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Managed Grazing in Riparian Areas

Livestock Systems Guide

Abstract: This publication is designed to help farmers and ranchers identify and use locally appropriate grazing practices to protect riparian resources. Methods for protecting these environmentally fragile areas include keeping livestock from streambanks, properly resting pastures to restore degraded land, and determining the proper duration and season for grazing pastures. It examines adjusting general recommendations to fit your particular management objectives and environmental conditions.

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Introduction

Most riparian areas in the U.S. evolved with animals feeding on the lush vegetation and trampling on the streambanks to get to water. Although the original grazers were bison, moose, and deer rather than cattle, sheep, and goats, this evolutionary pressure means that most native riparian plant species regrow following a period of grazing (Mosley et al., 1998; Ohmart, 1996). When farmers and ranchers displaced these occasional grazers with continuously grazing livestock, riparian areas suffered. Provided with limited grazing area and little stimulus to move from one area to another, continuously grazed livestock trampled streambanks, congregated in the shade and cool breezes next to streams, and overgrazed the lush vegetation in these fertile areas.

Related ATTRA Publications

- Protecting Riparian Areas: Farmland Management Strategies
- Sustainable Pasture Management
- Rotational Grazing
- Nutrient Cycling in Pastures
- Assessing the Pasture Soil Resource
- Matching Livestock and Forage Resources in Controlled Grazing
- Grazing Networks for Livestock Producers

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Of the original riparian habitats in the western U.S., The Bureau of Land Management (BLM) and the U.S. Forest Service have estimated that only 20% still exist. They further noted that 46% of the riparian areas managed by the BLM were "functioning at risk," another 20% were "non-functioning," and that "riparian areas continue to decline." In large part, they attributed this decline in riparian health to the increased number of cattle on western rangelands (Belsky et al., 1999).

Nationwide, the National Research Council (NRC, 2002), with help from seven federal agencies, conducted a comprehensive study of riparian areas that found:

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Traditional agriculture is probably the largest contributor to the decline of riparian areas… The primary effects of livestock grazing include the removal and trampling of vegetation, compaction of underlying soils, and dispersal of exotic plant species and pathogens. Grazing can also alter both hydrologic and fire disturbance regimes, accelerate erosion, and reduce plant or animal reproductive success and /or establishment of plants. Long-term cumulative effects of domestic livestock grazing involve changes in the structure, composition, and productivity of plants and animals at community, ecosystem, and landscape scales.

Management intensive or rotational grazing seeks to protect land resources by mimicking the activities of wildlife. Instead of a herd of animals spreading out across a large pasture and grazing it throughout the season or year, livestock are grouped together and forced to graze a small pasture or *paddock* for a limited amount of time. When they have eaten about half the grass in the paddock, they are moved to another paddock and not allowed to return to the first paddock until the forage has grown back.

Research studies show that managed grazing can simultaneously enhance farm productivity, decrease input expenses, and protect the environmental conditions on the farm (Macon, 2002; Herrick et al., 2002; Paine et al., 1999; Berton, 1998). Even government agencies and environmentalists, who implicate continuous grazing as a primary cause of riparian degradation, now join with farmers and ranchers in promoting managed rotational grazing as a way to protect riparian areas (Lyons et al., 2000; Moseley et al., 1998; Leonard et al., 1997; Elmore, 1992).

Brush and weed management is the greatest potential environmental benefit that managed grazing provides to riparian areas. In Wisconsin, fisheries managers often contract with farmers to rotationally graze riparian areas. Brush removal by cattle maintains grassy buffers that are more effective in protecting water quality and providing fish habitat than are some woody buffers (L. Paine, personal communication). In various locations goats are used to control noxious weeds and non-native brush species in riparian areas, allowing for the growth of plants that provide healthy riparian conditions (Pittroff, 2001; Luginbuhl et al., 2000).

This publication provides guidelines for using managed grazing to protect riparian areas. These guidelines are based on the understanding that upland and riparian areas are not mutually exclusive systems but are interrelated parts of the watershed. Thus, the riparian grazing practices discussed here work together with management intensive grazing of upland areas to maintain farm productivity, economic viability, and environmental health. If you are not already familiar with rotational grazing, Table 1 provides a comparison of rotational and continuous grazing methods. I also recommend that you refer to the following ATTRA publications prior to implementing practices discussed here:

- Sustainable Pasture Management
- Rotational Grazing
- Matching Livestock and Forage Resources in Controlled Grazing
- Nutrient Cycling in Pastures
- Assessing the Pasture Soil Resource

Also, prior to reading this publication, you may want to read the ATTRA publication *Protecting Riparian Areas: Farmland Management Strategies* for background information on the structure and function of riparian areas and how they provide environmental, social, and economic benefits.

Upland Land Management Practices and Riparian Area Protection

As discussed in the ATTRA publication *Protecting Riparian Areas: Farmland Management Strategies*, good soil and water conservation practices on upland areas represent the first, and perhaps the most critical step for the protection of riparian areas. Healthy riparian areas are able to capture runoff water, filter out sediments, recycle nutrients, decrease pathogen populations, and degrade some toxic chemicals. However, upland areas with bare ground, eroded land, and compacted soil limit the ability of riparian areas to perform these functions. Concentrated runoff from degraded upland areas can flatten riparian vegetation and wash in seeds of invasive or upland plants that compete with native riparian plant species, while eroded sediments can bury preferred, water-loving vegetation (Debano and Schmidt, 1989). Runoff water can also contaminate riparian areas and streams with nutrients and pathogens carried in from agricultural areas or septic systems.

Unmanaged livestock grazing can degrade upland areas in three major ways:

- Livestock compact soil by trampling it, making paths, or repeatedly congregating in the same areas.
- Livestock without sufficient or good-quality forage will feed selectively on their preferred forages, reducing the ability of those species

Table 1. Comparison of Management Intensive and Extensive Grazing Practices

Management Practice	Management Intensive Grazing	Extensive Grazing
Number of paddocks	• numerous small pastures or paddocks • flexible in size • delineated using electric fences	• livestock grazed in a large, undivided pasture or range
Grazing duration	• limited grazing time, then moved to another paddock • dairy animals—moved once or twice a day. • meat animals—moved approximately every 3 to 7 days.	• livestock graze continually for an entire season within the same area • animals graze on the same pasture, during the same season, year after year.
Forage use monitoring	• forage use by animals monitored • animals moved when they remove about one-third to one-half of the forage growth	• monitoring forage use is minimal • forage management focus is on whether to cut, fertilize, or spray pasture
Pasture forage regrowth	• pastures rested and provided with sufficient time for forages to regrow before animals are allowed to graze again • height of forage used to determine when to permit grazing	• pastures are not usually rested
Alternative water sources	• water troughs or other water sources available • water sources are located away from streambanks	• water troughs or other water systems usually not provided • livestock usually dependent on streams for drinking water
Pasture selection based on soil conditions	• manager knowledgeable about the soil conditions in each paddock • animals not allowed to graze in areas with wet soils or erodible land	• animals have access to streambanks throughout the year • environmentally sensitive areas are not protected
Pasture shape and layout	• paddocks are set up to optimize forage use by grazing animals • watering areas, shade, and minerals are located in different areas of the paddock • pasture arrangement encourages animals to move rather than to congregate	• large pastures permit animals to move around large areas at will • animals are not discouraged from congregating for long times in one location
Management decision making	• continual monitoring of livestock and pasture resources • management practices revised based on observations • managers look for solutions within the context of the agro-ecosystem • land and animals are managed to keep problems from happening	• managers usually use “technological fixes” to address problems in pastures • production problems addressed after problem is observed • management methods focus on treatments such as spraying or fertilizing

Sources: Angermeier, 1997; Elmore, 1992; Clary and Webster. 1989.

to survive or reproduce. This creates bare areas and promotes the growth of weeds.

