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Lone Star Healthy Streams

Beef Cattle Manual

Endorsed By:

Texas and Southwestern Cattle Raisers Association

NRCS

Independent Cattlemen's Association of Texas

GLCI

Lone Star Healthy Streams

Keeping Texas Waters Safe and Clean...

Cover photograph courtesy of Matt Berg, Texas A&M University.

Lone Star Healthy Streams

Beef Cattle Manual

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Preface

About 300 Texas water bodies currently do not comply with state water quality standards established for *E.coli* bacteria. Elevated concentrations of *E.coli* bacteria in water are an indicator of fecal contamination and can pose an increased health risk to downstream users.

The Lone Star Healthy Streams program aims to educate Texas livestock producers and land managers on how to best protect Texas waterways from bacterial contributions associated with the production of livestock and feral hogs. To achieve this goal, groups of research scientists, resource conservation agencies, and producers have collaborated to compile this Lone Star Healthy Streams manual which includes best management practices (BMPs) known to reduce *E.coli* contributions to rivers and streams. In addition to reducing bacterial contributions, the BMPs listed in this manual will allow livestock and land owners to further protect Texas waterways from sediment, nutrient, and pesticide runoff.

We hope that landowners and livestock producers find the following information helpful in their pursuit of being the best natural resource stewards they can be. For more information about the Lone Star Healthy Streams program, please visit http://lshs.tamu.edu/.

Chapter 1

Water Quality in Texas

Water Quality in Texas

Water is a finite resource that can be significantly polluted by a variety of sources across the landscape. No one person, industry, or activity is to blame, but the agricultural sector often is singled out as a major contributor of pollutants to Texas's waterways. Although many think this claim is unjust, the agricultural sector can choose to regulate itself through stewardship and conservation practices rather than have the solutions determined by those who may not understand the industry.

Beef cattle producers need to carefully consider any measures they can take to minimize watershed pollution and reduce the potential for regulation. Pollution in water bodies has led to governmental regulations in the Vermillion River watershed in Illinois, the Fourth Creek watershed in North Carolina, the Chesapeake Bay watershed in Delaware, and many others across the United States.

Producers have many management options for improving water quality, some of which are fairly low cost and easy to implement. Several of these options also can improve animal performance and enhance the long-term health of rangeland and pastures.

Beef cattle producers can more easily make wise choices for reducing pollution originating on their operations if they know the benefits of clean water to agricultural operations, the current laws and policies on water quality, the ways that bacteria can enter water, and the range of solutions that are available for them to reduce water quality problems.

Value of Clean Water to Texas Agriculture

Clean water is vital to agricultural producers in Texas. Water is used for irrigating crops (Fig. 1) and raising livestock and is the reason why the Texas food and fiber system is valued at nearly $100 billion each year. Clean water can also improve animal health, gains, and reproduction, as well as increase recreational opportunities on farms and ranches.

Figure 1. Clean water is vital to crops and livestock in Texas. Photo by Blair Fannin, Texas AgriLife Extension Service.

Bacteria can severely reduce or even eliminate some of these valuable water-based activities and associated benefits. The costs of poor water quality include degraded ecosystems, limited agricultural production, reduced recreational opportunities, increased government regulation, increased water treatment costs, and threats to human health.

Water Quality Law and Policy

The foundation for surface water quality protection in the United States is the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA). Passed in 1972 and amended in 1977, the CWA was enacted to restore and maintain the chemical, physical, and biological characteristics of the nation's waters.

In brief, the Clean Water Act requires that states set standards for surface water quality; it also requires public and private facilities to acquire permits for discharging wastewater. At the federal level, the U.S. Environmental Protection Agency (EPA) is responsible for administering the water quality standards outlined in the Clean Water Act. The EPA delegates water quality management at the state level to the specific state environmental agency.

In Texas, the primary water quality agency is the Texas Commission on Environmental Quality (TCEQ, Fig. 2). The TCEQ is responsible for:

- Establishing water quality standards
- Determining how water quality will be managed
- Issuing permits for point source dischargers
- Reducing all types of nonpoint source pollution, except those from agricultural and silvicultural (forestry) sources

Point source pollution can be traced to a specific location and point of discharge, such as a pipe or ditch; nonpoint source pollution originates from multiple locations and is carried primarily by precipitation runoff.

In 1991, the Texas Legislature delegated some water quality authority to the Texas State Soil and Water Conservation Board (TSSWCB). The Board is responsible for administering the state's soil and water conservation law and for managing programs to prevent and reduce nonpoint source pollution from agriculture and forestry.

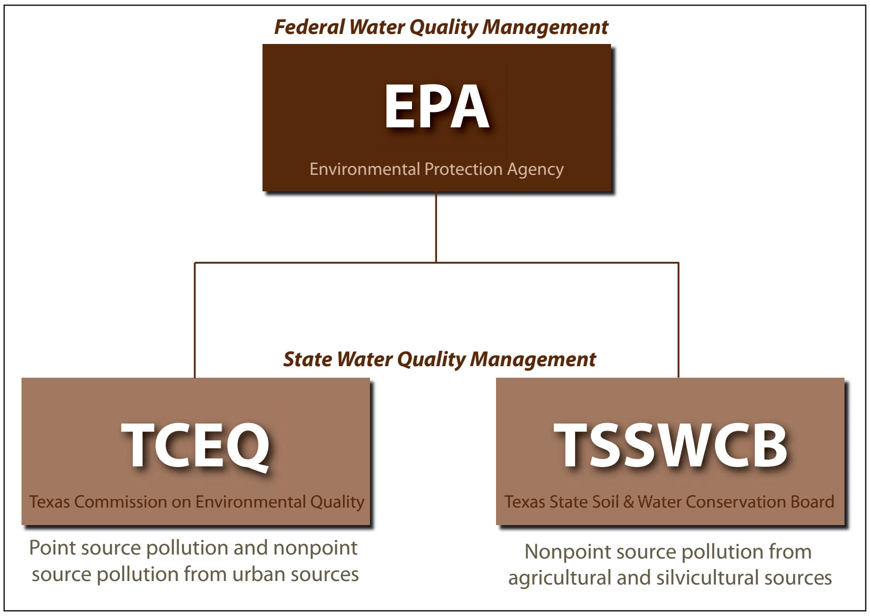

Figure 2. Hierarchy of federal and state agencies involved primarily in water quality management in Texas. Illustration by Jennifer Peterson.

To comply with Section 303(d) of the Clean Water Act, the TCEQ must report to the EPA on the extent to which each surface water body meets water quality standards. The report must be submitted every 2 years and is known as Texas Integrated Report for Clean Water Act, Sections 305(b) and 303(d).

The Integrated Report describes the status of all surface water bodies that were evaluated and monitored in the state over the most recent 7-year period. This report is the basis for the 303(d) List, which identifies all impaired surface bodies of water that do not meet water quality standards.

Water quality standards specify numeric levels of water quality criteria such as bacteria, temperature, dissolved oxygen, and pH that can be measured in a lake, river, or stream without impairing the designated use(s) assigned to that water body. Designated uses include aquatic life, fish consumption, public drinking water supply, and contact and noncontact recreation. Any water body whose water quality criteria measurements fall outside of the levels set by the standards for each designated use is considered impaired and is placed on the 303(d) List.

The Clean Water Act requires that a calculation be made on the pollution reductions needed to restore an impaired water body to its designated use(s). The calculation is called a total maximum daily load (TMDL). A TMDL must be developed for waters on the 303(d) List of impaired waters within 13 years of being listed. If the state does not develop a TMDL within the required time limit, the EPA will.

In Texas, both the TCEQ and the TSSWCB are responsible for developing and submitting TMDLs to the EPA. After a TMDL is complete, an implementation plan (I-Plan) must be developed. This plan includes a detailed description of the regulatory measures, voluntary management measures, and parties responsible for carrying out identified measures needed to restore water quality in accordance with the TMDL. Unlike the TMDL, the implementation plan must be approved by only the TCEQ or TSSWCB, not the EPA.

Regulatory measures are typically applicable only to point source dischargers such as concentrated animal feeding operations (CAFOs) or wastewater discharges. However, some U.S. watersheds have imposed regulatory measures on nonpoint sources also.

According to the 2010 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d), there were a total of 621 impairments in Texas. Of these impairments, 51% were due to elevated bacteria. As of February 2012, a total of 206 TMDLs have been developed for 134 water segments in Texas.

Some watersheds may have another option that may be more viable for solving complex water issues. Instead of developing a TMDL, they may be able to develop and implement a watershed protection plan (WPP). A WPP is a voluntary, stakeholder-driven strategy for improving water quality. These plans are developed and managed through partnerships among federal and state agencies and local groups and organizations. They rely heavily on stakeholder involvement at the local level.

To help communities create WPPs, the EPA has produced a guide, *Handbook for Developing Watershed Plans* to Restore

and Protect Our Waters. The handbook outlines nine key elements that each WPP should contain:

- Causes and sources of the water quality problem
- Load reductions needed to restore water quality
- Management measures needed to achieve the load reductions
- Technical and financial assistance needed to implement the management measures
- Information and education programs needed
- Implementation schedule
- Implementation milestones
- Criteria to determine success
- Monitoring needed to determine the effectiveness of implementation

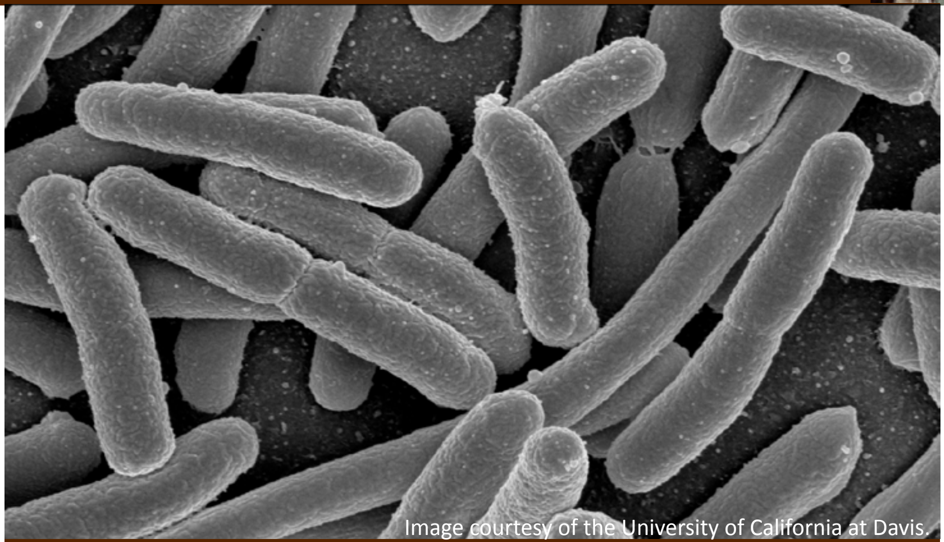

Image courtesy of the University of California at Davis.

Escherichia coli, commonly abbreviated as *E. coli*, is a rod-shaped bacterium found in the lower intestine of warm-blooded organisms. It was first discovered in 1885 by German pediatrician and bacteriologist Theodor Escherich.

Perhaps the most recognized strain of *E. coli* is O157:H7, which can cause serious food poisoning in humans and is often the cause of product recalls. In 2006, more than 200 people became sick and three people died after consuming spinach contaminated with *E. coli*.

E. coli are important for water quality because they act as indicator organisms—their presence in water can indicate the presence of other pathogens that can cause disease in humans.

The main difference between the two approaches is that TMDLs are required by federal law, and WPPs are voluntary. In general, a WPP gives communities a way to restore water quality, remove the body of water from the 303(d) List, and avoid regulatory action in the watershed. In some cases, however, development of a TMDL is unavoidable, especially if the impairment causes an emergency situation.

Sources of Bacteria in Texas Waterways

Fecal bacteria are microscopic organisms found in the feces of humans and other warm-blooded animals. By themselves, they are usually not harmful, but they are important because they are indicator species and can suggest the presence of pathogenic (disease-causing) organisms.

Pathogenic organisms include bacteria, viruses, or parasites that can cause waterborne illnesses such as typhoid fever, dysentery, and cholera. In addition to the potential health risks, elevated bacteria levels can also cause unpleasant odors, cloudy water, and increased oxygen demand.

The most common types of fecal bacteria that are measured to indicate the potential presence of harmful pathogens include:

total coliform, fecal coliform, fecal streptococci, enterococci, and *Escherichia coli* (*E. coli*). The EPA recommends *E. coli* as the most reliable indicator of contamination for freshwater and enterococci as the most reliable indicator in saltwater.

Bacterial contamination of surface waters is a major problem—it is the le ading cause of water quality impairment not only in Texas, but also nationwide.

Bacteria in Texas waterways can come from many sources across the landscape (Fig. 3):

- Wastewater treatment plants, especially from plants that are not up to code or functioning properly
- Leaky septic systems
- Pet waste
- Runoff from neighborhood streets and parking lots
- Wildlife, including deer, rodents, and large flocks of birds resting on public waters
- Feral hogs
- Grazing livestock (Table 1)

One method to pinpoint the sources of fecal bacteria is bacterial source tracking (BST). This expensive process examines the DNA structure of bacteria to determine if it originated from human, livestock, wildlife, pet waste, or avian sources.

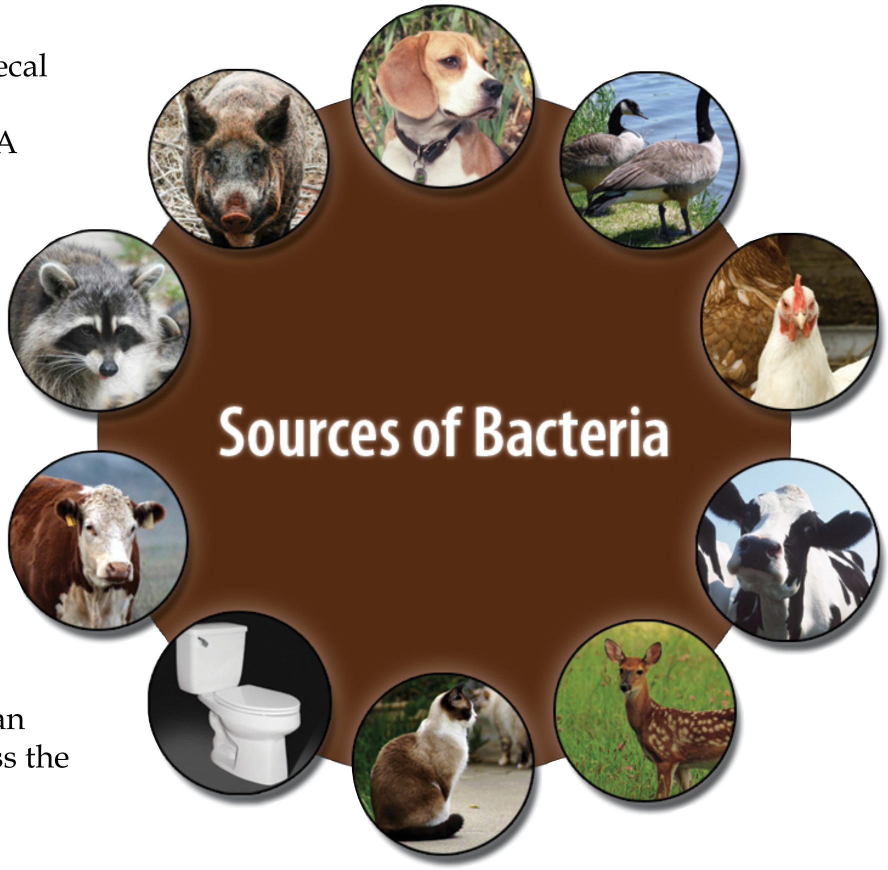

Figure 3. Bacteria in Texas waterways can originate from a variety of sources, including wastewater treatment facilities, wildlife, pets, and livestock. Illustration by Jennifer Peterson.

