession) rather than the type of plants found after recovery processes have stabilized (climax vegetation). Plants characteristic of early succession will catch sediments, causing streambank build-up and the enhancement of riparian water storage. These conditions will then facilitate the survival of latter succession, water-loving riparian species.
- Allow new plants to become well established and for succession processes to become established before grazing livestock or using other land management practice in the revegetated area. This establishment period may take several years, especially in arid areas or areas that were severely degraded.
- Restore upland areas in conjunction with the restoration of riparian areas. This will reduce the potential for riparian area degradation from water runoff, soil erosion, and preferential foraging by livestock and wildlife.
- Allow natural streamflow processes to occur—some flooding helps riparian areas to regenerate by depositing nutrient-rich soil and producing conditions suitable for the reestablishment of riparian species (Briggs, 1993; Naiman et al., 1992).

Appendix 3: Limited Ability of Riparian Areas to Control Phosphorus Movement into Streams

Improper management of phosphorus-containing fertilizers or manure across a watershed can stress the capabilities of riparian areas to protect against stream pollution and unbalanced algae growth that causes oxygen depletion and fish kills. Phosphorus attached to eroded sediments may be trapped by riparian vegetation only to be transported into streams later. As phosphorus accumulates in riparian areas, plants take it up, then die back and decompose. The mineralized phosphorus can then be transported by ground water flows into the adjacent stream. Alternatively, phosphorus-laden sediments may be washed into streams during floods (Naiman and Decamps, 1997; Uusi-Kamppa et al., 1997).

Runoff water often transports dissolved phosphorus through riparian areas directly into streams. Following intense storms or sudden snowmelts, runoff flows rapidly over the surface of the soil, often forming sheets or rivulets of water. These concentrated flows cannot be slowed sufficiently by streamside vegetation to be effectively absorbed by riparian soils. Even if water flow is slow enough to allow for soil infiltration, soils that already have an excess of phosphorus will not be able to hold any additional phosphorus transported into the area (Gilliam, 1994). The best protection against phosphorus movement into streams is to:

- Minimize runoff and erosion from adjacent areas
- Do not apply phosphorus fertilizers or manure at rates in excess of those needed for crop production or forage growth
- Monitor soil test levels of phosphorus in both upland and riparian soils to ensure that this nutrient is not building up in the soil to excessive levels
- Remove excess phosphorus from the soil through successive harvests without additional phosphorus fertilization

Appendix 4: Recommended Buffer Widths

Farmers and ranchers often want to know the minimum buffer width that they can use to obtain the environmental benefits afforded by a healthy riparian system. For land managers interested in balancing farm profitability with environmental protection, this distance is vitally important. If more land is placed into riparian buffers than is necessary to protect water quality or preserve aquatic habitat, potential profits are sacrificed. However, if the buffer width is insufficient to provide environmental benefits, then farmers lose profits while the larger public gains little from their efforts. The question of buffer width has been at the heart of wetland, water quality, and wildlife protection discussions for many years. The Natural Resources Conservation Service (NRCS) prescribes a minimum width of 15 feet on either side of streams and waterways within its Conservation Practice Standard 390—Riparian Forest Buffer (NRCS, 1998). NRCS Conservation Standard 391—Riparian Herbaceous Cover states that:

> *Riparian widths will vary depending on the requirements of wildlife species and associated environmental concerns.*

The appropriate width for a riparian buffer depends on a combination of management and environmental factors, and the priority given to these sometimes conflicting factors. Ideally, riparian buffers are maintained to provide all the environmental benefits discussed above. Government programs, and many landowners, tend to prioritize environmental concerns and weigh implementation costs against farm profits to identify practices that provide the greatest environmental benefit for the least cost. Under this scenario, a relatively small buffer area may be sufficient if the highest priority is reducing the transport of nitrogen into streams and good soil conservation practices are used on the adjacent fields. If protecting an endangered bird species is the prime concern, and the riparian area is surrounded by degraded uplands, a much wider and more diversified riparian buffer may be required.