- Congregating livestock deposit manure and urine in concentrated areas.

Unmanaged grazing practices can damage the structure and function of riparian areas in similar ways:

- Livestock transport seeds and vegetative propagules of noxious weeds into riparian areas.
- Most livestock selectively congregate in riparian areas, especially during hot weather.
- During hot, dry weather, livestock selectively graze on the more palatable species found in moist riparian areas, in preference to woodier or more mature plants found in upland areas.
- Livestock trample on moist riparian soil, causing soil compaction, hindering plant growth, and breaking down streambanks.
- Congregating livestock deposit manure and urine in and near streams.
- Livestock trample or congregate in streams, loosening bottom sediments and damaging stream channel shape and structure.

Table 2 provides more detailed information on the potential impacts of unmanaged grazing in riparian areas on soil and water resources, wildlife habitat, and human health and economic concerns.

While conservationists and other non-farm community members often blame farmers and ranchers for riparian degradation, these rural land managers may also be victims of poor upstream urban and suburban land management practices. Non-agricultural land use practices such as forestry, home building, road construction, and urban and suburban development can also decrease water infiltration and increase runoff, erosion, and contaminant transport into riparian areas (Wang et al., 1997). These non-agricultural activities that can degrade downstream grazed pastures or rangelands include:

- Replacement of forests and fields by houses, roads, and parking lots that do not permit water infiltration and encourage rapid, short-term or flash flooding in streams and ditches
- Artificial stream widening or straightening
- Construction, road maintenance, logging, or other activities that expose bare soil to the forces of erosion
- Poorly constructed or maintained septic systems
- Industrial or municipal activities that involve disposal of toxic materials
- Runoff of lawn chemicals, road salt, oil and tar from roads, yard waste, and other urban wastes

Poor upstream land management practices can also degrade riparian areas by increasing the potential for:

- Flooding of pasturelands
- Streambank erosion and the loss of pastureland into the stream
- Transport of contaminated soil onto pastureland
- Water contamination that could affect the health and productivity of livestock
- Loss of dependable quantities of water to meet the needs of livestock

The ATTRA publication *Protecting Riparian Areas: Farmland Management Strategies* discusses strategies for developing effective watershed management programs that recognize that everyone living in a watershed contributes to watershed problems and has a responsibility to find and implement solutions to these problems. This publication also provides a list of government programs that may be able to provide you with economic or technical assistance as you seek to implement riparian protection practices.

Managed Grazing for Riparian Protection

Farmers and ranchers use managed grazing practices in various areas of the country to improve pasture productivity, increase livestock growth, and protect riparian areas (Lyons et al., 2000; Clark 1998; Skinner and Hiller, 1996). The term "managed grazing" encompasses a range of strategies and philosophies. But the most critical component is *management*.

Most riparian grazing results suggest that the specific grazing system used is not of dominant

Table 2. Unmanaged Grazing Impacts on Riparian Structure and Function

Livestock Activities	When are Riparian Areas at High Risk for Damage?	How do Livestock Affect Soil and Water Resources?	What are the Effects on Society and the Environment?
• Manure deposition in and near streams • In-stream trampling and congregating by livestock	• When manure is deposited near streams during times of heavy rainfall or snowmelt • When manure is deposited in streams during the dry season when water levels are low	• Nutrients and pathogens from manure added to streams • Sediment loading of riparian areas and streams	• Decrease in available oxygen • Formation of toxic compounds • Decreased ability of fish to spawn and grow • Change in aquatic species • Human health impacts • Increased water treatment costs
• Soil compaction by livestock trampling	• When soils are wet or saturated • When animals graze or congregate in the same area for an extended period of time	• Increased erosion • Sediment loading of riparian areas and streams	• Impaired spawning and foraging by aquatic organisms • Disruption of fish migration • Alteration in aquatic food web • Increased cost of water filtration
• Loss of vegetation by livestock trampling and grazing	• During plant emergence • When environmental conditions slow plant growth • When forages are overgrazed	• Reduced water infiltration • Increased runoff	• Increased flooding • Reduced groundwater recharge • Lowered water table
		• Increased water velocity	• Removal of submerged vegetation • Reduced aquatic habitat diversity • Vulnerability of fish to flash floods • Increased streambank erosion
• Breakdown of streambanks by trampling	• When soil is wet or saturated • When there is little vegetation cover • When it is hot and livestock seek to cool themselves in the shade of streamside trees • When livestock seek to cool themselves in the stream • When alternative water sources are not available and livestock have unrestricted access to streams for drinking water	• Change in channel shape, structure, and form	• Lowered groundwater table • Narrowing of the riparian zone • Replacement of riparian by upland vegetation • Decreased plant roots to hold banks in place • Increased water turbidity • Fewer hiding spaces and pools for fish
		• Decreased streambank stability	• Reduced spawning habitat • Suffocation of fish eggs

Table 2 continued on page 7

Table 2. Unmanaged Grazing Impacts on Riparian Structure and Function, cont'd.

Livestock Activities	When are Riparian Areas at High Risk for Damage?	How do Livestock Affect Soil and Water Resources?	What are the Effects on Society and the Environment?
• Continuous grazing and trampling by livestock • Selective grazing on palatable species	• When soils are wet or saturated • During plant emergence • When environmental conditions slow plant growth • When forages are overgrazed	• Decreased herbaceous cover	• Less food for stream and aquatic organisms • Less shade and higher stream temperatures • Decrease in streambank stability • Less sediment trapping • Decreased water infiltration
		• Decreased species and age diversity	• Replacement of riparian by upland vegetation • Loss of sensitive bird species and wildlife habitat
• Browsing on trees and shrubs	• When forages are limited • During the hot, dry season when animals congregate near streams	• Decreased tree and shrub cover	• Decline in streambank stability • Less shade and higher stream temperatures • Loss of habitat for wildlife
• Livestock transport of seeds and vegetative propagules of noxious weeds into riparian areas	• When noxious plants are present in other areas of the pasture • When riparian areas are sufficiently degraded to favor propagation of noxious or invasive weed species	• Displacement of native species by noxious weeds	• Loss of food and habitat for wildlife • Water table lowered because of high water uptake by noxious species • Decreased amount of palatable forages

Sources: Sovell et al., 2000; Belsky et al., 1999; Leonard et al., 1997; Beegle et al., 1998

importance, but good management is—with control of use in riparian areas a key item (Clary and Webster, 1989).

Other critical components of riparian grazing practices include (Leonard et al., 1997; Clary and Webster, 1989):

- Combining managed upland grazing practices with good riparian grazing management
- Installing alternative watering systems and controlling grazing to minimize deposition of manure in or near streams
- Adapting grazing management practices to local conditions and to the species being grazed
- Employing long-term rest from grazing when riparian areas are highly degraded
- Employing short-term or seasonal rest to protect wet streambanks and riparian vegetation that is emerging, regenerating, or setting seed
- Maintaining streambank structure and function by maintaining a healthy cover of riparian vegetation
- Using a flexible approach that involves documenting mistakes so that they are not repeated

Grazing management guidelines to accomplish these objectives are provided in Table 3.