Although still in its developmental stages, BST can be a useful tool in watershed planning.

The process was used recently to analyze bacteria found in Peach Creek, Copano Bay, and the Leon River in Texas. It found that, on average, cattle accounted for about 19 percent of the bacterial contamination, wildlife accounted for 26 percent, and humans (septic systems and pets), 23 percent. Thus, while cattle contribute to bacterial contamination of Texas waterways, they apparently account for less contamination than wildlife and humans. Regardless of the source, excess bacteria levels are involved in more than 50 percent of the water quality impairments in Texas (Fig. 4).

Table 1. Fecal coliform production for major classes of livestock and feral hogs (Wagner and Moench 2009).

Animal	Daily fecal production (lbs/day/AU)	Daily fecal production (g/day/AU)	Fecal coliform density (cfu/g)	Fecal coliform (cfu/AU/day)
Beef Cattle	82	37,195	2.30E+05	8.55E+09
Horses	51	23,133	1.26E+04	2.91E+08
Goats	40	18,144	1.40E+06	2.54E+10
Sheep	40	18,144	1.60E+07	2.90E+11
Hogs	65	29,484	3.30E+06	9.73E+10
Layers	63	28,576	1.30E+06	3.71E+10
Pullets	63	28,576	1.30E+06	3.71E+10
Broilers	82	37,195	1.30E+06	4.84E+10
Turkey	47	21,319	2.90E+05	6.18E+09
Deer	15	6,804	2.20E+06	1.50E+10
Feral Hogs	65	29,484	4.10E+04	1.21E+09

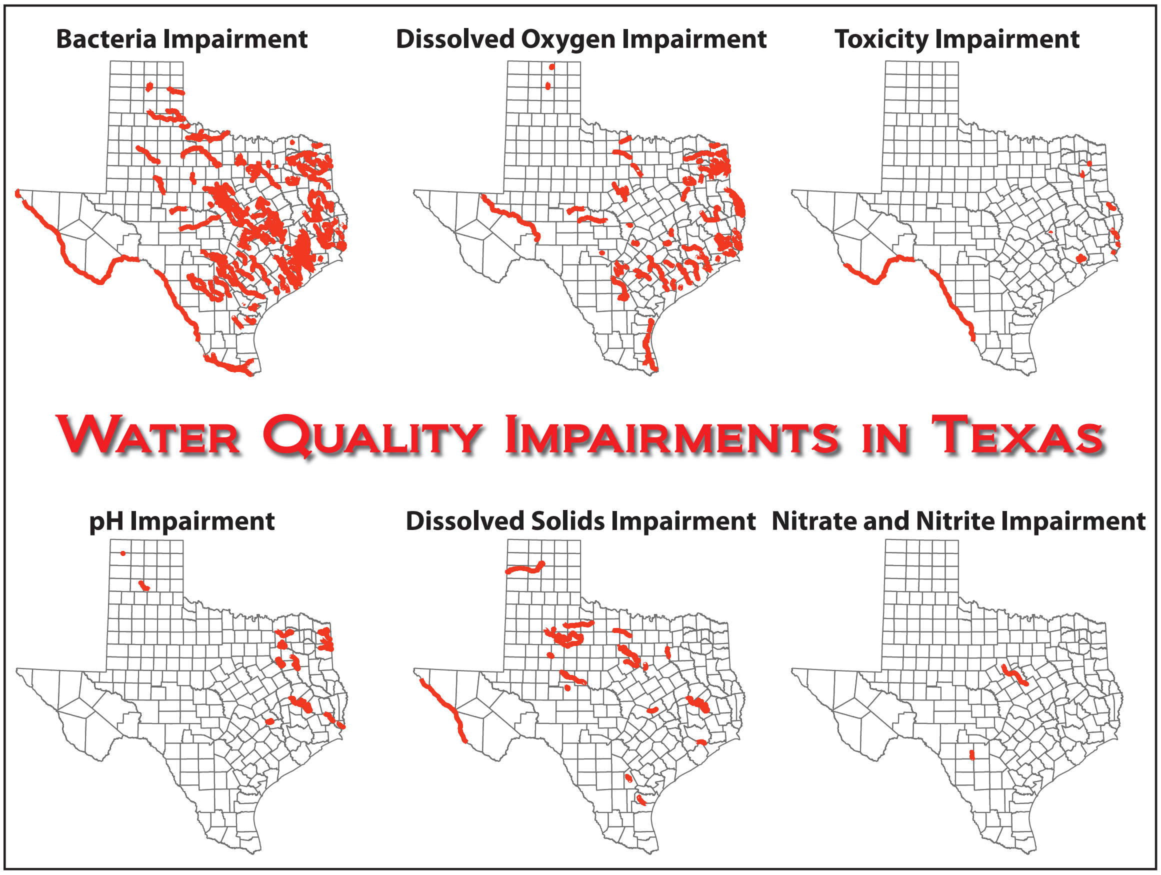

Figure 4. Types and locations of impairments in Texas water bodies. Source: TCEQ, 2008.

Bacteria Fate and Transport

The behavior of bacteria in water is not well understood because it involves many complex factors in the environment and in the organisms themselves. As a result, it can be a challenge to reduce their levels in waterways.

Several processes affect the fate and transport of fecal bacteria (Table 2).

- **Fate processes** include growth (cell division), death by predation, and die-off.
- **Transport processes** include advection (horizontal transport), dispersion, settling, and re-suspension from the sediment bed.

Both processes are altered by temperature, pH, nutrients, toxins, salinity, and sunlight intensity.

Computer models (Soil and Water Assessment Tool, Hydrological Simulation Program-FORTRAN) can be used to simulate the fate and transport of bacteria at the watershed-scale, however, the predictive strength of these models depends highly on the accuracy of the data entered into the model. A better comprehension of the fate and transport of bacteria is needed to understand the potential impact of the contaminant and to more effectively develop management strategies in a watershed.

Benefits of Voluntary Conservation Practices

Federal and state natural resource agencies are encouraging the voluntary use of effective conservation practices to improve water quality. Farmers and ranchers can

Table 2. Potential survival of fecal pathogens in the environment (Olsen 2003).

		Duration of Survival			
Material	**Temperature**	**Cryptosporidium**	**Salmonella**	**Campylobacter**	***E. coli* (O157:H7)**
Water	Frozen	>1 year	>6 months	2-8 weeks	>300 days
	Cold (5°C)	>1 year	>6 months	12 days	>300 days
	Warm (30°C)	10 weeks	>6 months	4 days	84 days
Soil	Frozen	>1 year	>12 weeks	2-8 weeks	>300 days
	Cold (5°C)	8 weeks	12-28 weeks	2 weeks	100 days
	Warm (30°C)	4 weeks	4 weeks	1 week	2 days
Cattle manure	Frozen	>1 year	>6 months	2-8 weeks	>100 days
	Cold (5°C)	8 weeks	12-28 weeks	1-3 weeks	>100 days
	Warm (30°C)	4 weeks	4 weeks	1 week	10 days
Liquid manure		>1 year	13-75 days	>112 days	10-100 days
Composted manure		4 weeks	7-14 days	7 days	7 days
Dry surfaces		1 day	1-7 days	1 day	1 day

do their part to minimize the runoff of agricultural pollutants into waterways by implementing practices that better manage water use, runoff, and chemical applications.

Although improvements in water quality from farmers' efforts can take years to detect, these practices can often result in tangible benefits. In one study, the benefits to water quality benefits from erosion control on cropland totaled over $4 billion per year. Another study found that erosion reduction measures on private lands in the United States increased the value of water-based recreation by about $373 million.

Although the implementation of conservation practices is currently voluntary and can require financial input by landowners, the benefits of having clean water resulting from these practices far outweigh the associated costs.

The goal of the Lone Star Healthy Streams program is to provide information to agricultural producers and landowners on practices that can help reduce bacterial contributions. These practices will enable the agricultural sector to do its part to improve water quality.

The Texas Beef Cattle Industry

Texas has a rich history in beef cattle ranching and production. All 254 Texas counties have beef cattle production. According to the Texas Department of Agriculture, Texas is the number one producer of beef in the nation. Texas A&M University estimates that cattle production and feeding generate $15 billion to $16 billion a year within the state's economy. These figures do not include the transportation, handling, and retail sales of beef. Add those numbers in, and cattle's economic impact skyrockets. The National Cattlemen's Beef Association calculates that for every dollar generated by sales of cattle and calves, $4 circulates within the economy. That means cattle sales worth $6 billion total $24 billion in economic impact to Texas.

Chapter 2

Best Management Practices For Beef Cattle

Photo courtesy of the Texas AgriLife Extension Service

Best Management Practices

Livestock producers can help improve water quality using two primary categories of BMPs:

- Those that manage vegetation in upland areas away from streams and rivers
- Those that protect riparian areas, which are environmentally sensitive areas along streams and rivers

BMPs for upland vegetation management involve the use of appropriate grazing management, stocking rates, and production practices to reduce runoff of contaminants. These BMPs increase water capture on site, increase forage production, reduce soil erosion, and reduce the amount of sediment, bacteria, nutrients, and pesticides moving into waterways.

BMPs for riparian area protection range from a reduction of the time that cattle spend in riparian areas to total exclusion of cattle from waterways. These BMPs aim to maintain healthy vegetation in the riparian area which acts as a natural buffer and reduce fecal contamination in waterways.

Best Management Practices For Upland Vegetation Management

Vegetation management BMPs optimize livestock production while protecting and/or enhancing the environment. Their overarching aim is to increase the amount of vegetative cover in pastures.

The amount of ground cover in a pasture affects not only animal performance, but also the amount of soil eroded from the pasture, the amount of water captured or lost from the site, and the amount of nutrients, sediment, and pesticides that reach the waterway.

Soil Erosion Due to Water
Stream bank erosion is defined as the displacement of soil from the banks of rivers or streams. In addition to topsoil, erosion removes valuable fertilizer nutrients such as nitrogen, phosphorus, and potassium which can contaminate water.

Soil erosion begins with raindrop impact: A raindrop falling on bare ground dislodges soil particles and destroys the soil structure causing considerable soil movement (Brady 1990, Branson et al. 1981). Once dislodged by raindrop impact, soil particles become suspended in the water and are removed from the site by overland flow, or runoff. Dislodged soil particles can also seal the soil surface by plugging the tiny pores between soil particles (micropores). This sealing action reduces water infiltration rates and increases runoff.

However, ground cover can dramatically reduce erosion. Plants intercept the raindrops, absorbing the energy of impact and protecting the integrity of the soil surface. Ground cover also reduces erosion by diminishing the energy of runoff water (Fig. 5).

After a raindrop makes impact, it is subject to three fates (Holechek et al. 1998):

- **Infiltration**, which is movement of water into the soil. Infiltration is determined primarily by the soil's texture. Water infiltrates and percolates faster through coarse-textured soils such as sands than through fine-textured soils such as clays.

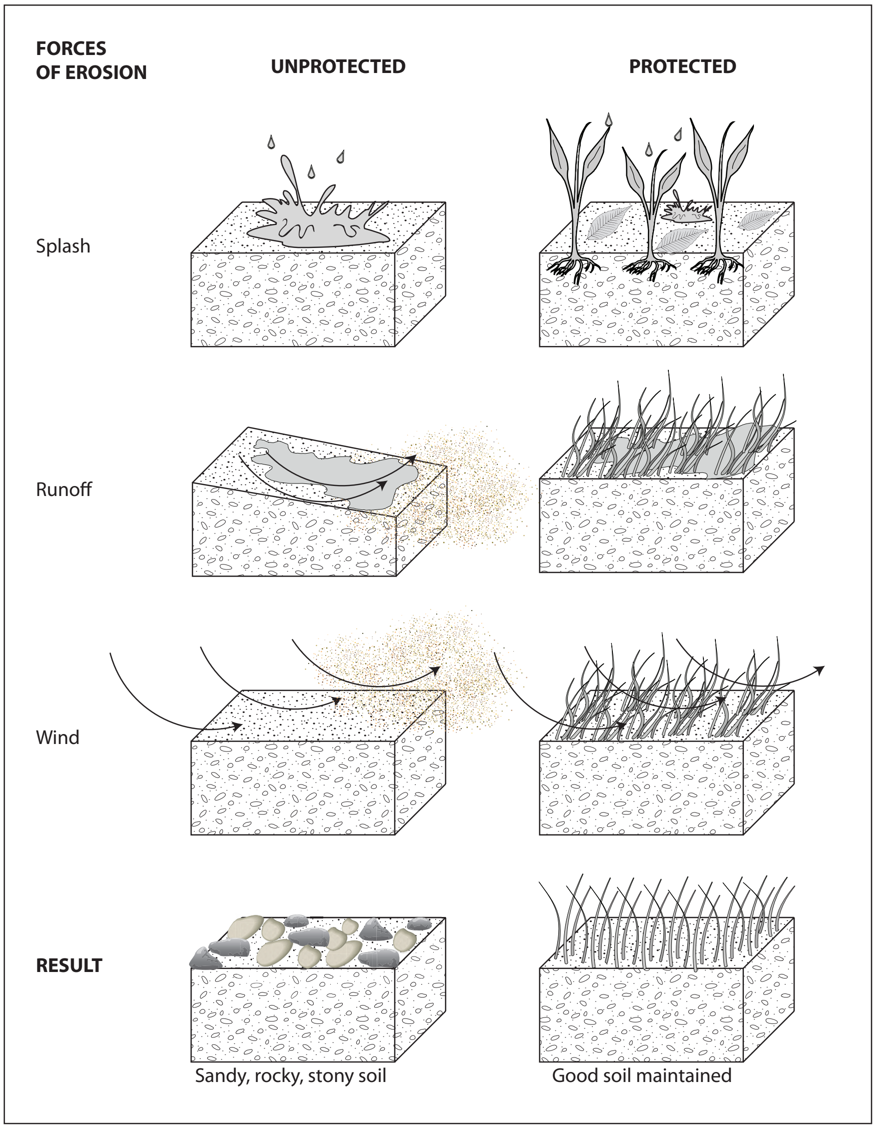

Figure 5. Vegetation effects on reducing soil erosion. Illustration by Jennifer Peterson (adapted from Nebel 1981 as used by Holechek et al. 1998).

- **Evaporation**, which can be positive or negative, depending on the amount of moisture in the soil.
- **Runoff**, which occurs when precipitation rates exceed infiltration rates of the soil.

Soil is lost when it is detached and transported from the site (Fig. 6). This can occur uniformly in nature as sheet or interrill erosion. Extreme interrill erosion can create soil pedestals around areas covered by materials that resist raindrop impact, such as rock. This phenomenon illustrates the highly erosive nature of raindrop impact (Thurow 1991).

Further erosion creates small, distinct flow paths (rill erosion) that can be corrected with tillage. However, if the erosion continues unabated, it may create deep channels (gully erosion). At this point, tillage may be unable to repair the damage, and vehicles may not be able cross the channels.

The quantity of vegetative cover can be reduced through introduced forage pastures and by overstocking pastures. The results are increases in overland water flow, sediment, bacteria, and pesticides in nearby waterways. Eventually, sediment reduces the capacity of surface water reservoirs.

The use of proper stocking rates maintains adequate ground cover, which reduces runoff and soil erosion and protects water quality.

Forage Production

Heavy grazing pressure and high stocking rates decrease the vigor and persistence of forage plants on rangeland and introduced forage pastures. If cattle remove more than 50 percent of the aboveground biomass, photosynthesis is slowed, which in turn


Figure 6. Typical erosion due to unprotected soil. Photo by Lynn Betts, USDA–NRCS.