The publication *A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation* (Wenger, 1999) provides an excellent overview of the hydrological, soil, topographic, and climate factors that need to be considered in assessing appropriate riparian buffer width. While this review focuses on the environmental conditions found in Georgia, its guidelines illustrate how different riparian use priorities affect buffer width and vegetation requirements. For example:

- A minimum of 100 feet of buffer width is required to effectively trap sediments, with wider buffers required on sloping lands
- The amount of sediment captured by riparian buffers declines by 7% to 38% as the slope increases from 11% to 16% (Dillaha et al., 1988). To account for this decreasing efficiency of riparian buffers in capturing sediments from steeper slopes, Swift (1986) recommends buffer widths based on the following formula:

  43 feet + (1.39 feet) x (%slope)
- Buffers 197 feet wide provide the greatest efficiency in the removal of eroded sediments
- Fifty foot buffers are usually sufficient to provide nitrogen control through plant uptake and denitrification
- Fifty feet is the minimum width for buffers to effectively trap and transform contaminants, including metals, pesticides, and biological pathogens, into less harmful forms
- Native forest buffers 35 to 100 feet wide are required to protect aquatic habitat: logging should be limited within this buffer zone to ensure that streams are adequately shaded, woody debris is available for habitat, and sediment inputs into streams are minimized.

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- Native forest buffers 300 feet wide are necessary to provide habitat for diverse terrestrial riparian wildlife
- A generalized buffer width recommendation for the protection of water quality is 100 feet, plus an additional 2 feet for each 1% of land slope. Buffers should also be extended to the edge of the floodplain.

Wildlife have specific habitat requirements for foraging, raising their young, and hiding from predators. The following list provides suggested buffer widths for different wildlife and bird species (CRJC, 2001):

Wildlife dependent on wetlands or watercourse	**Desired Width**
Bald eagle, nesting heron, cavity nesting ducks	600’
Pileated woodpecker	450’
Bobcat, red fox, fisher, otter, muskrat	330’
Beaver, dabbling ducks, mink	300’
Amphibians and reptiles	100-330’
Belted kingfisher	100-200’
Songbirds	
Scarlet tanager, American resdstart, rufous-sided towhee	660’
Brown thrasher, hairy woodpecker, red-eyed vireo	130’
Blue jay, black capped chickadee, downy woodpecker	50’
Cardinal	40’
Cold water fisheries	100-300’

In his review, however, Wenger (1999) notes that buffer width recommendations have the following limitations:

- While buffers are effective when water flow is uniform across a slope (sheet flow), their effectiveness in trapping sediment greatly decreases when water flow is concentrated into channels or small streams.
- The effectiveness of buffers to trap phosphorus declines over time. As phosphorus concentrations build up in riparian area, these areas may release more phosphorus into streams than they capture. Forested buffers leak more phosphorus than do grassed buffers (Osborne and Kovacic, 1993).
- To be most effective, buffers must extend along all streams, including intermittent and ephemeral channels.

Appendix 5: Economic Costs and Benefits of Riparian Buffer Protection

A comprehensive study of riparian areas by the National Research Council (2002) concluded that:

> *The future success of at least five national policy objectives – protection of water quality, protection of wetlands, protection of threatened and endangered species, reduction of flood damage, and beneficial management of federal public lands – depends on the restoration of riparian areas.*

Despite documented and wide-ranging benefits provided by riparian buffers, few state or federal regulations either prohibit potentially degrading land-use practices in riparian areas or provide incentives to protect the integrity of these fragile ecosystems (NRC, 2002).

Good riparian buffer management provides society with many economic benefits. Maintaining the function of riparian areas to reduce non-point source pollution can substantially reduce community costs for clean water (Qui and Prato, 1998). In Fairfax County, Virginia, the retention of forested riparian buffers reduced costs caused by water runoff following storms by $57 million (Palone and Todd, 1997). In addition, surveys of residents of the watershed indicated that they placed an economic value on many environmental contributions provided by buffers, such as the protection of habitat for endangered species and ensuring the survival of important fish species, such as salmon (Wenger and Fowler, 2000). In Georgia, riparian buffers have been incorporated into town and county planning ordinances. Besides providing environmental benefits, buffers were shown to also reduce the cost of treating drinking water, provide recreation and tourism benefits, attract new businesses and residents, and "protect the long-term economic health of a community" (Nelson et al., 2001).