Use Practices that Keep Livestock from Streams and Streambanks. As with upland grazing practices, livestock should be managed to ensure that they optimize forage use, graze evenly across paddocks, and do not congregate in any certain area. Constructing small paddocks that are more square than rectangular and placing water and any supplements at different corners of the paddocks encourages livestock to move around paddocks. Alternative water systems and controlled crossing areas are critical management tools for riparian areas. Providing livestock with water away from the stream keeps them from trampling and undercutting streambanks when they go to drink. It also can provide them with water that is cleaner, resulting in fewer veterinary bills and more productive growth. The appropriate watering system for your farm or ranch depends on the source of water, terrain of the land, and power availability for pumping (Burns and Buschermohle, 2000; Fyck, 2000). For large farms, solar or wind power may be an effective source of energy for pumping water. Of the two, solar power is usually the more cost-effective since it is relatively easy to install, requires little maintenance, and remains reliable for a long time (Morris et al., 2000; Buschermohle and Burns, 2000). Further information can be found in the ATTRA publications *Solar-powered Livestock Watering Systems* and *Freeze Protection for Solar-powered Livestock Watering Systems*.

If livestock need to cross streams, provide them with controlled stream crossings in the form of bridges, ramps, or designated fords. For designated fords, cover the stream bottom with coarse gravel to provide the animals with firm footing, while discouraging them from congregating or wallowing in the stream (Undersander and Pillsbury, 1999). In areas where streambanks or riparian vegetation is degraded and livestock exclusion is necessary to allow riparian areas to recover, solar-powered electric fences can provide a relatively inexpensive and low-maintenance method for setting up paddocks and exclusion areas (Morris et al., 2000). Your local Natural Resources Conservation Service can provide technical—and possibly some economic—assistance in the installation of stream crossings.

Controlled access points for stream crossing

Pastures that include a combination of riparian and upland areas should be grazed only when both areas have good-quality forages and tem-

Table 3. Riparian Management Guidelines

Management Objectives	Management Practices
Allow degraded riparian areas to recover	• Fence livestock out of heavily damaged riparian areas • Monitor area to identify regeneration of healthy riparian structures and functions • If necessary, revegetate riparian areas using native grasses and annuals and proper land preparation practices • Allow new plants to become well established before allowing livestock to graze in the revegetated area.
Minimize livestock dependency on riparian vegetation	• Limit grazing to times when the palatability of upland vegetation is relatively similar to that of the riparian vegetation • Install fences to enclose "special use" riparian paddocks which should be both relatively small to allow for careful management and include a combination of ecologically similar upland and riparian areas
Allow riparian vegetation to grow and reproduce	• Allow grazed plants to reestablish leaf area and build up stored reserves in their roots before regrazing the area • Do not graze vegetatively reproducing plants while they are spreading • Do not graze seed producing plants while they are setting seed • Do not graze when environmental conditions, such as cold weather or drought, restrict plant growth • Control noxious weed growth in upland pastures to minimize movement of seeds and vegetative propagules into riparian areas
Reduce soil compaction	• Do not allow grazing while the soil is wet or saturated • Do not graze compacted areas during spring thaws, during periods in winter before the land freezes, or when thaw conditions are likely • Do not graze riparian areas when banks are sloughing or breaking down • Minimize prolonged grazing or congregation around water, under shade, or in other favored areas • Discourage the formation of pathways
Minimize stream bank degradation	• Provide livestock with alternative sources of water • Provide livestock with designated stream crossing areas • Do not allow livestock to congregate in riparian areas for extended periods
Reduce concentration of manure in or near streams	• Place mineral supplements and watering tanks away from streambanks • Place sharp stones in any water crossing areas to discourage lounging in streams • Construct ramps or bridges to provide stream crossings that are not within the stream bed

Sources: Undersander and Pillsbury, 1999; Fitch and Adams, 1998; Moseley et al., 1998; Elmore, 1992

peratures are moderate. In arid areas, this usually occurs in late spring, while in more humid areas it occurs in late spring to late summer. If forage availability in upland areas is limited, livestock will selectively graze the riparian areas. They will also congregate in riparian areas during hot weather since the riparian areas are cooler. Unless grazing times are limited, animals will congregate along streambanks, causing soil compaction, vegetation loss by trampling and overgrazing, and water quality problems by depositing manure close to streams.

Methods for attracting livestock away from riparian areas

(Leonard et al., 1997)

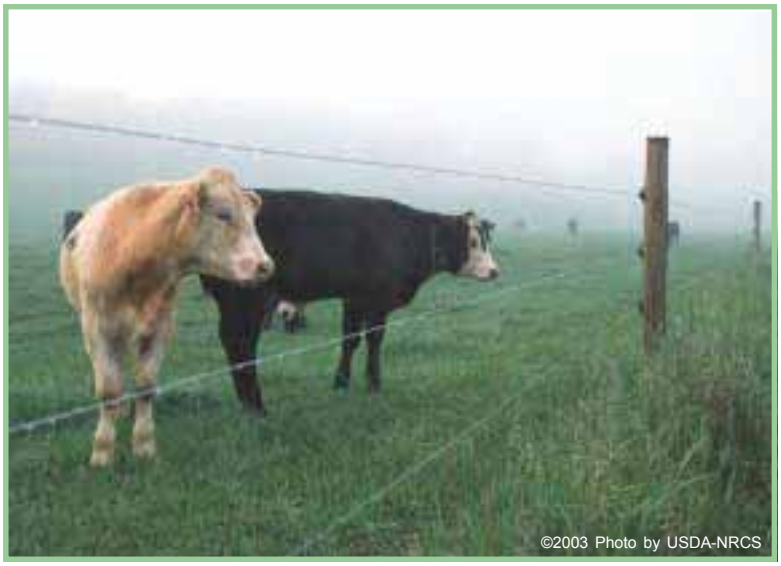
- Provide alternative watering systems.
- Plant palatable forage species on adjacent upland areas.
- Graze riparian areas when upland vegetation is abundant and riparian vegetation is in peak growth. Do not graze riparian areas when they are wet or scorched by drought.
- Use prescribed burning on upland areas to enhance forage production and palatability.
- Place feed supplements such as salt, grain, hay, or molasses in upland areas of paddocks away from the riparian areas.
- Place brush or boulders along streambanks to discourage livestock from grazing and congregating in riparian areas .

Funded by a Southern Sustainable Agriculture Research and Education (SARE) grant, researchers at Virginia Tech worked with a grazier to determine when "alternative watering systems could attract grazing cattle—which naturally seek cool streams during summer—away from the river. The impact was dramatic. The cattle clearly preferred to go to the water troughs. This resulted in decreased nutrient loading and sedimentation in the stream" (Berton, 1998).

Adapt Grazing Management Practices to Local Conditions. Upland managed grazing seeks to integrate forage and livestock production. This requires producers to adapt grazing practices to the type of livestock being raised, local environmental conditions, and seasonal climate changes. Thus, dairy farmers in Wisconsin or New York use very intensive rotational schedules for their milking herds, while beef farmers in Colorado or New Mexico use a much more extensive longer-duration rotation schedule. The difference in the grazing practices of these two situations reflects differences between high-production dairy herds feeding on lush, rapidly growing forages and slower-gaining beef animals feeding on more sparse vegetation.

Similarly, guidelines for well-managed riparian grazing systems cannot be "one size fits all." Instead:

> *The effectiveness of a given system depends on how well it fits both the ecological conditions of the grazing area and the management requirements of the livestock enterprise. Too often a grazing system developed for a specific application has been used elsewhere without adequate consideration of local site conditions (Elmore, 1992).*



Adaptation to local conditions involves understanding the following characteristics of the riparian areas being managed:

- What is (or was) the native vegetation: forests, shrubs and brush; or grasses, sedges, and reeds?
- What is the stream order: a first-order headwaters or a higher order tributary?
- What is the stream channel geology: is it rocky, gravelly, or composed of sediments?
- Is it a cold (trout) stream or a warm-water stream?
- What are the climatic conditions: is it humid or arid? Are winters cold throughout the season, or do freeze–thaw conditions occur?
- During which season do the heaviest rains usually fall: when vegetation is actively growing or during times when vegetation is dormant or emerging?