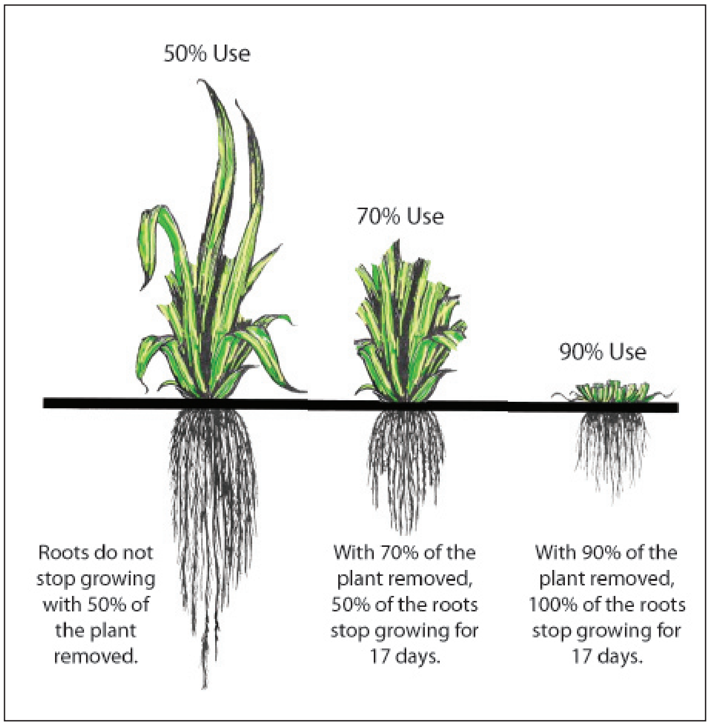

Figure 7. Effect of intensity of defoliation on root growth. Illustration courtesy of the Texas USDA–NRCS.

reduces root development and the amount of moisture and soil nutrients that may be taken up for plant production (Fig. 7).

The long-term results of this situation are reductions in plant vigor, frequency, and abundance, and increases in bare ground and less-desirable or undesirable plant species. This change ultimately leads to a degradation of range or introduced forage pasture condition.

If the stocking rate is not reduced, carrying capacity will be diminished, animal performance decreased, and the potential for profit eliminated. Input costs—for increased herbicides and winter feeding, for instance—associated with the enterprise will rise, making the bad situation worse.

Water Conservation

Perennial ground cover increases the amount of precipitation captured on site and decreases the amount lost as runoff. When the range is overused, undesirable plant species move in. These species generally do not provide the type of ground cover necessary to reduce runoff and increase infiltration. As a result, much of the precipitation is lost from the site, reducing forage production (Fig. 8) and minimizing recharge of underground aquifers. In clayey soils, the soil becomes compacted, which can lead to further reductions in infiltration rates and increases in overland flow.

Many studies have found that stocking rates affect infiltration rates (Holechek et al. 1998, Gifford and Hawkins 1978). Research findings conclude that:

- Ungrazed plots have higher infiltration rates than those of grazed plots.
- Moderate and light grazing intensities have similar infiltration rates.
- Heavy grazing causes definite reductions in infiltration rates over moderate and light grazing intensities.

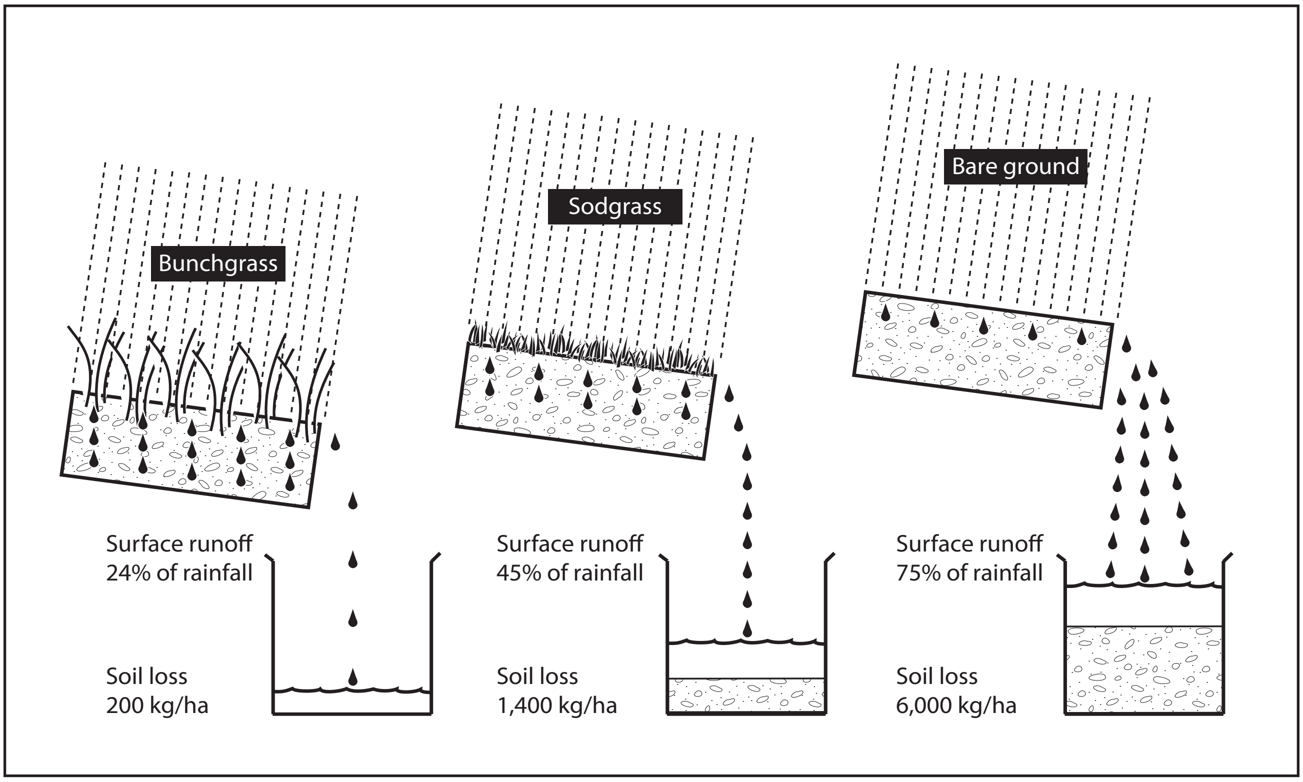

Figure 8. Influence of vegetation type on sediment loss, surface runoff, and rainfall infiltration from 4 inches (10cm) of rain in 30 minutes (adapted from Blackburn et al. 1996, by Knight 1993, and as used by Holechek et al. 1998).

Beef Cattle Production Practices

Prescribed Grazing
The controlled harvest of vegetation by grazing animals is known as prescribed grazing (NRCS Code 528). According to the NRCS, prescribed grazing is an appropriate practice to improve water quality, reduce soil erosion, maintain a stable and desired plant community, and improve or maintain the health and vigor of selected plants.

The NRCS further advises that producers implement practices to manage the duration, intensity, frequency, and season of grazing in or near surface waters. The practices should:

- Maintain enough plant cover to maintain soil moisture and to prevent soil erosion by wind or water
- Improve plant and water quality
- Enhance nutrient cycling by dispersing manure and increasing decomposition rates
- Encourage water infiltration
- Protect stream banks from erosion
- Keep fecal material away from water bodies
- Promote ecological and economically stable plant communities
- Provide adequate upland grazing areas to support riparian and wetland grazing sites

Grazing Management
Grazing management involves controlling *where, when, and how much* livestock graze. Close attention to grazing management—

primarily stocking rate—is critical for maximizing profit or minimizing loss.

The objective of proper grazing management is to match the availability and nutritional content of the forage with the nutritional requirements of grazing livestock to achieve the optimum production of meat, milk, and fiber. Often the only management change required is to develop a controlled breeding season that matches seasonal forage availability with the nutrient requirements of gestating or lactating females and that of growing animals. If producers are not using a controlled breeding season, this may be a logical place to begin an improved grazing management strategy.

Stocking Rate

Stocking rate is the most critical aspect of livestock production that is related to water quality and is under the direct control of the manager. No other single management practice has a greater effect on the sustainability of a livestock production enterprise (Redmon and Bidwell 1997).

Stocking rate is the number of acres required per animal unit for a grazing season that can be sustained on a long-term basis without degrading forage, water, or soil resources. A moderate stocking rate provides a good balance between plant and animal performance while maintaining adequate vegetative cover to protect soil and resources.

Although moderate stocking rates differ depending on site and forage species, general guidelines can be obtained from Standard Soil Surveys produced by the NRCS. Other information on appropriate stocking rates is available from local Extension and Soil and Water Conservation District offices or from successful producers who have a long history of production in the area.

Many pastures are overstocked but producers do not realize it. The reasons vary:

- Cows are larger than in previous years. Forage intake is related to body size, and cows today are 50 percent larger or more than cows were two generations ago.
- Woody (brush) species are continually invading and dominating previously productive pastures, thus reducing the carrying capacity of those pastures. Without brush removal, or livestock reduction, overstocking occurs.
- Inappropriate fertilizer and/or weed management inputs have reduced the amount of forage produced on some sites.
- Some producers base stocking rate on total acres instead of *grazeable* acres. Stocking rates should be adjusted according to factors that reduce the amount of property grazing animals can use. These factors include slope, brush density, rock cover, and distance to water.

To discuss the effect of stocking rate on animal performance, some definitions are necessary:

- **Stocking rate**: the number of animals on a given amount of land over a certain period of time. It is generally expressed as animal units per unit of land area.
- **Carrying capacity**: the stocking rate that is sustainable over time per unit of land area. A critical factor to evaluate is how well the stocking rate agrees with the carrying capacity of the land.

- **Animal unit (AU)**: a standard measure of livestock; a 1,000-pound beef cow is the standard measure of an animal unit (Table 3).

Table 3. Carrying capacity in terms of the animal unit (AU) concept.

Measure	Definition
Animal Unit (AU)	1,000-lb cow with calf
Animal Unit Day (AUD)	26 lb of dry forage
Animal Unit Month (AUM)	780 lb of dry forage
Animal Unit Year (AUY)	9,360 lb of dry forage

An example may illustrate the concept better. Assume that a livestock producer has 50 head of 1,000-pound cows on 200 acres for 12 months. The stocking rate of this operation would be calculated as follows:

Example 1: Calculation of Stocking Rate

Total Land Area ÷ [(#AUs) x (Grazing Season)]

200 acres ÷ [(50 AUs) x (12 months)]

Stocking Rate = 0.33 acres per AU month (AUM)
or
4.00 acres per AU year (AUY)

Because cattle and other grazing animals are not the same size, it is often necessary to convert to animal unit equivalents. The term animal unit equivalent (AUE) is useful for estimating the potential forage demand for different kinds of animals or for cattle that weigh more or less than 1,000 pounds. Animal unit equivalent is based upon a percentage (plus or minus) of the standard AU.

Again, assuming an intake of 26 pounds of forage dry matter per day, the 1,000-pound cow is used as the base animal unit to which other livestock are compared. The AUE for cattle that do not weigh 1,000 pounds is calculated as:

AUE = (BODY WEIGHT) ÷ 1,000

Table 4 lists different kinds and classes of animals, their AUEs, and their estimated daily forage demand. With this information, it is easy to convert different-sized animals to AUEs to determine the number of animals that could be grazed on a specific pasture for a specific period.

An appropriate stocking rate ensures that an adequate amount of ground cover will remain in the pasture. It protects soil and water resources as well as ensures an adequate supply of forage for the animal. Without that supply, animal performance drops (Fig. 9).

Grazing Systems

Grazing systems affect infiltration, runoff, water quality, and soil erosion. Three grazing systems appear to have the least effect on infiltration rate and sediment production (Table 5):

- Moderately stocked, continuous grazing
- Moderately stocked, three-herd, four-pasture grazing
- High-intensity, low-frequency grazing

The rest period appears to be the critical factor regarding compaction, infiltration, and runoff. Short-duration grazing produces more sediment on rangelands than does moderate-stocked continuous grazing (McCalla et al. 1984, Thurow et al. 1986, Weltz and Wood 1986b, Pluhar et al. 1987).

Research has also found that pastures without grazing have higher infiltration rates and less sediment production than those under moderate, double moderate, and triple moderate stocking rates (Warren et al. 1986 a, b, c). In this study, a 30 day rest period was not enough to reestablish adequate vegetative cover to aid in infiltration. The effect worsens as stocking rate increases.

Special attention should be paid to riparian areas. Once stream bank plant communities are disturbed, they are difficult, if not impossible, to reestablish through natural processes. To minimize damage to these areas, producers can install concrete or gravel limited-access water points and locate freeze-proof tanks and stock ponds away from riparian areas.

An important point is that *grazing systems generally have less impact on animal performance than do stocking rate or soil fertility.* No grazing system can offset the effects of overstocking or a poor soil fertility program.

Table 4. Animal unit equivalent (AUE) and estimated daily forage dry matter (DM) demand for various kinds and classes of grazing animals.

Animal Type		AUE	DM Demand (lb/day)
Dairy cattle		-	-
Cow	1,000 lb	1.00	26
	1,300 lb (last 2 months of gestation)	1.50	39
Bull, 1,500 lb, mature		1.40	36
Heifer, 550 lb, growing		1.00	26
Beef cattle		-	-
Calves	300 lb	0.30	8
	400 lb	0.40	10
	500 lb	0.50	13
	600 lb	0.60	16
Cows		1.00	26
Bulls		1.25	32
Horses		1.25	32
Sheep		0.20	5
Goats		0.17	4
White-tailed deer		0.17	4

Figure 9. Effect of adequate (left) versus inadequate (right) forage resources on animal performance. Photos courtesy of Bob Nichols, USDA–NRCS (left) and Florida Cooperative Extension Service.

Table 5. Infiltration rates and sediment production for two types of plant communities and five grazing treatments (adapted from Pluhar et al. 1987 and as used by Holechek et al. 1998).

	Infiltration Rate (mm/hr)[1]		Sediment Production (kg/ha)[1]	
Grazing Treatment	**Midgrass**	**Shortgrass**	**Midgrass**	**Shortgrass**
Short-duration (14 pastures)	-	-	-	-
Before grazing	95	75	37	63
After grazing	64	55	105	105
Short-duration (42 pastures)	-	-	-	-
Before grazing	81	86	41	61
After grazing	85	79	75	53
Merrill 3-herd/4 pasture	-	-	-	-
Before grazing	86	80	28	45
After grazing	81	68	71	54
Moderate continuous	89	85	35	30
Exclosure	88	-	23	-

[1] Stocking rate was the same for all treatments.

In addition, no single grazing system will meet the requirements of all producers; that is, there is no "one-size-fits-all" program. Certain tracts of land lend themselves to one type of grazing system better than others, and management philosophies and experience levels of producers will dictate how livestock will be manipulated. However, generalized grazing systems have been developed to facilitate livestock movement and improve forage use efficiency.

Below are grazing systems that may be practical in Texas for livestock on rangeland or on introduced forages such as bermudagrass, bahiagrass, kleingrass, Old World bluestem, cereal grains, ryegrass, and forage legumes. The systems include continuous stocking, rotational stocking, grazing systems for growing livestock, strip grazing, and limit grazing. For most commercial livestock producers, implementing some form of rotational stocking system would probably be beneficial; producers of registered livestock may wish to use a continuous moderately stocked system.

Continuous stocking: Most producers use continuous grazing because it requires the least managerial input and is generally the least expensive to implement. Although criticized by some as ineffective, continuous grazing has several advantages over other grazing systems, including enhanced animal performance.