For farmers and ranchers, protecting riparian areas involves the actual costs of establishing and maintaining them as well as the potential costs associated with loosing access to these areas (Nakao and Sohngen, 2000). Potential economic benefits landowners may obtain from riparian buffer establishment include:

- Value of trees or forages that can be harvested from riparian area
- Potentially cleaner water for livestock and for irrigating crops
- Protection from regulatory fines and other expenses

Farmers may obtain additional benefits if land management changes are made on a whole-farm basis. For example, ranchers in Manitoba, Canada, experienced greater weight gain from their cattle and obtained better pasture forage growth after implementing rotational grazing and riparian buffer management practices, as well as installing alternative watering systems (Sopuck, 2001). Economic studies of rotational grazing practices report increased profitability compared to conventional systems. On dairy farms, these savings are attributed to lower costs for fertilizer, seed, machinery, and labor (Berton, 1998) while on beef farms, savings come from increased land carrying capacity, decreased parasite problems, and lower animal handling expenses (Macon, 2002).

The Conservation Reserve Program (CRP) and the Wildlife Habitat Incentives Program (WHIP) are designed to provide farmers with economic incentives for riparian protection. These programs, administered through the Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA), provide farmers with technical assistance for planting forests or vegetation in riparian areas and economic assistance for installing stream fencing and alternative watering systems, and for revegetating streambanks.

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Farmers also obtain annual payments to maintain riparian areas and keep them out of production. Unfortunately, payments provided under these programs are often less than farmers could earn from growing crops or raising animals in riparian areas. The environmental and conservation objectives of NRCS or FSA may also limit a farmer's access to these programs. In addition, farmers enrolled in crop subsidy programs may see decreased subsidy payments and additional regulations if they enroll in CRP or WHIP (Stoodley, 1998).

Table A.3 (next page) provides a list of federal and non-government programs that assist farmers in the protection of riparian buffer areas.

Table A.3. Incentive Programs for Riparian Protection

Federal Programs

Natural Resources Conservation Service

Conservation Reserve Program (CRP)
http://www.fsa.usda.gov/pas/publications/facts/html/crp02.htm
- provides 25% of cost to restore riparian areas, 50% of cost to plant riparian vegetation, and pays yearly rental rates

Wildlife Habitat Incentives Program (WHIP)
http://www.nrcs.usda.gov/programs/whip/WhipFact.html
- provides technical assistance and cost-share payments to help establish and improve fish and wildlife habitat

Wetland Reserve Program
http://www.nrcs.usda.gov/programs/wrp/
- helps landowners restore and protect wetlands on their property. Provides technical assistance and covers costs of wetland and riparian restoration activities. Pays rental rate for keeping land out of agriculture

Farmland Protection Program
http://www.nrcs.usda.gov/programs/fpp/
- provides up to 50% of fair market value for conservation easements on highly erodible agricultural land

U.S. Fish and Wildlife Service

Partners for Fish and Wildlife Program
http://partners.fws.gov/
- provides landowners with economic and technical assistance to protect fish and wildlife habitat on their land

Bring Back the Natives Grant Program
http://cfpub.epa.gov/fedfund/program.cfm?prog_num=2
- address land management practices to eliminate causes of habitat degradation and provide multiple species benefits within watersheds with land managed by the Bureau of Land Management, the Forest Service, or the Bureau of Reclamation

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Table A.3. Incentive Programs for Riparian Protection (cont'd.)

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Non-Profit Organizations

The Conservation Fund
http://www.conservationfund.org/
- community-based grants for land and water conservation efforts, including land easements, riparian protection, environmental education programs, and sustainable ranching practices

The Nature Conservancy
http://nature.org/
- community-based programs to protect wildlife and wildlife habitat through land use and riparian protection programs and conservation easements

National Fish and Wildlife Foundation
http://www.nfwf.org/index.htm
- community-based grants for riparian restoration and other projects to protect the habitat of fish and wildlife

Trout Unlimited
http://www.tu.org/index.asp
- the Embrace-A-Stream (EAS) grant program funds hands-on fishery resource, research, and education work by Trout Unlimited chapters and councils, including watershed assessment and planning, native fish recovery, riparian reforestation, and stream channel restoration.