You need to take these issues into consideration when you develop and implement riparian grazing practices. If, instead, you follow "to the letter" practices developed in an environment different from your own, your well-intentioned management efforts may prove to be ineffective or even detrimental to riparian protection. See Table 4 for guidelines in selecting managed riparian grazing systems appropriate to your locality and to the management objectives of your farm or ranch.

Sovell et al. (2000), working in southeastern Minnesota, demonstrated that streams with grassy buffers were able to catch and filter eroded sediments better than woody buffers, which had little understory vegetation. They also found that when grassy riparian areas were continuously grazed, streams had high coliform counts and turbidity. But when grassy riparian areas were rotationally grazed, water quality was not significantly different from that measured in ungrazed grassy buffer strips.

They noted that rotational grazing did cause coliform counts to rise briefly while the cattle were grazing on streambanks. However, these counts decreased within two weeks after taking animals out of the riparian paddocks.

Based on these results, the researchers concluded that for streams that move slowly through the plains and rolling hills of Minnesota, rotationally grazing riparian areas can protect water quality as well as, if not better than, some woody buffers. They also found that short-duration rotational grazing of streambanks had only limited and short-term impacts on water quality.

Employ Long-term Rest from Livestock when Riparian Areas are Highly Degraded. While grazing and riparian restoration can coexist in many areas, in highly degraded areas livestock exclusion is necessary to initiate the recovery process. The duration of the necessary rest period depends on the amount of degradation, the local environmental conditions, and whether active restoration practices are being implemented in addition to providing the area with rest from livestock. Ultimately, the objective of providing rest is the recovery of the streambank and its functional riparian plant community (Clary and Webster, 1989).

Before discussing methods for resting and restoring riparian areas, let's examine some typical characteristics of severely damaged riparian areas (Shock, 2000; Moseley et al., 1998; Whitaker-Hoagland et al., 1998; Platts and Raleigh, 1984):

- A low water table and decreased water storage capacity
- Slow vegetative growth and poor forage production
- Limited vegetation and roots to help protect and stabilize banks
- Change in vegetation species and types, replacement of native vegetation by exotic vegetation, or replacement of water-loving vegetation by upland vegetation
- In areas with woody riparian areas, reduced numbers and health of trees, combined with limited shade and higher temperatures of stream water

Table 4. Managed Riparian Grazing Systems

Management Practice	Description of Grazing System	When to Use This Practice	Management Guidelines	Comments
Pasture Layout				
Riparian-Upland Pasture	• Relatively small rangeland paddocks containing both upland and riparian vegetation	• Enough good quality forage available in upland areas so livestock do not depend on riparian vegetation for their foraging needs	• Remove livestock while upland forages are still plentiful	• Designate riparian paddocks for special use such as reserve forage or dormant season grazing
Riparian Pasture	• Riparian areas managed separately from uplands	• Paddocks relatively small so that livestock impact on soil and vegetation can be carefully monitored and managed • Useful for obtaining specific management objectives, such as weed management • Timing of grazing not dependant on condition of upland vegetation	• Monitor and manage to restore favorable riparian conditions	• Season and duration of grazing selected to favor growth of desired vegetation and to deter propagation of undesired species
Corridor Fencing	• Permanent exclusion of livestock from stream-bank areas by fences	• Provides rapid recovery of degraded riparian areas	• Permanent fences are costly and may exclude use of riparian areas that have become revegetated and environmentally functional • Electric or other non-permanent fences allow more management flexibilty at a lower cost	• Farmers and ranchers are often hesitant to install corridor fences • Corridor fencing alone does not address management needs of the broader landscape

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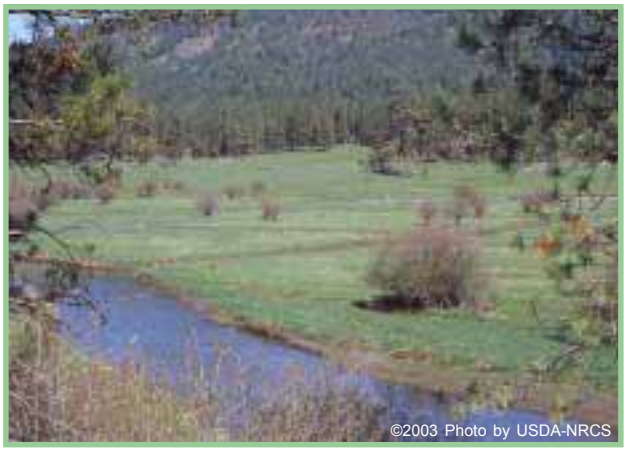
Table 4. Managed Riparian Grazing Systems, cont'd.

Management Practice	Description of Grazing System	When to Use This Practice	Management Guidelines	Comments
Guidelines for Rotating Animals				
Time-controlled grazing	• Uses recurring periods of grazing and rest among several paddocks • Rate of rotation varies with the rate of plant growth • Management focuses on obtaining ecological and production objectives	• Intensive management allows for protection of critical riparian resources • Useful for dairy and other high production livestock operations	• In most riparian areas, livestock should be moved when 4 to 6 inches of forages remain • Specialized timing and intensity of grazing can be used to control weed growth	• Short-duration, intensive stocking can produce hoof action that helps incorporate manure and seeds into soil while increasing pathways for water infiltration • Hoof action can be detrimental in arid areas where microbiotic crusts are critical for soil health
Seasonal rotation	• Livestock grazed only during times when risks to the environment are limited • Relatively short grazing periods used but not managed as intensively as time-controlled grazing	• Good for beef production operations • Riparian areas should be in healthy condition prior to using this system	• Implement with alternative watering systems and other practices that encourage animals to congregate away from streambanks	• Goats can be grazed in riparian areas if brush or less palatable weeds need to be cleared out
Three pasture rest rotation system	Three pasture rotation system • Only 2 pastures grazed each year • Rotation schedule for pastures - year 1: spring grazing; year 2: late summer and fall grazing; year 3: complete rest	• Designed to meet physiological needs of herbaceous plants • Not appropriate for use in shrub-dominated riparian areas since young woody plants do not have sufficient rest time to become established	• A semi-extensive grazing practice that rests each pasture area once every 3 years • Needs to be managed to protect against streambank degradation in spring and forage depletion in the fall	• If used in woody riparian areas, limit grazing time during the late summer rotation to when herbaceous crops are only half used. This will limit livestock feeding on woody plants. • Adding more pastures will increase the amount of time land is rested and will further protect woody species

Sources: Undersander and Pillsbury 1999; Fitch and Adams, 1998; Mosley et al., 1998; Leonard et al., 1997; Clark, 1998; Clary and Webster, 1989; Elmore, 1992.