Individual animal performance—whether measured by live-weight gain, calving percentage, or milk production—is typically higher for livestock in continuous grazing systems (Table 6) under moderately stocked conditions. The improved performance is due to a higher degree of diet selectivity by the animal. If allowed the opportunity, grazing livestock will typically select a more nutritious diet than would be offered by a typical forage sample.

Other grazing systems that involve cattle movement between pastures do not allow the animal as much freedom in diet selection. In those systems, performance is generally reduced because the animal must consume forage that it might not otherwise select. Animal performance varies greatly under different grazing systems, depending on the forage base, stocking rate, time of season, fertility level, moisture availability, and other factors.

The major disadvantage of continuous grazing systems relates to the variable growth rate of forage crops. For example, during early spring, bermudagrass grows quickly, requiring a relatively heavy stocking rate to harvest it most efficiently. Later in the summer, when less rain falls, the forage grows more slowly, and animal numbers must be reduced. To optimize forage use under continuous grazing, producers should vary the stocking rate

Table 6. Beef steer performance under continuous and rotational grazing systems (adapted from Ball et al. 1991).

Pasture Species	Grazing Treatment	Average Daily Gain (lb)	Change From Continuous Stocking (%)	Gain/acre (lb)	Change From Continuous Stocking (%)
Warm-season					
Bermudagrass + N	Continous	1.37	-	738	-
	Rotational - 4[1]	1.27	-7	749	+1
Bermudagrass + N	Continuous	1.31	-	535	-
	Rotational - 4[1]	0.99	-24	419	-22
	Strip	0.86	-19	434	-19
	Green chop	0.81	-38	577	+8
Sericea lespedeza[2]	Continuous	1.87	-	306	-
	Rotational - 3[1]	1.65	-12	276	-10
Cold-season					
Orchardgrass + N	Continuous	1.30	-	364	-
	Rotational - 4[1]	1.23	-5	388	+8
Tall fescue[3] + alfalfa	Continuous	1.70	-	313	-
	Rotational - 4[1]	1.77	+4	308	-2
Tall fescue[3] + N	Continuous	1.62	-	290	-
	Rotational - 10[1]	1.39	-14	354	+22
Tall fescue[4] + N	Continuous	1.28	-	243	-
	Rotational - 10[1]	1.02	-20	349	+44
Wheat/ryegrass + N	Continuous	2.16	-	746	-
	Rotational - 6[1]	1.72	-20	733	-2

[1] Number following rotational is the number of paddocks used in the system.
[2] *Sericea lespedeza* was a low-tannin type.
[3] Tall fescue was endophyte free.
[4] Tall fescue was endophyte infected.

by adjusting either livestock numbers or pasture size.

One way to quickly adjust pasture size and maintain a proper stocking/forage rate is to use inexpensive electric fencing. Another way is to simply open or close gates of a multi-paddock operation. Excess forage from the part of the pasture not being grazed during the rapid growth phase should be cut as high-quality hay. In fact, cutting excess forage for hay or silage is one of the best ways to implement the “variable stocking rate” pasture management scenario.

If a variable stocking rate is not used to match varying forage levels, pastures will be overstocked at some times and understocked at other times. Overstocking coupled with a poor fertility program typically leads to an invasion of weeds and undesirable grasses such as broomsedge and threeawn. Animal performance then declines, and the carrying capacity of the pastures is reduced.

Conversely, understocking results in patch (or spot) grazing, in which the animals repeatedly graze the same area as soon as regrowth is available. The animals continue to use the previously grazed areas because immature regrowth is more palatable and of higher nutritive value. As a result, ungrazed areas in the pasture continue to mature, decline in nutritive value, and become increasingly less palatable. Forage is wasted and the profit potential from the livestock operation declines.

The bottom line regarding continuous grazing is that it can be profitable if the stocking rate is varied to match the variable growth rate of the pasture. If livestock demand is matched to forage production using the “variable stocking rate” management option, the forage is used more efficiently.

Rotational stocking: In a rotational grazing system, livestock are moved from one pasture to another for short periods. The concentration of livestock temporarily overstocks the pasture, increasing forage harvest efficiency. More of the available forage is consumed, and little is wasted.

When rotationally grazing, producers should pay close attention to determine the optimum time to move livestock to another paddock. Timing is the critical element in rotational grazing and requires considerable management expertise. Because forage species grow at different rates, grazing time may be as few as 1 or 2 days or as much as 7 to 10 days per pasture, depending on climatic conditions. In general, move animals in to graze when plants reach a height of 8 to 10 inches and remove them when there are 3 to 4 inches remaining in the pasture.

If the livestock are moved according to the calendar rather than forage availability, animal performance or forage use may be less than optimal.

Varying forage levels may require that producers skip one or more pastures in the grazing rotation and cut the skipped units for hay if excess forage is produced. This cutting will help control weed species and prevent mowed areas from becoming too mature and less nutritious.

Rotational stocking offers several benefits:

- Harvest efficiency is improved, which may allow slightly more (10 percent to

15 percent) livestock than in a poorly managed continuous grazing system.

- Livestock can be controlled better and potential health problems observed earlier because the producer spends more time with the livestock.
- In the spring, early weed species can be controlled more easily.

The disadvantages of rotational stocking include:

- Individual animal performance is reduced. In a rotational stocking system, livestock do not have the diet selectivity of those in a continuous stocking system. This lack of diet selectivity typically reduces animal performance, especially when animals are grazing warm-season forages.
- More fences must be built, although the expense may be offset somewhat by using low-cost electric fencing.
- Additional water development may be necessary.
- Extra labor costs will be required to move livestock.

Some forage species may perform best under rotational grazing, which can increase harvest efficiency and the nutritive value of warm-season perennial grasses. For example, if weeping lovegrass is not rotationally grazed, it is patch grazed by livestock and quickly becomes excessively mature and unpalatable. The livestock then avoid the plants, and forage is wasted.

Rotationally grazing cool-season forage crops may not be as important to the grazing animal, but rest between grazing events may increase the dry-matter production of the plants. Reseeding annual clover species should also be rotationally grazed to promote seed production and stand persistence.

Rotational stocking can help ensure that an appropriate amount of forage residue remains in paddocks to serve as filter strips that protect waterways by trapping contaminants.

<u>Grazing systems for growing animals</u>: Growing animals require more nutrients than do mature males or dry, pregnant females. Grazing systems that have been designed to provide a higher nutritional plane for growing animals include forward creep grazing and creep grazing.

Forward creep grazing is a slight modification of rotational grazing:

1. The livestock herd is split into two groups: "first and last" or "leader and follower" grazers. The first grazers (leaders) are typically younger animals that need more nutrients than do mature animals. The last grazers (followers) are typically mature animals with lower nutritive requirements.
2. The leaders are allowed to graze a paddock first and obtain forage of the highest nutritive value.
3. When about a third of the forage has been consumed, the first grazers are rotated to a new paddock.
4. The last grazers (followers) are then given access to the paddock to consume the forage until about 40 to 50 percent of the aboveground biomass is left.

Growing animals perform better under this variation on rotational grazing than under simple rotational grazing.

Creep grazing, on the other hand, involves the installation of a creep gate to allow younger animals access to forage of higher value. In this system, younger animals have free access to other pastures generally planted to high-quality annual forages, but the size of the creep gate opening prevents mature animals from entering the pasture.

Creep access can be allowed in both warm- and cool-season forages. The species typically used in creep-grazing systems are small grains, ryegrass, and/or clovers for fall and winter grazing, and forage sorghum, sorghum-sudan hybrids, various millets, and cowpeas for summer grazing.

A pasture creep gate is simple to build and install. It can be made of wood or metal and installed either as a gate or as a panel in the fence line. It can also be used in electric fences.

The opening in a creep gate used for calves is generally 18 inches wide, which will accommodate calves weighing up to 600 pounds. The width can be varied to meet the specific requirements of the producer and the livestock.

To limit larger calves from entering the creep pasture, a simple horizontal bar can be added and made adjustable for height. The typical adjustment range for the bar varies from 24 to 48 inches from the ground. Because these gates are often permanently installed in a fence, a second horizontal bar can be added to close the gate completely.

Research has demonstrated that providing growing cattle with creep access to forages of higher nutritive value can add 50 or more pounds at weaning. Creep gates can provide an excellent return for their nominal investment.

Strip grazing: Although used primarily with dairy herds, strip grazing can be adapted to other livestock operations. Strip grazing uses two portable fences (typically electric) to allot a small area of the pasture for grazing (Fig. 10). The livestock are confined to an area smaller than that required for the entire herd. This technique is an intensive form of rotational grazing with a somewhat higher labor requirement. As with other rotational grazing systems, the temporarily overstocked condition results in high harvest efficiency; however, animal performance is typically reduced.

The forages best suited for strip grazing are forage sorghums, sorghum-sudan hybrids, and millets. But any forage may be used. Beef cattle often graze field-cured forage sorghum during the fall and winter in a slight modification of strip grazing.

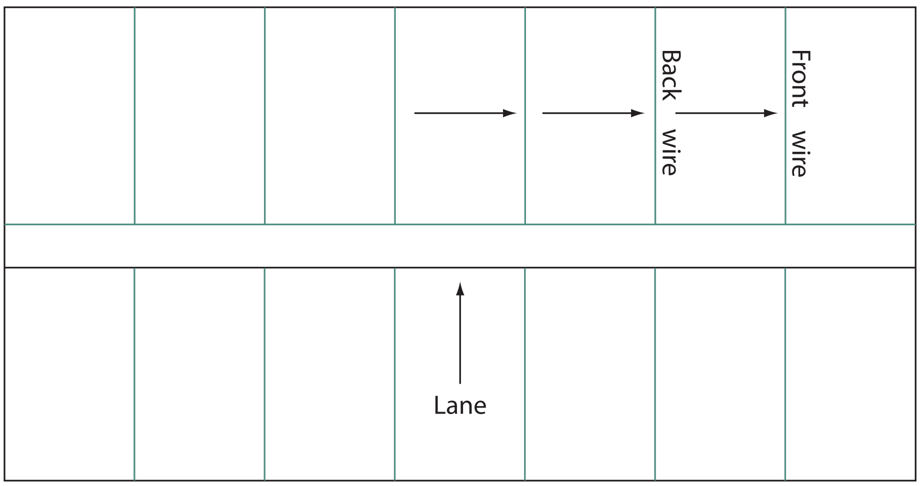

Figure 10. Large pasture divided down the center length-wise with lane in the middle. Paddocks are strip-grazed by moving temporary front wire and back wire across the pasture. This design allows for flexible paddock size and easier machinery work. Illustration courtesy of the USDA-NRCS.

Strip grazing allows the forage to be consumed with a minimum amount of trampling of good forage. The use of one portable fence ahead of the animals prevents them from trampling and thus wasting the field-cured forage.

Limit grazing: Rather than buy relatively expensive protein supplements during the fall and winter, many producers use a grazing system known as limit grazing. In the limit grazing system, livestock spend most of the time on dormant pasture/native range and receive an adequate amount of good-quality hay.

The livestock are also allowed to graze cool-season pastures for a limited time rather than continually. Because properly fertilized cool-season forages generally provide more nutrients than are required by dry pregnant females, they can be given less grazing time. Although most limit grazing systems involve cool-season forages, producers could use the same management strategy using warm-season forages.

Forages that are high in nutritive value can be managed to serve as supplemental protein for mature livestock and help enhance the performance of growing animals. Dry pregnant females can be limit-grazed 1 or 2 hours on alternate days or every third day to conserve forage and still meet their protein requirements. Because lactating cows and growing animals require more nutrients than dry cows, they should be allowed to graze about 2 hours each day on the high-quality forage.

A less efficient limit-graze schedule, but more practical for some people, is to allow 1 full day of grazing on forage of high nutritive value followed by 2 to 4 days of grazing on dormant grass, depending on the animals' crude protein requirements. However, more forage will be lost because of increased trampling, the presence of bedding areas, and dung and urine spots in the pasture.

This system depends on the cattle having an adequate supply of dry grass and/or good quality hay to serve as a source of energy when they do not have access to the better forage. Animal performance is better with limit grazing than with other fall-winter grazing systems using only dormant grass pastures or hay.

Potential bacterial reductions with prescribed grazing: Grazing management evaluations done at Texas A&M University found that rotational grazing, if timed appropriately, was a very effective practice for reducing *E. coli* runoff. The impact of grazing timing in relation to a runoff event was much more significant than the impact of level of grazing (i.e. moderately stocked or heavy stocked) or stocking rate. When runoff occurred more than two weeks following grazing, *E. coli* levels in runoff were decreased more than 88 percent. Based on these findings, upland sites should be grazed during rainy seasons when runoff is more likely to occur and creek pastures and other hydrologically connected areas should be grazed during periods when runoff is less likely (e.g. summer and winter in much of Texas).

Changing the grazing intensity from heavy to moderate can reduce *E. coli* levels by 200 percent over a 7-month period (Tate et al. 2004). The EPA has found that *E. coli* can be reduced by 72 percent when prescribed grazing is implemented with other practices such as contour farming, grassed waterways, nutrient management, and pest management. In another study, fecal coliform was reduced by 90 to 96 percent when the grazing intensity was reduced from heavy to no grazing (Tiedemann et al. 1987, 1988).

Additional Pasture Management Practices
Other pasture management practices that can help you reduce bacterial contamination are soil testing, installing laneways, installing loafing and feeding pads, controlling weeds, mowing/clipping pastures, and dragging pastures.

Soil testing: An inexpensive soil test can help you determine the types and amounts of fertilizer and lime needed for good pasture growth. Applying fertilizer at the appropriate rate and time will help prevent nutrient runoff from over-fertilized pastures. Applying fertilizer at the appropriate rate and time will save money because only the amount needed is applied.

It is best to soil test least once every 3 years to determine the types and amounts of fertilizer and limestone needed before seeding. Your local Texas AgriLife Extension county office (http://agrilifeextension.tamu.edu/) has information available to help you with this process.

Install laneways: Laneways between paddocks help confine cattle traffic and minimize soil compaction. They protect water quality by reducing sedimentation and allowing the water to filter into the soil instead of running off.

Laneways that are well planned and constructed will also (Wrigley and Bell 2006):

- Reduce lameness and environmental mastitis
- Enable easier and faster stock and vehicle movement
- Provide all-weather farm access
- Allow easy access for fence maintenance, etc.

Install loafing and feeding pads: Loafing and feeding pads provide a place for cattle to be held and fed during wet weather. They can be made of porous material such as sawdust or impervious concrete. The pads reduce soil compaction and help protect the pasture.

Weed control: The presence of weeds in a pasture can often indicate overgrazing, poor forage density, or inadequate fertilization. Weeds can out-compete the forage for water, nutrients, and sunlight. Over time, they can reduce the pasture's longevity and nutritional value.

For the best weed control, maintain a dense, healthy stand of grasses and legumes through proper soil fertility, cutting/mowing management, and higher seeding rates.

Mowing/clipping pastures: Livestock can be spot grazers that, if left uncontrolled, can result in a very uneven forage growth pattern in a pasture. Cattle prefer to eat shorter plants because they have less fiber and more protein and nutrients.

Mowing and clipping pastures occasionally during the growing season will discourage weed growth, spur new grass growth, prevent weeds from reproducing, encourage the livestock to use the pasture more uniformly, and prevent the grass from becoming too mature. Pastures may need to be clipped three or more times per year.

Dragging pastures: Areas where excessive manure collects in a pasture can contribute to uneven grazing—livestock typically do not graze near these areas. Use chain or link harrows to help distribute the manure more evenly across the pasture.

This practice can reduce the parasite and bacterial populations by exposing them to air and sunlight; it can also help smooth over areas that the livestock have dug up with their hooves. Dragging pastures helps water and air penetrate the soil.

A good time to drag a pasture is immediately after it has been clipped or mowed.

Burning pastures: Burning can help control undesirable vegetation, prepare for harvesting or seeding, control plant disease, reduce wildfire hazard, improve wildlife habitat, improve plant production, remove debris, and increase seed production.

Burns must be planned carefully. The plan should address the location/description of the burn area, pre-burn vegetation cover, management objectives, required weather conditions, notification list, equipment list, personnel assignments, post-burn evaluation criteria, firing sequence, and ignition method. It should have all necessary approval signatures. Burning should be conducted only by those who have the experience and knowledge necessary to maintain the safety of the people involved.

For more information on prescribed burning, see Planning a Prescribed Burn, available from the Texas AgriLife Extension Service at https://agrilifebookstore.org/.

Final Thoughts on Grazing Systems
The key to proper grazing management is to obtain a balance between animal diet selectivity and harvest efficiency; the "right" system will vary among locations and producers. Producers should carefully match livestock nutrient requirements with forage availability.

Either a continuous or a rotational grazing system will make the optimum use of available forage and increase animal performance, thus creating a profitable livestock operation, depending on the producer's managerial expertise.

Producers who are considering changing the type of grazing system of their operation, or those who are new to livestock production, should:

- Think through the process as it relates to their expectations and the inputs required for each system
- Seek an optimum balance of harvest efficiency, resource conservation, water quality issues, including bacteria, and individual animal performance.

The most significant aspect of a grazing system, however, is to provide grazing livestock with an adequate amount of forage of appropriate nutritive value. This requires choosing the proper forage species for grazing, an appropriate soil fertility program based on soil test recommendations, and the proper stocking rate. One of the most important benefits of achieving an adequate level of forage is improve water quality.

Pest Management

An integrated pest management approach uses routine management practices to minimize the regular use of pesticides.

These strategies include:

- *Match the appropriate stocking rate to the grazing management unit*: Overstocking a pasture degrades soil quality, increases site disturbance, and allows weeds and other unwanted species to invade. Exotic species can out-compete native species for moisture and nutrients. Using the appropriate stocking rate minimizes the number of unwanted weed species in the pasture, and thus the routine application of herbicides.
- *Implement grazing systems that allow for biological control of unwanted, but palatable and nutritious weed species*: Livestock can be trained to eat weed species that are nutritious and palatable. By managing your herd, livestock can be used to control weeds rather than relying on the use of herbicides.
- *Use appropriate fertility programs on introduced-forage pastures*: Applying the appropriate soil nutrients at the proper rate and time will encourage the growth and vigor of desirable forage species that can out-compete less desirable weed species.
- *Adopt prescribed burning programs*: Prescribed fire can safely and efficiently reduce competition from many weed species, especially woody species. For more information on prescribed burning, visit http://www.texasagriculture.gov/Home/ProductionAgriculture/PrescribedBurnProgram.aspx
- *Follow label directions exactly*: When pesticides are required, following label directions will help control target species while protecting the environment. **People who use pesticides in a manner inconsistent with label directions are violating state and federal laws.**

Summary of BMPs for Upland Vegetation Management

Forage-based livestock production systems can be sustainable in maintaining or even enhancing the environment. However, producers must adopt BMPs for the use of appropriate stocking rates, fertilizers, and pesticides if they are to protect the environment as well as increase the potential for profit. Finally, implementing vegetation management BMPs can help protect Texas waterways from bacteria and other pollutants, thus improving water quality now and in the future.

Best Management Practices for Riparian Area Protection

Beef cattle producers can adopt several BMPs to protect riparian areas and measurably reduce bacteria levels in water bodies associated with grazing livestock. Potential BMPs range from allowing cattle full access to riparian areas, limiting their access, and excluding their access all together:

- *Provide alternative water sources* to reduce the time livestock spend drinking from streams (NRCS Code 614).
- *Provide salt and minerals* to encourage livestock to move away from riparian areas.
- *Provide shade facilities* to encourage livestock to spend time away from the riparian area (NRCS Code 717).
- *Install above-water cattle crossings* to discourage loafing and protect water quality 9NRCS Code 578).
- *Install single-animal, hardened water points* in streams to discourage loafing in the stream or riparian area.

- *Implement rotational stocking systems* that reduce the time livestock spend in pastures with riparian areas.
- *Use appropriate stocking rates* that ensure an adequate amount of ground cover remains in pastures, thus, allowing pastures to trap bacteria and/or nutrients in the vegetation and reduce the level of potential pollutants that leave the field and enter the water body.
- *Schedule the use of riparian-area pastures* during the times of year that minimize the impact to the riparian area and water quality.
- *Build fence* to exclude livestock from riparian areas (NRCS Code 382).

Figure 11. Cattle obtaining water directly from streams can increase bacteria levels due to direct deposition. Photo by Doug Boyer, USDA–NRCS.

While the most protective BMP is full exclusion, it is not always feasible (Fig. 11). One of the most common sources of fecal bacteria entering waterways is the direct deposition of feces into the stream while cattle are drinking or loafing in the water. When cattle are totally excluded from the riparian area, bacteria levels in the waterway are reduced significantly.

If cattle are given full access, they may spend a lot of time loafing in sensitive streamside areas for shade and water. These areas are often overgrazed, making the forage plants less able to filter out bacteria, sediment, nutrients, and pesticides that enter the waterway after a rain. Also, cattle trails can degrade stream banks, leading to increased runoff and erosion.

Riparian Area Protection: No Exclusion, Full Access

For many beef cattle production systems, it is not desirable or feasible to totally exclude cattle from the riparian pastures. Nevertheless, these systems must be managed properly to protect water quality from fecal deposition of bacteria and nutrients, sediment production, and destruction of vegetative filter strips, which help protect waterways from runoff of bacteria, nutrients, pesticides, and sediment. Full access of grazing livestock to streams may also destroy stream banks (Fig. 12).

An integral part of riparian area protection is rotational stocking, which is discussed earlier in this handbook. Below are other suggested BMPs for riparian pastures that do not use exclusionary fencing.

Alternative Water Sources

A watering facility is a permanent or portable off-stream water supply, such as a trough or pond system, that provides drinking water for livestock and/or wildlife and also helps improve animal distribution. If a riparian area is completely protected by exclusionary fencing, the landowner must develop alternative water sources for cattle.

Figure 12. Stream bank destruction caused by uncontrolled access by cattle. Photo by Lynn Betts, USDA–NRCS.

Many producers consider the development of an alternative water source as nothing more than an expense. However, costs can be lowered significantly by participating in financial assistance programs from various state and federal agencies. These programs provide up to $13.74 per foot of well depth, based on the 2009 Environmental Quality Incentives Program (EQIP) Standard Rate. An added benefit of developing an alternative water source is that during droughts when surface water sources are depleted, it can provide the water necessary for beef cattle producers to remain in business.

Alternative water sources take several forms and may require drilling a water well. Where electricity is available, electric water pumps can pump water from a well, and it can then be gravity-fed to satellite watering locations. One well of appropriate capacity can provide water to several locations on the ranch.

If electricity is not available, as is generally the case, windmills (Fig. 13) or solar-powered pumps (Fig. 14) can deliver water from groundwater aquifers to the soil surface. Again, the water can be gravity-fed from a central holding location to several additional sites so that one well, if situated appropriately on a high point of the ranch, can gravity-feed several satellite water locations.

The cost of installing watering facilities will vary with the design of the system and the materials used. The following estimates are from the NRCS:

- **Watering troughs**: $450 to about $7,600, depending on the size and material (plastic, galvanized metal, fiberglass, or concrete)
- **Electric water pumps**: $1,900 to $4,000, depending on the size
- **Solar water pumps**: $5,700 to $12,000, depending on well depth
- **Windmills**: $8,200 to $17,800, depending on fan diameter
- **Pond**: $2.08 to $10.08 per cubic yard, depending on size

In areas where the complete exclusion of riparian pastures is not warranted, alternative water sources can significantly


Figures 13 and 14. One of the oldest alternative water sources, the windmill, is still popular in many parts of Texas. Solar-powered water wells are becoming increasingly popular for developing alternative water sources. Photos courtesy of Oklahoma Farm Bureau (left) and Cheney Lake Watershed Inc.

reduce the amount of time that cattle spend in the water loafing and therefore how much fecal material they deposit into the waterway. Studies have shown that where alternative water sources were established but cattle still had full access to riparian pastures, bacteria levels were 51 percent to 94 percent lower than in those pastures where an alternative water source was not provided (Table 7).

Even when cattle have full access to a waterway, an alternative water source can be an effective tool for protecting the riparian area and improving water quality because it can dramatically change the amount of time cattle spend in and near a stream. In one study, GPS collars were used to demonstrate that cattle spent from 43 percent to 57 percent less time in streams when provided an alternative water source (Wagner and Redmon 2011). Another study found a 51 percent reduction in cattle use of the stream area (Sheffield et al. 1997). Miner et al. (1992) found a 90 percent reduction in the amount of time cattle spent in the stream when provided access to an off-stream trough.

In addition to benefiting riparian areas, alternative water sources may improve

Table 7. Bacteria reductions in streams where alternative water sources were available.

Type of Bacteria	Reduction	Reference
E. coli	85%	Byers et al. 2005
Fecal coliform	94%*	Hagedorn et al. 1999
	51%	Sheffield et al. 1997
Fecal *streptococci*	77%	Sheffield et al. 1997

* when combined with other practices.

cattle performance. Water in troughs is generally of higher quality and contains less sediment and fecal coliform than water found in streams and rivers. Studies have found that when presented with alternative water sources, cattle spend much more time drinking from troughs than they do from streams, and calves gained 9 percent more weight from cows drinking clean water compared with pond water (Willms et al. 2002).

An alternative water supply alone, however, will not achieve the targeted improvements in water quality unless it is implemented in conjunction with good grazing management (McIver 2004).

Shade Structures

Providing shade facilities can help reduce the time that cattle spend in riparian areas. Beef cattle are sensitive to temperatures above 75°F and will seek relief from the sun's rays during the heat of the day. Some studies indicate that providing shade in grazing pastures can also increase animal performance (Paul and Turner 2000).
The total shade requirement for grown beef cattle is about 30 to 40 square feet per head (Turner 2000). Shade facilities can be either permanent or temporary and can be made of treated lumber or steel (Fig. 15).

Although the roof of the shade structures may be tin, many producers use 80 percent shade cloth. Shade cloth not only restricts most of the sun's rays and heat, but it also allows heat to dissipate through the weave of the cloth. Shade cloth structures are relatively inexpensive and easy to repair. In the winter, producers should remove and store the cloth to lengthen its useful life.

Shade structures are recommended in most states and by the EPA as an effective BMP. Research suggests that phosphorus,

Figure 15. Shade structures constructed with a tin roof (top) and a shade cloth (bottom). Photos courtesy of The Samuel Roberts Nobel Foundation Inc. (top) and Larry Redmon, Texas AgriLife Extension Service.

sediment, and *E. coli* contamination can be reduced in streams if cattle have access to non-riparian shade and alternative water sources (Byers et al. 2005). Franklin et al. (2009) demonstrated an 85 percent reduction in *E. coli* in runoff when both shade structures and alternative water sources were used.

Preliminary research conducted by Texas A&M University found an 11 percent to 30 percent reduction in the percent time that cattle spend in the creek when a shade structure was made available.

The costs of shade structures vary with size and building materials. Prefabricated models require only assembly and cost about $1,200. Others require welding and other special construction skills and cost about $6.50 per square foot.

Shade does not always have to be constructed. Natural shade (Fig. 16) may also be used to draw cattle out of the riparian area. Producers should consider providing natural shade, especially when clearing and establishing new grazing pastures. Leaving several shade trees in a pasture is a BMP that has zero establishment cost.

Figure 16. Cattle standing beneath a natural shade facility—a mesquite tree. Photo by Hank Prinsen.

Above-Water Cattle Crossings

Above-water crossings can be used to reduce contamination if the site is not subject to flooding. For example, Figure 17 indicates that the above-water crossing is protecting the nearby stream banks: The cattle are moving over the bridge and not traveling up and down the fragile stream banks.

Figure 17. Above-water cattle crossing structure. Note the unaffected adjacent stream banks. Photo by Garnet Baker.

Salt, Mineral, and Feeder Locations

This practice involves the placement of feed, salt, and/or mineral locations off-stream as an attempt to improve grazing distribution and encourage livestock to move away from sensitive riparian areas (Fig. 18). This practice is often used in conjunction with providing an alternative water source. However, cattle are unlikely to respond if they must travel far to access feeding sites, or if the feeding sites are too far from a water source.

Dolev et al. (2010) used GPS collars to track livestock use of external feeding sites placed more than 500 meters away from a water source. They found a decrease of 50 percent to 100 percent in utilization of the areas surrounding the water source. Furthermore, off-stream salt and mineral locations can help improve grazing distribution and reduce stream bank destabilization and associated erosion due to trampling and overgrazing of banks (McInnis and McIver 2001).

Supplemental feeding locations resulted in the following benefits:

- Gains in beef cattle increased by 0.2 to 0.4 pound per day.

Figure 18. A feeder can be used to help draw cattle away from unprotected riparian areas. Photo courtesy of Socha Farms.

Figure 19. Example of an in-stream watering point installed on a local farm pond to prevent cattle from disturbing the adjacent riparian area. Photo by Jeff Vanuga, USDA–NRCS.

- Annual net returns increased by $4,500 to $11,000, depending on cattle prices and precipitation levels
- Cattle distribution improved.
- The development of uncovered and unstable stream banks was reduced by 9 percent over two grazing seasons.

Many different types of off-stream supplements can be used to feed beef cattle and to better disperse grazing away from critical riparian areas. Energy supplements including corn gluten meal, barley, and wheat as well as protein supplements including soybean meal and cottonseed meal are all good choices. Salt and molasses supplements can also be used effectively.

The costs of these supplements vary greatly. For the latest hay prices, see the National Hay Feed and Seed Weekly Summary at http://www.ams.usda.gov/mnreports/lswfeedseed.pdf.

Riparian Area Protection: Exclusion with Limited Access

In-Stream Watering Points

An in-stream watering point gives livestock limited access to a waterway while preventing access to as much of the surrounding riparian area as possible (Fig. 19). This technique allows cattle to drink from the stream, but reduces the amount of time that they spend loafing there, thereby reducing the amount of fecal material deposited in the waterway. In most cases, the entry points that livestock already use can be upgraded by properly sloping the access point and by providing a stable surface for livestock to stand on.

Allowing some access by cattle may be warranted in areas where a pasture is next to or includes a stream or where it is impractical to totally exclude cattle from the riparian area. For example, cattle may need to access pastures on both sides of a stream, or other sources of water may be unavailable.

The watering point should be narrow to discourage loafing in the stream area. Confined areas encourage cattle to simply water and move on. Large herds may need multiple in-stream water points.

For these watering points, a hardened surface is typically extended to the stream at access points. The surface also protects the stream bottom and reduces the amount of sediment stirred up by the cattle. In turn, water quality improves, aquatic habitats are maintained, and reservoirs downstream receive less sediment.

Avoid creating livestock access points where (Berg and Wyman 2001):

- The channel grade or alignment changes abruptly
- The channel bed is unstable
- There are overfalls, which are turbulent sections of a stream where strong currents pass over underwater ridges
- Large tributaries enter the stream
- There is a newly located or constructed channel
- A culvert or bridge is immediately upstream or downstream
- The water is deep and moving fast

No research could be found specifically on the effect of in-stream watering points on bacteria reductions. However, one of the main goals of this BMP is to limit the amount of time that cattle spend loafing in the stream. In consequence, less fecal matter will be deposited directly into the stream, and less bacteria will enter the waterway.