- Excessive sediment in the channel from bank and upland erosion
- Reduced or eliminated late-summer stream flows
- Poor fish habitat because of poor water quality and/or poor channel morphology
- Poor wildlife habitat quality
- High coliform bacteria counts from upland waters or adjacent land

Areas that are badly degraded or have been abused for many years will take a long time to recover. Similarly, riparian areas in more fragile environments, such as arid regions or areas with long winters, will take a longer time to recover than areas with more moderate climates or more humid conditions. In western ranges, degraded areas should be rested until vegetation provides a complete cover over the soil surface and at least half of the vegetation is composed of natural species (Winward, 1989). For riparian areas across the country, the rest period should also allow for the establishment of sufficient vegetation to stabilize the streambank, filter sediments, and allow nutrient recycling. Management practices that favor riparian area revegetation include (Askey-Doran, 2002; Oversby and Smith, 2001; Undersander and Pillsbury, 1999; Briggs, 1993):



- Checking to see whether seed sources for native plants are still present in the area. If they are, allow these plants to reestablish naturally for one year.
- Being aware that weed growth will surge for a time after livestock are excluded from the riparian area. If seed sources for native plants are present, these plants will be able to compete with upland plant species as soil conditions improve and the water table rises.
- Providing weed control, especially if invasive or noxious weeds are present. If you prefer not to use herbicides, you can smother weeds with organic matting. Desired plants can be planted through this matting. In less degraded areas, grazing once or twice in the late summer can control weeds.
- Using the natural regeneration of plants to guide your choice of plants to use for assisted revegetation.
- Planting native grasses and forbs if riparian vegetation is not able to regenerate naturally.
- Stabilizing streambanks with rip-rap or fast-growing plants before revegetating other portions of the riparian area.
- Allowing new plants to become well established before allowing livestock to graze in the revegetated area. This establishment period may last several years, especially in arid or severely degraded areas.

Grazing Duration. You can rotationally graze riparian areas that have established a high water table and a diverse cover of water-loving vegetation while not harming, and in some cases even benefiting, riparian conditions. However, the length of time that an area can be grazed and the duration of rest periods between grazing cycles depends on the plant species growing in the riparian area, the type of livestock you are grazing, the amount of prior degradation, local environmental conditions, and your production objectives. Providing riparian areas with sufficient rest for critical plant species to regrow and reproduce is central to maintaining riparian health. In fact, several leading researchers and practitioners stress that timing rest periods appropriately and providing a sufficient duration of rest are more important than the specific grazing practice used (Leonard et al., 1997; Elmore, 1992).

Graziers often use stubble height to monitor upland pasture conditions and to help them make decisions regarding when to rotate livestock. Stubble height can also be used as a management tool in riparian areas. The recommended height of forage residues following grazing differs ac-

cording to environmental conditions (Clary and Leininger, 2000). For example:

- Four-inch (10 cm) stubble will usually maintain plant vigor, trap sediment, and protect soils from compaction when trampled.
- In woody streambanks, moving livestock after they have grazed the forage to 6–8 inches (15–20 cm) may be necessary to ensure that they are not feeding on willows or other riparian trees because of a lack of non-woody forages.
- Stubble height is not a useful guide in areas where streambanks are rocky or where woody vegetation dominates in the riparian zone.

Seasonality of rotational grazing practices in healthy riparian areas. Besides duration of grazing, the time of year when livestock are allowed access to riparian areas is also critical to maintaining and restoring riparian health. Factors that determine the appropriate time to graze animals in riparian areas include:

- Riparian soil moisture following snowmelt, rainfall, and heavy streamflows
- Dominant type of riparian vegetation and its periods of peak growth and dormancy
- Reproductive characteristics of critical riparian plants: do they reproduce vegetatively or by seed? If by seed, when does it set?
- Freeze and thaw cycles during the winter

Riparian areas should not be grazed when they are wet and most vulnerable to compaction. In the northern U.S., this means excluding animals from riparian areas during late winter snowmelts and spring rains and not allowing animals in until the soil dries. Similarly, in areas with heavy late-season rains, livestock should be moved out of riparian areas in the fall.

Timing of riparian grazing is important for preventing erosion and the degradation of soil and water quality. In the spring, grazing should be delayed until vegetation completely covers the riparian soil. This ensures that animals do not dislodge bare soils and cause erosion. Fall grazing can be used in some areas if it is carefully monitored, leaving enough vegetation at the end of the season to protect against spring runoff and erosion. Thus, riparian areas should either be grazed in the early fall to allow for forage regrowth before winter or grazed later in the fall, but only on a limited and well-monitored basis.

Timed grazing can also be used to protect healthy vegetative growth in riparian areas. Periodic grazing can be used to remove the apical meristems or top portions of grasses and sedges. This promotes vegetative reproduction by stimulating the sprouting of additional stalks or tillers (Mosley et al., 1998). However, in areas where annual plants are critical components of the riparian ecosystem, grazing should not occur when these species are setting seed.

Table 5 provides a summary of environmental conditions to consider when deciding which seasons are most appropriate for riparian grazing in your area.

A report from the Saskatchewan Riparian Project (Huel, 1998) describes how careful timing and reduced duration of grazing in riparian areas improved environmental conditions and productivity on a ranch in the east-central part of the province:

The 3700 acre pasture had previously been divided into two very large paddocks which were grazed continuously throughout the summer by two herds of cattle. The cattle spent most of their time close to the creek, overgrazing this area while areas farther away were hardly grazed at all. This resulted in poor riparian condition, productivity and severe damage to the streambanks. In 1993, a grazing management plan divided the two large paddocks into eleven smaller units and created additional water sources. The riparian area was divided into three paddocks, one or two of which are rested each year. When these paddocks are grazed, gazing is deferred until the end of summer. These practices have improved the condition and productivity of the riparian area considerably as indicated by plants returning to the areas of bare soil on the streambanks. These environmental benefits have been achieved with no overall reduction in livestock numbers.

Understand How Different Livestock Species Graze. Grazing managers should understand the grazing patterns of the animals they manage (Stuth, 1991). Different species prefer

Table 5. Appropriate Times for Grazing as Affected by Local Environmental Conditions

Management Practice	Description of Grazing System	Is This Practice Appropriate for your Area?	Management Guidelines	Comments
Winter grazing	• Livestock graze riparian areas during winter after the ground has frozen	• Requires cold winters that do not have freeze-thaw conditions • Should not be used when trees are young or becoming established	• Remove livestock from riparian areas before ground thaws • Maintain sufficient vegetation cover for the capture of spring runoff • Monitor stands of herbaceous vegetation to ensure that livestock are not forced to depend on trees for forage • Place salt and minerals away from riparian areas	• Vary grazing locations from year to year • Cull or exclude animals that loaf in riparian areas
Spring grazing	• Livestock graze riparian areas during spring	• In arid areas, time grazing to coincide with times when the palatability of upland forage is similar to that of riparian forages • In humid climates, graze after streambanks have dried out, but remove livestock before vegetation growth slows down because of late summer dry conditions	• Manage grazing to ensure adequate seed growth and root production	• Hoof action in the spring can mix seeds and litter with the soil • Soil texture determines how dry soils need to be before livestock can trample on streambanks without causing compaction
Fall grazing	• Livestock grazing is deferred until fall	• Initiate grazing when cool-season species have become productive on adjacent upland areas • Defer grazing until grass and sedge seeds have ripened and been dispersed • Effective in areas where cool streambank temperatures discourage animals from congregating in riparian areas	• Monitor vegetation cover to ensure a complete cover remains to protect soil against winter and spring runoff and erosion • Monitor browsing on woody species to ensure protection of these plants	• Promotes the growth of herbaceous plants • Decreases the growth of woody species

Sources: Undersander and Pillsbury 1999; Mosley et al., 1998; Leonard et al., 1997; Elmore, 1992.

different forages and graze them to different heights. Species that forage on shrubs and trees may do so at different stages in the plants' growth. Different livestock species also have different herding and camping characteristics. Grazing management practices should be designed to work with an animal's natural preferences and instincts (Leonard et al., 1997).