- In-stream watering points can also:
- Prevent or minimize water degradation from sediment, nutrients, and organic materials
- Reduce stream bank erosion
- Enable livestock to cross or provide them a stable area to drink from the stream

Costs should be similar to those for a stream crossing. For more information, contact your local county AgriLife Extension agent, Soil and Water Conservation District (http://www.tsswcb.state.tx.us/swcds), or the Natural Resources Conservation Service (http://www.usda.nrcs).

Hardened Stream Crossings

A stream crossing is a stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles. Geotextile and gravel can be used to establish hardened stream crossings, which facilitate cattle movement, reduce loafing time in the stream, and reduce stream turbidity and sediment loading (Fig. 20).

Figure 20. Hardened crossing points constructed of geotextile fabric, concrete panels, and fine gravel to facilitate cattle movement across specific points in the stream. Photo courtesy of Chenago County Soil and Water Conservation District.

If these crossings are established in conjunction with exclusionary fencing, cattle readily use them, preferring the hardened surface over cattle trails up and down stream banks.

Stream crossings can be built in several different ways using different kinds of materials. Regardless of the design and materials used, the NRCS requires multi-use crossings to be at least 10 feet wide and cattle-only crossings to be at least 6 feet wide. Width is measured from the upstream end to the downstream end of the stream crossing and doesn't include the side slopes.

Most important in the construction design is to slope the stream banks on each side and to provide a firm streambed. Other considerations:

- Flatten the banks enough for livestock or equipment to move safely down them.
- Protect banks with gravel and filter fabric.
- Make the streambed firm enough so livestock or equipment will not cause ruts. For gravel or bedrock streams, additional streambed work may not be needed.

If constructed properly, very little maintenance of the stream crossing should be required. Checking the stream crossing on a regular basis is important to ensure the crossing is functioning properly. Regularly check for eroded areas and repair them right away before the problem expands.

Hardened stream crossings improve water quality by reducing erosion and restricting direct access to waterways. They minimize pollution such as sediment, nutrients, bacteria, and organic matter in the surrounding water bodies.

When combined with other BMPs, stream crossings can reduce the levels of these bacteria:

- *E. coli* by an average of 46 percent (Meals, 2001)
- Fecal coliform by 44 to 52 percent
- Fecal streptococci by 46 to 76 percent (Inamdar et al., 2002)

Hardened stream crossings can be used in conjunction with other practices such as fencing which have been shown to reduce concentrations of bacteria. Refer to this practice description on page X in this resource manual for more in depth information on bacterial removal efficiencies.

Stream crossings can also provide these benefits:

- Easier travel way for equipment and vehicles
- Clearer water in the stream
- Reduced risks of herd health problems, such as foot diseases and leg injuries, associated with unstable footing
- Improved water quality by reducing sediment, nutrient, organic, and inorganic loading to the stream
- Reduced stream bank destabilization and associated erosion due to trampling and overgrazing of banks
- Regeneration of riparian zone vegetation to act as a full or partial buffer

The cost of building and maintaining hardened stream crossings is moderate if the stream is small to moderate sized. Larger stream crossings may cost much more to build. Expenses may include the costs of:

- Labor for grading the stream banks and bottom
- Gravel and filter fabric

- Hog panels, stone, or other material to go in the bed of the stream
- Fencing to lead the livestock to the crossing
- Required building permits

According to the NRCS, a concrete crossing (3,000 psi concrete with rebar) and associated permits costs about $325 per cubic yard. A 120-foot-long crossing made of 4-inch rock over non-woven geotextile costs $60 per ton installed. Both estimates include all costs associated with labor, equipment, and installation.

Riparian Area Protection: Full Exclusion

Exclusionary Fencing

According to the EPA (2003), excluding and/or controlling livestock access to sensitive areas, such as stream banks, wetlands, and estuaries, through the use of exclusionary practices, is one grazing management measure to consider when managing rangeland, pasture, and other grazing lands to protect water quality and aquatic and riparian habitat.

Exclusionary fencing can reduce bacteria levels from 30 to 94 percent (Table 8). Other benefits of fencing include:

- Decreased health risks associated with livestock standing in muddy areas
- Decreased herd injuries associated with livestock climbing steep and unstable stream banks (Lombardo et al. 2000)
- Improved water quality from reducing sediment, nutrient, bacterial, organic, and inorganic loading to the stream (Owens et al. 1996, Sheffield et al. 1997, Line et al. 2000, Lombardo et al. 2000)

Table 8. Effectiveness of exclusionary fencing in removing different kinds of bacteria from runoff.

Type of Bacteria	Reduction	Reference
E. coli	46%	Meals 2001
	37%	Meals 2004
Total coliform	81%	Cook 1998
Fecal coliform	94%*	Hagedorn et al. 1999
	90%	Line 2002
	70%	Lombardo et al. 2000
	66%	Line 2003
	52%[1]	Meals 2001
	42%	Meals 2004
	41%	Brenner 1996
	30%	Brenner at al. 1994
	30%[2]	Cook 1998
Fecal *streptococci*	76%[2]	Cook 1998
	73%	Galeone 2006
	51%[1]	Meals 2001
	30%	Meals 2004
Fecal *enterococci*	57%	Line 2003

* when combined with in-pasture water stations.
[1] when combined with protected stream crossings and stream bank bioengineering.
[2] when combined with alternate water sources, filter strips, and manure management.

- Reduced erosion of stream banks caused by trampling and overgrazing of banks
- Regeneration of riparian zone vegetation to act as a full or partial buffer (Odion et al. 1988, Kondolf 1993, Knapp and Matthews 1996, Kauffman et al. 1997, Dobkin et al. 1998, Ranganath et al. 2009)
- Greater distribution of grazing and better use of forage
- Increased fish production (Bowers et al. 1979)

Producer considerations include the length of the stream segment to be fenced out and ongoing issues with fence maintenance in areas subject to periodic flooding. Many ranchers who use this practice reduce maintenance by placing the fences above the flood-prone areas. The fenced-out area could be used for hay production or periodic short-term mob grazing.

Exclusionary fencing, however, does not preclude managers from using riparian area pastures. The pastures can be used for hay production and also can be grazed if the grazing is managed appropriately, leaving enough ground cover to filter out contaminants.

Managers should consider riparian areas as "special use" pastures. With full exclusion, these pastures can be used as reserve or emergency pastures for use during the dormant season. During this period, grazing can actually help the riparian plant community by removing standing dead grass, which will allow vigorous new grass production. Protected riparian areas generally develop into excellent wildlife habitat, which could provide enhanced opportunities for consumptive or non-consumptive uses of specific wildlife species.

Managers should monitor the riparian area carefully and, when the forage has been reduced to a predetermined height, rotate the cattle to a different pasture. Height stakes can indicate when it is time to move the cattle. The stakes become visible when the forage is grazed to the proper height (Riparian Area Management Handbook, 1998), signaling that it is time to rotate the livestock.

Fencing costs depend on the material used, the length needed, and the terrain on which the fencing is installed. According to the NRCS, permanent electric fence costs about $1.80 per foot on normal terrain, while four-strand barbed-wire fence costs about $2.16 per foot on normal terrain and about $3.05 per foot on steep or rocky terrain. Keep in mind, however, that a hotwire or temporary fence can be used to accomplish the same goal of limiting access by cattle to the riparian area.

The NRCS and the TSSWCB offer financial assistance programs to help landowners with exclusionary fencing, as well as additional incentives in the form of rental fees for the areas excluded (up to $259 per acre).

Filter Strips

Exclusionary fencing may not completely protect the riparian area if adequate vegetative filter strips are not maintained along the waterway. As previously mentioned, the riparian area must be protected from overstocking and overgrazing so that vegetative filter strips can be maintained to further protect streams from runoff of bacteria, nutrients, pesticides, and sediment after heavy rains. A filter strip is an area of herbaceous vegetation that is established between a body of water and cropland, grazing land, or disturbed land (NRCS Code 393; Fig 21).

In addition to protecting water quality, filter strips can also improve soil aeration, create wildlife habitat, provide shade that improves soil moisture content, recycle nutrients that promote plant growth, and help protect riparian areas. If riparian areas are protected from overstocking and overgrazing, they will naturally develop effective vegetative filter strips that further

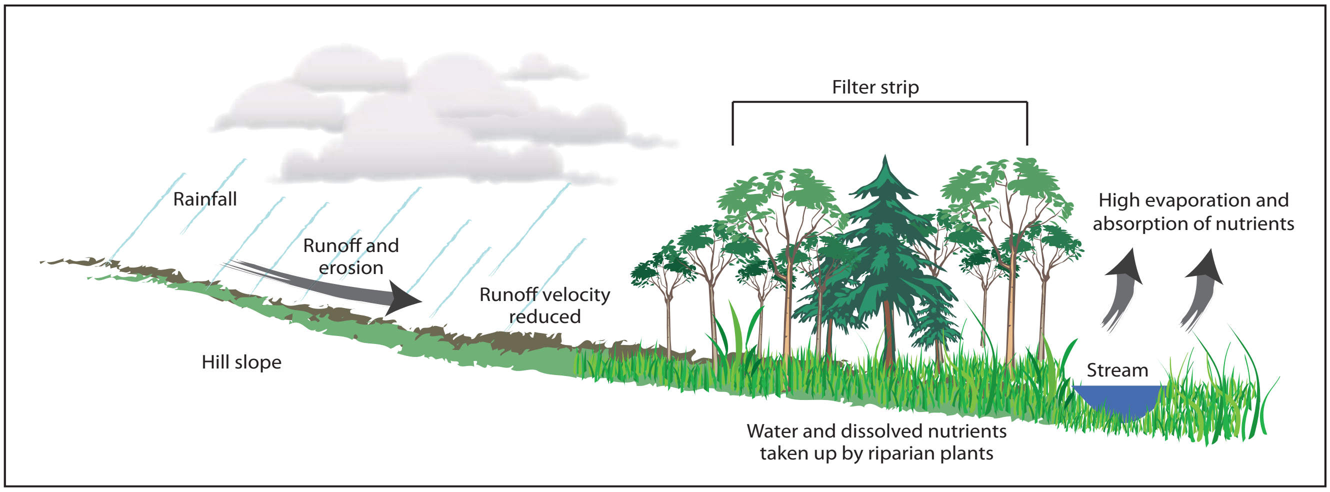

Figure 21. Conceptual model of how vegetative filter strips protect a stream from contaminants and the riparian area from erosion. Illustration by Jennifer Peterson.

protect the stream from runoff containing bacteria, nutrients, pesticides, and sediment.

For adequate protection, filter strips should have specific minimum widths, which vary according to the slope of the land (Table 9).

Their effectiveness of filter strips depends on:

- The amount of sediment that reaches the filter strip
- The amount of time that water is retained in the filter strip
- The steepness, length, and slope of the filter strip
- The infiltration rate of the soil
- The type and density of vegetation used in the filter strip
- The uniformity of the water flow through the filter strip
- The correct installation and maintenance of the filter strip (Smith 2000)

Research has found that filter strips can reduce up to 99.995 percent of bacteria in runoff from land where beef and/or dairy cattle are present (Table 10). In addition, filter strips are effective in removing other contaminants, including atrazine, herbicides, nitrate-nitrogen, sediment, soil, and total phosphorus. They also stabilize the soil, provide shade to help the soil hold moisture, and protect it from the eroding forces of wind, water, and raindrop impact.

The costs of establishing a filter strip vary according to seed, fertilizer, labor, and equipment costs. The NRCS estimates that filter strip installation can cost from $275 to $310 per acre, depending on whether native or nonnative plants are used. However, in many instances, a landowner need only change the stocking rate and/or grazing system to encourage filter strips to develop naturally.

The NRCS offers technical and financial assistance programs to offset up to 50

Table 9. Minimum widths for vegetative filter strips. Standards and Specifications No. 393, USDA-NRCS Field Office Technical Guide, 2004.

Slope	Minimum Width of Buffer Strip
1–3%	25 ft
4–7%	35 ft
8–10%	50 ft

Table10. Effectiveness of filter strips in removing different kinds of bacteria from runoff.

Type of Bacteria	Reduction	Source
E. coli	99.7%	Casteel et al. 2005
	94.8%-99.995%	Tate 2006
	91%	Mankin and Okoren 2003
	57.85%-98.9%	Goel et al. 2004
Total coliform	97%-99.4%	Casteel et al. 2005
	81%	Cook 1998
	69%	Young 1980
	66.89%-92.12%	Goel et al. 2004
Fecal coliform	100%	Lim et al. 1998
	99%	Sullivan 2007, Lewis et al. 2010
	87% and 64%	Fajardo et al. 2001
	83.5%	Mankin and Okoren 2003
	83% and 95%	Larsen et al. 1994
	81%	Stuntebeck and Bannerman 1998
	75% and 91%	Coyne et al. 1998
	69%	Young 1980
	67%	Roodsari et al. 2005
	55.59%-99.78%	Goel et al. 2004
	43% and 72%	Coyne et al. 1995
Fecal streptococci	83.5%	Mankin and Okoren 2003
	76%	Cook 1998
	74% and 68%	Coyne et al. 1998
	70%	Young 1980
Cryptosporidium parvum	99.9%	Atwill et al. 2002
	99.4%	Trask et al. 2004
	99%	Mawdsley et al. 1996
	97%	Miller et al. 2008
	93.5% to 99.4%	Tate et al. 2004
Giardia	26%	Winkworth et al. 2008

percent of the cost of implementation. For more information, contact the NRCS at http://offices.sc.egov.usda/gov/locator/app?agency=nrcs.

Rip-Rap

A low-maintenance alternative to fencing is the placement of large rocks (rip-rap) to keep cattle from using specific trails or stream crossings in limited areas where stream banks are less stable (Fig. 22).

Studies have shown that cattle tend to avoid areas where large stone covers 30 percent or more of the ground (Lyons et al. 2003). Preliminary data from research

Figure 22. This stream bank has been stabilized from erosion with rip-rap. Photo courtesy of the USDA-NRCS.

conducted by Texas A&M University found rocks measuring 4-8 inches in diameter were slightly effective in hindering cattle whereas rocks measuring at least 12 inches in diameter were highly effective.

Understanding this aspect of cattle behavior, producers may be able to use rip-rap in specific instances to alter cattle movement and afford some riparian protection. In fact, these large stones may help strengthen these heavily used areas and reduce the time cattle spend loafing around watering areas (Ziehr 2005).

Practices that limit direct access to a water body by livestock, people, and machinery have the same benefits as exclusionary fencing. They help prevent pollution and erosion and improve the aesthetics of the land. Rip-rap slows the flow of runoff so that less sediment and other pollutants enter the water body (Massachusetts Department of Environmental Protection, 2003).

Non-grouted rip-rap costs about $35 to $50 per square yard, whereas grouted rip-rap costs $45 to $60 per square yard (Mayo et al. 1993). Rip-rap has not been fully tested as an exclusionary device; more research is needed on height, width, and percent cover parameters needed to effectively alter cattle behavior for riparian area protection.

Summary of BMPs for Riparian Area Protection

Although livestock contribute to bacterial loading in water bodies, beef cattle producers can help protect riparian areas using management strategies that work well and, in many instances, cost little to implement and maintain.

BMPs for riparian area protection range from totally excluding cattle from sensitive areas using fencing, to providing full access of riparian areas but with management practices to limit the amount of time that cattle spend there. Other BMPs include the creation of in-stream watering points and hardened stream crossings that work to minimize the time cattle spend loafing and thereby reduce direct fecal deposition into water bodies. In taking steps to protect waterways, beef cattle producers benefit themselves and all Texans.

Manure Management BMPs

Manure is a good soil amendment and a valuable source of nutrients for plant growth. However, livestock manure contains bacteria and other pathogens; if the manure is not managed properly, it can contaminate waterways and harm people and livestock. Pathogens in manure include parasitic roundworms (such as strongyles), *E. coli*, *Listeria monocytogenes*, *Salmonella* spp., *Clostridium tetani*, *Giardia* spp., and *Cryptosporidium* spp.

The average 1,000-pound beef cow produces about 82 pounds of manure per day, which adds up to 13 to 15 tons of manure every year. Manure management BMPs help reduce the volume of manure, destroy the harmful pathogens it contains, and ensure that it does not contaminate water sources. BMPs include using waste storage structures (NRCS Code 313), using waste properly (NRCS Code 633), soil testing and nutrient management (NRCS Code 590), and composting (NRCS Code 317).

Waste Storage Structure

A waste storage structure is an impoundment such as an earthen storage pond, an above- or below-ground storage tank, or a sheltered concrete slab area designed to temporarily store wastes such as manure, wastewater, and contaminated runoff so it does not pollute water bodies downstream (Fig. 23). Ideally, manure is stored until it can be applied to fields at the proper time (based on crop needs and soil fertility tests) instead of applying it repeatedly to the same field based on convenience.

In general, manure storage sites should be located 50 to 100 feet from any stream or drainage course and away from water wells. County or city agencies may require different setback distances than those required by state agencies. Landowners who store manure in or next to a drainage course may be fined by regulatory agencies.

More information about local manure storage requirements is available from the NRCS and local public health or planning departments.

A manure storage facility located inside a floodplain must be protected from flooding or damage from a storm or flood (Council of Bay Area Resource Conservation Districts 2003). Otherwise, rainfall will saturate the stored manure and cause nutrients, bacteria, and other contaminants to leak out of the pile and into surrounding waterways.

Table 11 shows how long-term manure storage (6 to 30 weeks) can decrease the bacteria in waterways. The rate of pathogen decline in stored manure depends on management and storage conditions. Temperature, aeration, pH, and dry matter content all influence pathogen decline rates during storage (Nicholson et al., 2005).

Factors that affect the amount of bacteria in runoff include the type of animal manure, the manure storage method, the age of the manure, the time interval between manure applications, the amount and intensity of rainfall, and other soil and environmental factors that affect bacteria survival, such as soil pH, moisture, soil type, and ambient temperature.

Figure 23. Dry stack manure storage area. Photo courtesy of the Livestock and Poultry Environmental Learning Center.

Waste storage facilities are often used in conjunction with other practices such as fencing, filter strips, and prescribed grazing to reduce concentrations of bacteria. Long-term manure storage (6 to 30 weeks) provides other benefits also:

- Decreased average annual load of total suspended solids by 19 percent (Brannan et al. 2000)
- Decreased average annual load of nitrate-nitrogen by 17 percent, soluble nitrogen by 33 percent, total nitrogen by 35 percent, particulate nitrogen by 38 percent, ammonium-nitrogen by 45 percent, and soluble organic nitrogen by 52 percent (Brannan et al. 2000)
- Decreased average annual load of soluble phosphorus by 23 percent, total phosphorus by 54 percent, soluble organic phosphorus by 66 percent, and particulate phosphorus by 72 percent (Brannan et al. 2000)
- Decreased weed viability (broadleaf and grass species) by 65 to 70 percent (Rupende 1998, Neto and Jones 1986, Pleasant and Schlather 1994)
- Increased availability of nitrogen and potassium (Rupende 1998)

The most common and practical type of manure storage for a small livestock operation is the dry stack system. This type of storage area has three walls at least 4 feet tall. The most effective dry stack storage facilities have poured concrete floors, sloped slightly to direct any drainage to an adjacent vegetative filter strip.

Table 12 shows NRCS cost estimates for various types of facilities. Consult your local NRCS office for more information on manure storage areas and financial assistance programs (http://offices.sc.egov.usda/gov/locator/app).

Table 11. Effectiveness of manure storage in removing different kinds of bacteria from runoff.

Type of Bacteria	Reduction	Reference
E. coli	97% - >99%	Meals and Braun 2006, Nicholson et al. 2005
Total coliform	>99%%	Patni et al. 1985
Fecal coliform	>99%	Patni et al. 1985
	44%*	Inamdar et al. 2007
Fecal *streptococci*	>99%	Patni et al. 1985
	46%-76%*	Inamdar et al. 2007

* when used in combination with fencing, stream crossings, water troughs, nutrient management, conservation tillage, and grassed waterways.

Table 12. Cost estimates for constructing different types of waste storage facilities (NRCS 2011).

Type of Waste Storage Facility	Cost	Practice Life
Small storage tank (storage limited to 2,000 gallons)	$2.00/ gallon	20 years
Waste storage pond	$2.30/cubic yard	20 years
Dry stack facility (earthen floor)	$10/ square foot	20 years
Dry stack facility (concrete floor)	$13.76/ square foot	20 years
Dry stack facility (concrete/earthen floor combo)	$13.76/ square foot	20 years

Waste Utilization

This BMP concerns the proper use of agricultural wastes such as manure, wastewater, and other organic residues (Fig. 24). Manure is often applied to pastures, cropland, and landscapes because it is a soil conditioner and a good source of plant nutrients (Kelly 2011). Manure applied to pastures and cropland can improve soil structure and fertility. But it must be applied properly to protect water bodies.

Figure 24. A manure slurry is applied to this field to help manage the animal waste and to add nutrients to the soil. Photo courtesy of the USDA–NRCS.

On pastures, manure can be spread evenly to a depth of ½ to 1 inch without suppressing pasture vegetation. On cropland, a 2-inch layer of manure can be applied; to prevent losses of nutrients and bacteria in runoff, the manure should be incorporated into the soil by shallow disking or harrowing immediately after spreading. In landscaped areas, manure can be used as a mulch to suppress weeds and conserve soil moisture.

The most important aspect of this practice is applying the manure at the proper rate and time to avoid potentially catastrophic water quality problems. Because manure can contaminate rainfall runoff, maintain at least 100 feet of vegetative buffer between water bodies and areas where manure is applied. Also leave a buffer between manured areas and drinking water supplies—150 feet for private wells and 500 feet for public wells.

Calibrate your manure spreader properly to avoid over-application. Apply manure and compost to actively growing pasture in the spring so the plants can use the nutrients efficiently. If the manure is applied during the dormant season, excess nutrients can accumulate in the soil because plants cannot use them.

Studies have shown that runoff has the most bacterial contamination when rain falls within 48 hours of manure application (Mishra and Benham 2008). Therefore, do not apply manure when rain is expected. In areas of high rainfall, or if the manure must be applied in the rainy season, have enough conservation practices in place to keep runoff from entering and contaminating water bodies.

Waste use goes hand in hand with soil testing and nutrient management. To use manure efficiently, you must know the nutrient content of stored manure and obtain a soil test to determine how much of each nutrient your soil needs. Then you can select the correct application rate to ensure that the soil and plants absorb the manure nutrients.

Research has found that after manure is deposited on land through manure application, or directly by animals, approximately 3 to 23 percent of the fecal coliform content is lost in runoff (Robbins et al. 1971). However, applying the waste at the appropriate time and rate will prevent excessive runoff of bacteria, nutrients, and other contaminants, and will protect water quality.

The survival rate of bacteria in animal wastewater applied to crops and pastures depends on pH, soil moisture, temperature, and other environmental factors. One study found that 50 hours of bright sunlight was enough to destroy virtually all fecal coliforms that were in the wastewater when it was applied to the land (Bell and Bole 1976). Other research found that total and fecal coliform numbers declined 10-fold every 7 to 14 days after the waste application (Entry et al. 2000). At about 90 days, total and fecal coliforms had been eliminated.

The NRCS estimates the cost of waste utilization to be $20.45 per acre (on-farm) to $44.74 per acre (off-farm). This includes the costs of a soil test, calculating a nutrient budget, record keeping, transport, and application.

Contact the NRCS office at the local USDA Service Center for more information on using waste and financial assistance programs (http://offices.sc.egov.usda/gov/locator/app).

Soil Testing and Nutrient Management

These practices involve managing the These practices involve managing the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments and require both a soil test and a manure test.

Once you know the nutrient needs of your soil and the nutrient content of the manure, you can calculate a nutrient budget for nitrogen, phosphorus, and potassium that considers all potential sources of nutrients, including manure deposited by the animals, wastewater, commercial fertilizer, crop residues, legume credits, and irrigation water. Then you can determine the amount of stored manure that can be applied safely without the risk that excess nutrients will pollute surface water and groundwater.

Before spreading manure, have the soil analyzed by a laboratory to determine its fertilizer needs and to establish a baseline for future monitoring (Fig. 25). Testing is especially important if manure has been applied to a pasture for many years. Because nutrients such as nitrogen and phosphorus are released over time, a field that has been used for manure disposal may already have high levels of nutrients and salts (San Francisco Bay Resource Conservation and Development Council 2001).

Figure 25. A soil sample being placed into a soil sample bag. Photo courtesy of Mark McFarland, Texas AgriLife Extension Service.

In Texas, soil sample bags, sampling instructions, and information sheets for mailing samples to the Soil, Water, and Forage Testing Laboratory at Texas A&M University (http://soiltesting.tamu.edu) can be obtained from your county Extension office. See Appendix A for information on collecting and sending soil samples.

In addition to a soil test, have a laboratory analyze the manure to determine its nutrient content. This analysis will help ensure that manure application meets but does not exceed plant nutrient requirements.

For example, some of the nitrogen in manure may not be in a form that is immediately available for plant use, or more fertilizer may be needed to supply specific nutrients (San Francisco Bay Resource Conservation and Development Council 2001).

Manure samples also can be sent to the Soil, Water, and Forage Testing Laboratory at Texas A&M University. See Appendix B for information on taking manure samples. More information on manure testing is also available from your county Extension office.

Using soil testing and nutrient management practices on your farm or ranch will help minimize bacterial contamination of waterways by ensuring that the proper amount of manure is applied at the appropriate time. This BMP also helps reduce nutrient contamination, which causes algae blooms and eutrophication (low dissolved oxygen in water). Without laboratory analyses of your soil and manure, it is impossible to know the nutrient requirements of your soil and the nutrient and bacterial composition of your manure. Thus, the over-application of manure becomes a real concern.

When manure is applied according to soil test recommendations, it can offset the cost of fertilizer, improve plant growth and animal health, minimize nonpoint source pollution of surface and groundwater, protect air quality by reducing nitrogen emissions (ammonia and nitrous oxide compounds) and the formation of atmospheric particulates, and maintain or improve the physical, chemical, and biological condition of soil.

A routine soil analysis can be obtained for as little as $10 per sample from the Texas AgriLife Extension Service Soil, Water, and Forage Testing Laboratory at Texas A&M University. The laboratory also does other soil analyses (Table 13). A manure analysis costs $15 per sample. This test analyzes levels of calcium, copper, magnesium, manganese, nitrogen, phosphorus, potassium, sodium, zinc, and percent moisture.

Composting

Many farmers, ranchers, and landowners spread manure straight to the land after removing it from the housing, either because of inadequate storage capacity or simply for convenience. This practice can be harmful because fresh manure contains more pathogens than does stored or treated manure (Smith at al. 2000).

A good option for livestock owners is to compost manure. Composting reduces the volume of the material and makes it more useful on-site (Fig. 26). Composting is a managed process that accelerates the decomposition and conversion of organic matter into stable humus, which can improve pastures, fields, and/or gardens.

Composting livestock manure can take 30 to 60 days; adding bedding to the manure

Table 13. Description and costs of soil tests available through the Texas AgriLife Extension Service Soil, Water, and Forage Testing Laboratory at Texas A&M University.

Test	Description	Cost per Sample
Routine Analysis (R)	pH, NO3-N, Conductivity and Mehlich III by ICP P, K, Ca, Mg, Na, and S.	$10
R + Micronutrients (Micro)	DTPA Zn, Fe, Cu, and Mn.	$15
R + Micro + Hot Water Soluble Boron (B)	Primarily for sandy or eroded soils, low in organic matter for the crops, alfalfa, cotton, peanuts, and root crops.	$20
R + Detailed Salinity (Sal)	Saturated paste extractable Ca, Mg, K, Na, conductivity and pH	$25
R + Micro + Sal	See above.	$30
R + Micro + Detailed Limestone Requirement (Lime)	The limestone recommendation is based on the amount of exchangeable acidity measured in the soil and the optimum soil pH level for the crop.	$20
R + Micro + B + Lime + Organic Matter + Sal	This analysis gives the percent organic matter in soil or compost determined by the loss on ignition. Most plants do best in soils with organic matter contents between 4 and 8 percent. Finished composts usually range from 40 to 60 percent organic matter.	$50
R + Textural Analysis	The total amounts of sand, silt, and clay sized particles are determined. Soils are categorized according to USDA soil textural classifications.	$20
R + Organic Matter	See above.	$20

may require as long as 6 months to compost. Although composting requires extra time and expense, the benefits far outweigh the costs.

Successful composting depends on the following factors (Warren and Sweet 2003):

- **Air**: Microorganisms need oxygen to decompose manure properly. Therefore, manure should be combined with bulkier materials such as wood shavings, lawn clippings, straw bedding, or hay.
- **Moisture**: Microorganisms also need moisture. The composting material should have about 50 percent moisture.
- **Particle size**: Because small particles decompose faster than do larger ones, shred bulky materials before adding them to the compost pile.
- **Temperature**: Effective composting requires temperatures of 131 to 149°F.
- **Pile size**: Smaller compost piles stay cooler and dry out faster than larger ones. A pile at least 3.5 by 3.5 by 3.5 feet (1 cubic meter) will stay hot enough for year-round composting, even in the winter.
- **Nutrients**: Microorganisms need nutrients such as carbon and nitrogen for proper decomposition. The ideal carbon-to-nitrogen ratio (C:N) for effective composting is about 30:1. A mixture of one part manure to two parts bedding (by volume) will usually provide

Figure 26. Multiple bin compost system. Photo courtesy of O_2 Compost.

this ratio, although it can be altered depending on the amount and type of bedding material used (Table 14).

An on-farm composting system can be designed in several ways, and no single design is appropriate for all sizes and types of animal facilities. Tailor your composting system to accommodate the number of animals, the space and equipment available, and the amount of time and effort you will commit to managing the pile.

To protect water quality, the most important factor to consider is the physical location of the pile. Select a fairly flat site, avoid low-lying areas, and locate the pile away from groundwater and surface water sources.

Composting can effectively reduce pathogens to levels that are acceptable in organic soil amendments. When the temperature of a compost pile is at least 113°F for more than 3 days, almost 100 percent of *E. coli*, total coliform, fecal coliform, and Salmonella will be killed (Crohn et al. 2000, Larney et al. 2003, Millner et al. 2010, Sobsey et al. 2001). Reduce management and increase pathogen die-off by adding straw to the pile, which increases aeration, self-heating capacity, and heat retention (Millner et al. 2010).

Besides eliminating bacteria, composting manure reduces levels of ammonia-nitrogen, water-soluble phosphorus, water-soluble organic matter, total soluble salts, weed seeds, and parasite eggs and larvae. It also reduces odor and breeding sites for flies. Composted manure has 40 to 50 percent less volume than does fresh manure. It is an excellent soil amendment that can be used on the ranch or given or sold to others.

The cost of constructing a compost facility depends on its size and the materials used. According to the NRCS, a 6-bin composter with 1,440 cubic feet of bin space costs about $19.74 per cubic foot to build, operate, and maintain (including materials and labor).

For more information on composting and financial assistance programs, contact the NRCS office at the local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app).

Summary of Manure Management BMPs
Proper manure management should be an important concern for every livestock owner. Manure must be stored, handled, recycled, and disposed of properly to protect water quality and keep animals, people, and the surrounding environment healthy.