Grazing livestock in riparian areas on hot days should be avoided since animals tend to congregate on streambanks where they find shade and cooling breezes. Conversely, on cool days, cold air pockets found in riparian areas will discourage livestock from grazing or congregating in these areas (Moseley et al., 1998). Sheep tend to cause less damage to riparian areas than cattle because they do not like to congregate in low-lying areas where they feel vulnerable to predation (Glimp and Swanson, 1994). In contrast, large herbivores, such as cattle, are "central place foragers," with their central place being near water (Stuth, 1991).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Specialized grazing management practices can also successfully control weeds and non-native woody species. By understanding the growth habits and reproductive cycles of noxious and non-native plants in relation to those of desired riparian plants, the timing and duration of livestock grazing can be managed to favor their feeding on weeds or unwanted brush (Paine and Ribic, 2001). Changing or combining livestock species can also help control weeds. For example, goats can be used to control blackberries, multiflora rose, honeysuckle, and many other troublesome plants (Luginbuhl et al., 2000). In California, goats are used to control yellow star thistle (Pittroff, 2001), and in Wisconsin, a research study is using Scottish Highland cattle in rotational grazing to help control prickly ash, multiflora rose, wild parsnip, and box elder (Shepard, 2001). For more information on the use of multispecies grazing for weed control, see the ATTRA publication, *Multispecies Grazing*.

A ranching family in the Diablo Canyon area of California has restored native perennial grasses by using high-density short-duration grazing with cattle and browsing of coastal scrub by goats. They rotate Spanish meat goats through brushy areas two to three times per year. This practice has allowed them to "demonstrate effective and environmentally sensitive vegetation management within the scope of an economically viable meat goat business" (Macon, 2002).

Summary

Management intensive rotational grazing provides farmers and ranchers with a method for productively managing their livestock while protecting ecologically important riparian ecosystems. To be effective, these management practices must be flexibly implemented based on knowledge of local climate, native riparian vegetation, current riparian health, and livestock behavior.

Rotational grazing can also be installed incrementally to obtain the most benefit from each change. For example:

- First, install alternative watering systems away from streambanks. This will increase animal productivity by ensuring access to clean water while protecting riparian areas by encouraging animal congregation around the troughs rather than on streambanks or in streambeds.
- Alternatively, install controlled stream access points. Encouraging animals to drink or cross streams in specific, managed locations will cut down on random trampling of streambanks, and will also decrease the risk of animal injury.

- Secondly, improve upland forage quality through a combination of rotational grazing, overseeding, and fertility management. As upland forage quality improves, animals will be less likely to selectively feed on riparian plants.
- As you install fences for rotational grazing, set up sufficient paddocks to keep livestock out of riparian areas during times when these areas are most vulnerable to degradation. High-risk times include when the soil is wet or partially frozen, when plants are emerging or setting seed, or when plant cover is limited because of dry conditions.

While the guidelines provided in this publication can assist you in the design and initial implementation of productive and environmentally beneficial riparian grazing practices, locally appropriate management requires ongoing monitoring of livestock and riparian health. It also requires the flexibility to revise management practices based on your observations and management objectives. Cooperative Extension Educators, Natural Resource Conservation Service grazing specialists, and other experienced graziers can help you monitor and adjust your grazing practices. Grazing groups provide an excellent opportunity to learn from the experience of others, while providing you with the opportunity to ask questions about practices you are trying out on your farm. For a list of grazing groups in the U.S. and suggestions for starting a group, see the ATTRA publication *Grazing Networks for Livestock Producers*.

Recommended References

Citation	Annotation
Pasture management in moist climates	
Clark, E.A. 1998. Landscape variables affecting livestock impacts on water quality in the humid temperate zone. Canadian Journal of Plant Sciences. Vol. 78. p. 181–190.	Provides an overview of grazing impacts on water quality in humid climates. This paper argues that the potential impact of grazing on water quality is affected by climate, landforms, and biophysical characteristics of the watershed. Managed grazing practices can minimize impacts of livestock on water quality.
Huel, D. 1998. Streambank Stewardship: A Saskatchewan Riparian Project. Saskatchewan Wetland Conservation Corporation. Regina, Saskatchewan. Accessed at: <http://www.wetland.sk.ca/pdfs/landowner/streamstew_FULL.pdf>.	A well-illustrated guide to riparian area ecology, restoration, and agricultural use. Contains several riparian health checklists and case studies of farmers and ranchers who implemented riparian conservation practices.
Moseley, M., R.D. Harmel, R. Blackwell, and T. Bidwell. 1998. Grazing and riparian area management. p.47–53. In: M.S. Cooper (ed.) Riparian Area Management Handbook. Oklahoma Cooperative Extension Service, Division of Agricultural Services and Natural Resources, Oklahoma State University and the Oklahoma Conservation Commission. Accessed at: <http://pearl.agcomm.okstate.edu/e952/e-952.pdf>.	This short article provides a nice combination of ecological and management guidelines. A description of the relationship between grazing pressure and forage growth is followed by strategies to manage grazing in riparian areas. Four grazing management choices are outlined: encouraging animals to use upland areas, allocating riparian areas into special use pastures, providing total exclusion from riparian areas, and constructing controlled access points.
Sovell, L.A., B. Vondracek, J.A. Frost, and K.G. Mumford. 2000. Impacts of rotational grazing and riparian buffers on physiochemical and biological characteristics of southeastern Minnesota, USA, streams. Environmental Management. Vol. 26, No. 6. p. 629–641.	A well documented comparison of rotationally-grazed, fenced grass, and woody riparian buffer areas and their impact on water chemistry, physical habitat, biotic indicators, fecal coliform, and stream turbidity. Results showed that grassy or rotationally-grazed buffers protected against stream sedimentation better than woody buffers.

Recommended References continued on page 19

Recommended References, cont'd.

Citation	Annotation
Pasture management in moist climates, cont'd.	
Shelton, V. No date. Streamside Grazing in Indiana. Natural Resources Conservation Service. Accessed at: <http://www.ftw.nrcs.usda.gov/glti/presentations.html>.	A Power Point slide presentation that provides guidelines for management of riparian areas in Indiana grazing systems. Focus is primarily on alternative water systems and stream crossing areas used to minimize the time animals spend in and near streams.
Undersander, D., and B. Pillsbury. 1999. Grazing Streamside Pastures. University of Wisconsin Extension, Madison, WI. 16 p.	A short but clearly written pamphlet focusing on intensive managed grazing of grassy streamside pastures. Practical advice on paddock layout, installing alternative watering systems, reseeding streambanks, and managing trees in riparian areas is provided.
Range management in arid environments	
Clary, W.P., and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. Gen. Tech. Rep. INT-263. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.	Provides recommendations for grazing methods appropriate to riparian areas at different levels of functional health or degradation. Focuses on the use of grazing practices to achieve environmental objectives including streambank stabilization and habitat restoration.
Elmore, W. 1992. Riparian responses to grazing practices. In: R.J. Naiman (ed.) Watershed Management: Balancing Sustainability and Environmental Change. Springer-Verlag. New York.	Describes the role of riparian areas in protecting water quality and storing water for recharge of subsurface aquifers and how poorly managed grazing practices have degraded these functional capabilities of riparian areas. Several types of rotational and seasonal grazing practices are described, with their application to specific environmental conditions emphasized.
Leonard, S., G. Kinch, V. Elsbernd, M.Borman, and S. Swanson. 1997. Riparian Area Management: Grazing Management for Riparian-Wetland Areas. Technical Reference 1737-14. U.S. Department of the Interior. Bureau of Land Management. National Applied Resource Sciences Center. Denver, CO.	A concise overview of riparian management objectives is followed by a detailed discussion of livestock interactions with the riparian environment and how grazing practices that protect riparian areas take both animal behavior and plant growth characteristics into account. Particular emphasis is placed on grazing management strategies and their impact on riparian areas. Guidelines are provided to help producers determine the appropriateness of strategies for their location.
Cows and Fish. Alberta Riparian Habitat Management Program. 2002. Accessed at: <http://www.cowsandfish.org/index.html>.	A very detailed Web page developed by a multi-agency program in Alberta, Canada. Includes highly illustrated, easy-to-use checklists for monitoring streambank health, water quality in riparian areas, biodiversity, and grazing practices. Also provides agency personnel with guidelines for implementing community-based riparian protection programs. Case studies of communities and producers are available through this Web site.

Recommended References continued on page 20

Recommended References, cont'd.

Citation	Annotation
Range management in arid environments, cont'd.	
Macon, D. 2002. Grazing for Change: Range and Watershed Management Success Stories in California. California Cattlemen's Association, Sacramento, CA.	Profiles of nine ranches in California and how land owners and managers have implemented changes to enhance the productivity of their operation while meeting their stewardship goals. Each profile compares the historic management of the land with current management practices with emphasis placed on tools and innovations used to obtain management objectives. Ranchers also discuss how they modify practices based on on-going monitoring of their animals and land.
Sustainable Ranching Research and Education Project: Ranching With Nature. University of California Cooperative Extension. 1998. Accessed at: http://www.foothill.net/~ringram.	This project is dedicated to research to develop sustainable ranching techniques, increase rancher awareness of sustainable alternatives to conventional practices, and help ranchers increase the sustainability of their business. Besides written material, they also sell an audio tape series is based on information from the California Grazing Academy.
Water and Riparian Area Issues of Western Rangelands. Rangelands West. Policy Issues. 2002. Accessed at: http://rangelandswest.org/policy/water.html	An excellent list of annotated links to projects involved in riparian protection and management on western rangelands.
Riparian ecology and buffer management	
Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation. Vol. 54, No. 1. p. 419–431.	A comprehensive survey of the scientific literature on livestock impacts on riparian areas in arid, western rangelands. Well-referenced tables summarize livestock impacts on water quality, stream channel morphology, hydrology, soils in riparian zones, instream vegetation, streambank vegetation, and aquatic and riparian wildlife. While authors acknowledge differences between extensive and more managed grazing practices on riparian degradation and the potential for riparian recovery, most articles cited address impacts of extensive grazing. Authors note that a review of the literature on managed grazing practices in the West indicates that these practices afford protection of riparian areas and allow these fragile ecosystems to recover, but state that in all cases reviewed, exclusion provided better protection than riparian grazing.
Butler, L.D., J.B. Cropper, R. H. Johnson, A.J. Norman, and P.L. Shaver. 2002. National Range and Pasture Handbook. United States Department of Agriculture. Natural Resources Conservation Service. Grazing Lands Technology Institute, Fort Worth, TX 472 p. Accessed at: <www.ftw.nrcs.usda.gov/pdf/NRPH.PDF>.	Developed as the basic policy handbook for NRCS to assist farmers and ranchers in planning and applying resource conservation practices on rangelands, this document also serves as a detailed guide to the management and ecological assessment of rangelands. Chapters cover inventory of grazing land resources, management of grazing land, livestock nutrition, husbandry, and behavior, rangeland and pastureland hydrology and erosion, and wildlife management on grazing land. Evaluation documents include detailed checklists of resource indicators including indicators for riparian health and a decision support guide for considering riparians for grazing.

Recommended References continued on page 21

Recommended References, cont'd.

Citation	Annotation
Riparian ecology and buffer management, cont'd.	
Correll, D.L. 1997. Buffer zones and water quality protection: general principles. In: N.E. Haycock, T.P. Burt, K.W.T. Goulding, and G. Pinay (eds.) Buffer Zones: Their Processes and Potential in Water Protection. The Proceedings of the International Conference on Buffer Zones September 1996. Quest Environmental. Harpenden, Hertfordshire, UK. p. 7–20. Accessed at: <http://www.riparianbuffers.umd.edu/manuals/correll.html>.	A succinct review of the literature on buffer zones and water quality protection, focusing on biochemical reactions in the reduced soil environment of stream buffers. Interrelationships between denitrification, vegetative growth, and nutrient retention by buffers are clearly described. Seven pages of references.
Federal Interagency Stream Restoration Working Group. 2001. Stream Corridor Restoration: Principles, Processes, and Practices. Part 653 of the National Engineering Handbook. USDA-Natural Resources Conservation Service. Accessed at: <http://www.usda.gov/stream_restoration/newtofc.htm>.	Provides an overview of stream corridors, steps in restoration plan development, and guidelines for implementing restoration of riparian areas. Part I describes stream corridor structure, processes, functions, and impacts of disturbances. Part II examines restoration plan development, and Part III describes how information in the first two parts can be used to create a riparian restoration initiative.
R.J. Naiman (ed.) Watershed Management: Balancing Sustainability and Environmental Change. Springer-Verlag. New York.	Chapters in this book address watershed ecology, impact of grazing and other land use management practices on watershed structure and function, and methods for organizing diverse groups of people to discuss watershed concerns and implement watershed management practices and policies.
Naiman, R.J., and H. Decamps. 1997. The ecology of interfaces: Riparian zones. Annual Review of Ecology and Systematics. Vol. 28. p. 621–658.	A comprehensive and clearly written overview of the ecology of riparian areas. Issues addressed include nutrient cycling, channel morphology, plant cover and diversity, wildlife habitat, human impacts on riparian ecology, and riparian restoration and management.
National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. National Academy Press. Washington, D.C. Accessed at: <http://books.nap.edu/books/0309082951/html/index.html>.	Describes structures, functions, and environmental services of riparian areas and the impacts of local environmental conditions and human activities on these characteristics. Detrimental impacts of human activities on riparian areas are subdivided into hydrological (stream) alteration, agricultural, industrial, urban, and recreational impacts. After reviewing the current status of riparian lands in the U.S., authors provide recommendations for land management practices, legal ordinances, and monitoring tools for riparian area protection.

Recommended References continued on page 22

Recommended References, cont'd.

Citation	Annotation
Riparian ecology and buffer management, cont'd.	
Prichard, D. 1998. Riparian Area Management: A User's Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. Technical Reference 1737-15. U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center. Denver, CO.	The form and function of riparian areas are described with particular emphasis on monitoring tools for assessing the condition of riparian areas. Scientific evidence is provided for each indicator explaining potential causes for degradation and how changes in riparian structure affect environmental functions, such as water quality protection and provision of wildlife habitat.
Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. Office of Public Service and Outreach. Institute of Ecology. University of Georgia. Athens, GA. Accessed at: <http://outreach.ecology.uga.edu/tools/buffers/lit_review.pdf >.	While this publication was developed to provide local governments in Georgia with guidelines in developing riparian buffer protection plans, information contained in this document is relevant to most areas of the United States. Sections of this publication examine the structure and size of buffers required to trap sediments, absorb phosphorus, and treat nitrogen flowing into riparian areas. It also discusses buffer conditions required to provide habitat for various terrestrial, bird, and aquatic species. The final section provides guidence to communities and other localities involved in developing and implementing buffer management legislation.
J.E. Williams, C.A. Wood, and M.P. Dombeck (eds.) 1997. Watershed Restoration Principles and Practices. American Fisheries Society, Bethesda, MD.	Contains 28 chapters from 52 recognized scientists and practitioners of watershed-scale restoration work. The book stresses the need for long-term approaches that emphasize community involvement and sound ecological principles. Includes case studies from around the country that address ecological principles, range management practices, and community action components of watershed management and restoration.
Whitaker-Hoagland, J., M. Howery, A. Stacey, R. Smith, S. Tully, R. Masters, D. Leslie, Jr., and S. Stoodley. 1998. Managing riparian areas for wildlife. p. 55–61. In: M.S. Cooper (ed.) Riparian Area Management Handbook. Oklahoma Cooperative Extension Service. Division of Agricultural Services and Natural Resources. Oklahoma State University and Oklahoma Conservation Commission. Accessed at: <http://pearl.agcomm.okstate.edu/e952/e-952.pdf>.	Describes the importance of riparian areas as wildlife habitat and how grazing practices can impact on the quality and characteristics of this critical habitat. Recommeds removing grazing animals from areas inhabited by grassland birds while these birds are nesting. Also lists the amount of riparian buffer area required to provide protection for various wildlife species.
Winward, A.H. 2000. Monitoring the Vegetation Reources in Riparian Areas. General Technical Report RMRS-GTR-47. United States Department of Agriculture-Forest Service. Rocky Mountain Research Station. Ogden, UT.	Provides a detailed discription of vegetation community types as related to environmental condtions. Methods are provided for encouraging regeneration of desired riparian species and monitoring the progress of riparian revegetation. Species lists focus on vegetation native to the western intermountain region.

Recommended References continued on page 23

Recommended References, cont'd.

Citation	Annotation
Natural Resource Conservation Service Standards	Acessed at: <http://www.ftw.nrcs.usda.gov/nhcp_2.html>
Controlled stream acess for livestock watering. Code 730	Access areas shall not be more than 20 linear feet of stream and shall not extend more than five feet into the stream. Fences exclude livestock from the stream at locations other than the access point.
Stream crossing. Code 728	Construction of stream crossings using a combination of geotextile filter cloth and stone aggregates.
Streambank and shoreline protection. Code 580	Treatments used to stablize and protect banks of streams. Protective measures shall be compatible with the bank or shoreline materials, water chemistry, and channel hydraulics.
Stream habitat improvement and management. Code 395.	Emphazises the establishment of an ecologically self-sustaing stream-riparian system consistent with the watershed conditions and geomorphic setting.
Riparian forest buffer. Code 391.	Establishment of forest buffers that complement natural features and mimic natual riparian forests. Livestock shall be controlled or excluded as necessary to achieve and maintain intended buffer purpose.
Riparian herbaceous cover. Code 390.	Protection and enhancement of riparian vegetation and water quality by reducing its use for haying and grazing until the desired plant community is well established. The management plan shall consider habitat and wildlife objectives.
Bibliographies	
Correll, Dave. 1999. Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances. Accessed at: <http://www.serc.si.edu/SERC_web_html/pub_ripzone.htm>.	An annotated and indexed bibliography of the world literature including buffer strips and interactions with hyporheic zones and floodplains. Contains 648 citations coded by document type, vegetation type, water quality parameters, and riparian processes.

Recommended References continued on page 24

Recommended References, cont'd.

Citation	Annotation
Bibliographies, cont'd.	
Driscoll, Melissa, and Bruce Vondracek. 2002. Water, Grass & Livestock: An Annotated Bibliography of Riparian Grazing Publications. Land Stewardship Project. White Bear Lake, MN. 36 pp. Accessed at: http://www.landstewardshipproject.org/resources-pubs.html. or available from Land Stewardship Project for $5.00. telephone: 651-653-0618	A very comprehensive listing of literature relevant to riparian grazing, particularly in the eastern U.S. Contains both technical research studies on ecological interactions associated with riparian grazing and practical pasture–management guides. Document lists are sub-divided into 1) Practical, on-the-ground information, 2) The stream bank, 3) The riparian area, 4) The upland area, and 5) Western United States Riparian Area Issues.
Makuch, Joe. 1995. Riparian Zones and Filter Strips in Agricultural Operations. January 1988–January 1995. Quick Bibliographic Series no. QB 95–09. National Agricultural Library. Accessed at: <http://www.nal.usda.gov/afsic/AFSIC_pubs/qb95-09.htm>.	179 citations that can be organized by author or subject. Some contain abstracts, others only descriptive terms. Includes citations on riparian ecology, buffer management, riparian grazing, crop management and riparian areas, and role of buffers in the control of nutrient and pesticide movement into streams.
Williams, Jack. 2002. Annotated Bibliography of Riparian Ecosystems: Primary Literature Sources. Accessed at: <http://www.mtnvisions.com/Aurora/biblio.html>.	Lists 20 books and selected journal articles with particular emphasis on riparian ecology and restoration.
Journals with frequent articles on riparian protection, restoration, and managed grazing	
Journal of Soil and Water Conservation. 7515 N.E. Ankeny Road, Ankeny, Iowa 50021 Web page: <http://www.swcs.org/f_pubs_journal.htm>.	
Journal of Range Management. Web page: <http://uvalde.tamu.edu/jrm/jrmhome.htm>	
Fisheries. American Fisheries Society 5410 Grosvenor Lane, Suite 110, Bethesda, Maryland 20814 Web page: <http://afs.allenpress.com/afsonline/?request=search-simple>.	
Journal of the American Water Resources Association. AWRA. Box 1626. Middleburg, VA 20118-1626. Web page: <http://www.awra.org/jawra/index.html>.	

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Buschermohle, M.J., and R. T. Burns. 2000. Solar-powered livestock watering systems. University of Tennessee, Agricultural Extension Service. Accessed at: <www.utextension.utk.edu/pbfiles/pb1640.pdf>.

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Clary, W.P., and W.C. Leininger. 2000. Stubble height as a tool for management of riparian areas. Journal of Range Management. Vol. 53. No. 6 p. 562–573.

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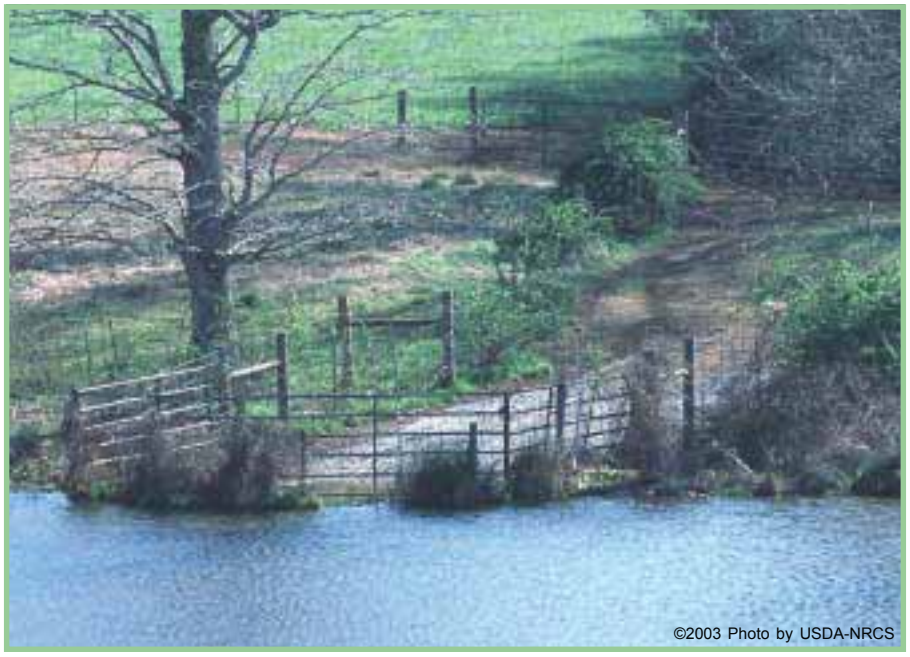

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