Table 14. Carbon to nitrogen ratios for manure and bedding materials (Warren and Sweet 2003).

Material	C:N Ratio*
Raw cattle manure	10-15:1
Grass clippings	25:1
Cattle manure with bedding	20-30:1
Grass hay	30-40:1
Straw	40-100:1
Paper	150-200:1
Wood chips, sawdust	200-500:1

* C:N ratios represent comparative weights. For example, 20 pounds of cattle manure would contain 1 pound of nitrogen, while 500 pounds of sawdust would contain 1 pound of nitrogen. To estimate the C:N of a mixture, average the ratios of the individual materials. For example, a mixture of equal parts manure and straw might have a C:N of 30:1 ((20 + 40)/2 = 30).

Storing manure, applying it to land at the proper rate and time according to soil and manure tests, and composting it are all responsible ways to control the spread of pathogens to groundwater and surface water. As always, assess your situation and goals, and implement the practices that work best for you and your land.

Mortality Management BMPs

Animal mortality must be managed to protect the health of people, animals, and the environment (Gould et al. 2002), so it is important to know your options and plan ahead. Disposing of carcasses properly reduces odors, bacterial contamination, and the spread of disease. Mortality management will provide the following benefits:

- Less pollution of groundwater and surface water.
- Reduced odors from improperly handled carcasses.
- Reduced damage to crops and forages.
- Decreased risk of diseases spreading to animals feeding on the carcass.
- Provide contingencies for normal and catastrophic mortality events.

Large numbers of animals can die from a disease epidemic or natural disaster, but these events are rare. This section focuses on the normal, day-to-day deaths from illness or injury that every operation must deal with. Several methods discussed may be applicable to the management of large-scale mortalities if scaled appropriately and conducted under the guidance and supervision of pertinent state and environmental agencies. See Appendix C for information from the TCEQ regarding the disposal of domestic and exotic livestock carcasses.

The on-farm disposal of dead animals should always be done in a manner that protects public health and safety, does not create a nuisance, prevents the spread of disease, and prevents harm to water quality (TCEQ 2005). To determine the requirements for using any of the following options, contact the local regulatory agency (in Texas, the TCEQ or the Texas Animal Health Commission).

Acceptable ways for managing mortality include the following methods (Gould et al. 2002):

1. Rendering
2. Composting
3. Incineration
4. Sanitary landfills
5. Burial

Rendering

Rendering recycles the nutrients contained in the carcasses of dead animals, most often as an ingredient in animal food, especially for pets. The meat can also be used to feed large carnivorous animals in zoos. In the process of rendering, carcasses are exposed to high temperatures (about 265°F) from pressurized steam to destroy most pathogens (Rahman et al. 2009).

The rendering market has changed in recent years because of the falling prices of meat and bone meal and concerns over bovine spongiform encephalopathy (BSE, or mad cow disease). In Texas, a person must be licensed by the state to pick up dead animals for rendering. There are a handful of rendering facilities in Texas, and most require that animals be removed within 24 hours of death.

Depending on the distance to the facility, the cost of rendering ranges from $25 to about $200 per animal. Proper biosecurity measures must be used to minimize the spread of disease from farm to farm by rendering plant vehicles and personnel.

For a list of rendering facilities in Texas, visit http://nationalrenderers.org.

Although rendering can be a cost-effective way of dealing with a livestock carcass, it might not be an option for all livestock owners. The biggest challenges in using this disposal method are the lack of timely pickup service and long distances between rural areas and rendering plants (Rahman et al. 2009). In many areas, the numbers of rendering facilities are limited and in many cases are declining due to increased costs and biosecurity risks associated with transporting mortalities (Glanville et al. 2009).

Composting

Composting uses the natural decomposition process in which microorganisms, bacteria, and fungi break the carcass down into basic elements (organic matter). The biosecurity agencies in the United States and other countries consider composting an effective way of managing routine and emergency mortalities (Wilkinson 2007).

Composting has advantages over other methods of carcass disposal when conducted properly. It costs less; the piles and windrows are easy to prepare with machinery available on the farm; and it is less likely to pollute air and water. Proper composting will destroy most disease-causing bacteria and viruses. Composting is popular in areas where burial and incineration are restricted or impractical.

To compost a carcass, select a site where surface water will not run off into the compost pile, where leachate from the pile will not run off the site, and where raw or finished compost nutrients will not leach into groundwater.

Other requirements (Gould et al. 2002):

- The carbon-to-nitrogen ratio must be between 15:1 and 35:1.
- The moisture content must be between 40 and 60 percent.
- Enough oxygen must be available to maintain an aerobic environment.
- The pH must range from 6 to 8.
- Temperatures must range between 90 and 140°F.

Large carcasses can be composted in bins or static windrows (Keener et al. 2000). Bins are three-sided compartments; compost material is cycled through the bins as different decomposition stages are reached.

Windrows are long, continuous rows of compost material. For large animals, pile or windrow composting is usually easier and more effective. In this practice, the compost pile or windrow is constructed in the open on a concrete floor or a compacted soil surface such as clay. The pile is aerated by natural air movement and is turned periodically to encourage decomposition.

The cost of composting a whole animal is about $4 per carcass (Looper 2007).

Incineration
Incineration destroys carcasses by burning them with fuel such as propane, diesel, or natural gas. The incineration of a 1,000-pound animal can cost from $600 to $1,000, depending on the location and current price of fuel.

Despite the relatively high cost, incineration/cremation is one of the most environmentally friendly ways to dispose of a carcass. Air and water quality are protected because of strict state and federal environmental regulations that apply to incinerators. The remaining ashes pose no environmental threat and can be returned to the owner for burial or sent to a landfill for disposal.

Burning carcasses in a pit on site also is an acceptable method of disposal in Texas. Open-pit or open-pile burning should be a method of last resort, however. Make sure that personnel and property will be safe, and choose a proper location away from public view.

According to the TCEQ, burning must take place downwind of or at least 300 feet from occupied structures. If possible, the burning must take place during the day when winds are 6 to 23 mph. It must be monitored closely, and all burning must be completed on the same day.

Incineration may actually be required for certain disease diagnosis and may not be available due to burn bans or air quality restrictions.

Sanitary Landfills
Landfills are an alternative to burial. However, not all municipal landfills accept animal carcasses. Some landfills that accept livestock carcasses will not take the remains of a chemically euthanized animal.

The cost is usually about $80 to $150. Contact your local landfill for more information.

Burial
Although burial is a common method of carcass disposal, it can harm surface water and groundwater if done improperly. According to the TCEQ, the burial site should not be located in an area with a high water table or with very permeable soils.

For example, areas with sandy or gravelly soils and a shallow groundwater table must not be used as burial sites. Furthermore, animals should be buried at least 300 feet from the nearest surface water, at least 300 feet from the nearest drinking water well, and at least 200 feet from adjacent property lines.

A backhoe will be needed to dig a hole at least 6 feet deep. Renting a backhoe costs $100 to $200.

Texas law requires notification 48 hours prior to any excavation to assure utilities are properly marked. To locate all your utility services before you dig, call 1-800-dig-tess. In addition, deeds must be marked with burial sites according to TCEQ as well.

Potential bacterial reductions with proper mortality management: Most studies on pathogen reduction and mortality management have focused on composting and incineration. The key is to maintain temperatures that are high enough to eliminate pathogens. Composting controls nearly all pathogenic viruses, bacteria, fungi, and protozoa (Wilkinson 2007).

Bin and static pile composting systems can dramatically reduce bacteria levels: A study by Mukhtar et al. (2003) found that even with little maintenance of the piles, levels of *Salmonella* and fecal coliform bacteria were almost undetectable after 9 months. The study concluded that a low-maintenance bin-composting operation can successfully dispose of livestock carcasses and bedding in temperate climates during seasons of normal precipitation.

Other studies of horse, deer, cow, and other animal carcass composting have found similar results (Sander et al. 2002, Jones and Martin 2003, Blake 2004, Schwarz et al. 2008).

Summary of Mortality Management BMPs

When deciding on a disposal method for your livestock, consider your emotional and financial needs and carefully research local regulations. By weighing all aspects of the various options in advance, you will be prepared with a method that is both humane and environmentally responsible. Of utmost importance is disposing of the animal carcass correctly to avoid environmental, health, or legal problems.

Chapter 3

Sources of Technical and Financial Assistance for BMP Implementation

Photo courtesy of the Texas AgriLife Extension Service

Sources of Technical Assistance for BMP Implementation

Many agencies offer free consultations on issues you may be facing or plans you would like to implement. These agencies also routinely conduct free seminars and short courses on current information and management practices in agriculture. The agencies include the local Soil and Water Conservation District, the Texas State Soil and Water Conservation Board, the USDA–Natural Resources Conservation Service, and the Texas AgriLife Extension Service.

Soil and Water Conservation Districts

Soil and Water Conservation Districts are independent political subdivisions of state government, like a county or school district. The first SWCDs in Texas were organized in 1940 in response to the widespread agricultural and ecological devastation of the Dust Bowl of the 1930s. There are currently 216 SWCDs organized across the state. Each SWCD is governed by five directors elected by landowners within the district.

SWCDs serve as the state's primary delivery system through which technical assistance and financial incentives for natural resource conservation programs are channeled to agricultural producers and rural landowners. SWCDs work to bring about the widespread understanding of the needs of soil and water conservation. SWCDs work to combat soil and water erosion and enhance water quality and quantity across the state by giving farmers and ranchers the opportunity to solve local conservation challenges. SWCDs instill in landowners and citizens a stewardship ethic and individual responsibility for soil and water conservation.

SWCDs assist federal agencies in establishing resource conservation priorities for federal Farm Bill and CWA programs based on locally-specific knowledge of natural resource concerns. SWCDs work with the USDA NRCS, USDA Farm Service Agency, USEPA, Texas AgriLife Extension Service, TFS, and others when necessary to assist landowners and agricultural producers meet natural resource conservation needs.

Texas State Soil and Water Conservation Board

The Texas State Soil and Water Conservation Board (TSSWCB) offers technical assistance to the state's 216 SWCDs. The TSSWCB was created in 1939 by the Texas Legislature and is the lead agency in Texas for planning, implementing, and managing programs and practices to reduce agricultural and silvicultural nonpoint source pollution.

The primary means for achieving this goal is through water quality management plans (WQMPs), which are site-specific plans developed through and approved by SWCDs for agricultural or silvicultural lands. Five regional offices (Fig. 27) help local districts and landowners develop these plans.

The TSSWCB also works with other state and federal agencies on nonpoint source pollution issues as they relate to the state water quality standards, Total Maximum Daily Loads, Watershed Protection Plans, and the Coastal Management Plan.

Natural Resources Conservation Service

The USDA Natural Resources Conservation Service (NRCS), a federal agency, helps landowners and managers improve and protect their soil, water, and other natural resources. For decades, private landowners have voluntarily worked with NRCS specialists to prevent erosion, improve water quality, and promote sustainable agriculture.

The agency employs soil conservationists, rangeland management specialists, soil scientists, agronomists, biologists, engineers, geologists, engineers, and foresters. These experts help landowners develop conservation plans, create and restore wetlands, and restore and manage other natural ecosystems.

Texas AgriLife Extension Service
The mission of the Texas AgriLife Extension Service is to provide community-based education to Texans. Its network of 250 county Extension offices, 616 Extension agents, and 343 subject-matter specialists makes expertise available to every resident in every Texas county. These specialists and agents are a technical resource for agricultural producers throughout the state.

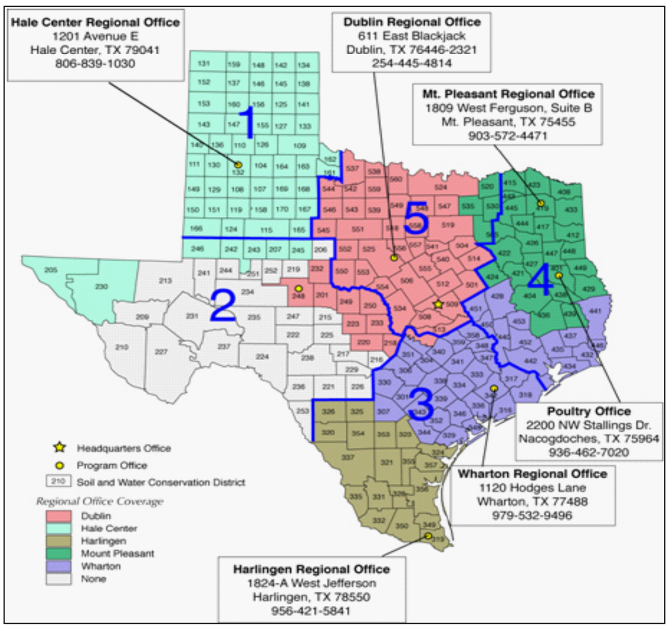

Figure 27. Map showing the five regions of the Texas State Soil and Water Conservation Board. Illustration courtesy of the Texas State Soil and Water Conservation Board.

Sources of Financial Assistance for BMP Implementation

Financial assistance for implementing BMPs is provided primarily through the Texas State Soil and Water Conservation Board, Natural Resources Conservation Service, and USDA Farm Service Agency.

Texas State Soil and Water Conservation Board
In addition to technical assistance, the TSSWCB can also offer financial assistance for the implementation of BMPs. Two programs offered by the TSSWCB provide financial assistance for the implementation of water quality management plans (WQMP) and the installation of BMPs:

- Water Quality Management Plan Program: Provides financial assistance to eligible landowners for WQMP implementation of up to 75 percent with a maximum of $15,000 per plan. Landowners and operators may request the development of a site-specific water quality management plan through local SWCDs. Plans include appropriate land treatment practices, production practices and management and technology measures to achieve a level of pollution prevention or abatement consistent with state water quality standards.
- The Clean Water Act Section 319(h) Nonpoint Source Grant Program: The U.S. Environmental Protection Agency distributes CWA 319 funds to state agencies involved in water quality management (in Texas, the TCEQ and TSSWCB). This assistance provides funding for various types of projects that work to reduce nonpoint source water pollution. Funds may be used to conduct assessments, develop and implement

TMDLs and watershed protection plans, provide technical assistance, demonstrate new technology, and provide education and outreach.

Natural Resources Conservation Service
The Environmental Quality Incentives Program (EQIP) is the primary program offered by the NRCS for implementing BMPs.

EQIP is a voluntary conservation program that supports production agriculture and environmental quality. The program provides financial assistance to farmers and ranchers to implement BMPs. It is designed to address both locally identified resource concerns and state priorities. In FY 2011, the Texas allocation for EQIP was just under $58 million.

The amount of funding available for EQIP varies among counties. To be eligible for this program, a person must be involved in livestock or agricultural production and develop a plan of operations. This plan defines the objective to be achieved by the conservation practice proposed and a schedule of practice implementation. Applications are then ranked by the environmental benefits achieved and the cost effectiveness of the proposed plan.

The NRCS also offers other programs for BMP implementation:

- The Conservation Security Program provides financial and technical assistance to promote conservation and natural resource improvement.
- The Grassland Reserve Program is a voluntary program that helps landowners and operators restore and protect grassland.
- The Wetlands Reserve Program provides technical and financial support for landowners restoring wetlands.
- The Wildlife Habitat Incentives Program offers financial incentives to develop habitat for fish and wildlife on private lands.

For more information, see the NRCS website at http://www. nrcs. usda. gov/.

USDA Farm Service Agency
The Farm Services Agency administers several programs that can help in BMP implementation, including the Conservation Reserve Program, Conservation Reserve Enhancement Program, and Source Water Protection Program.

<u>Conservation Reserve Program</u>: This program provides annual rental payments and financial assistance to establish long-term, resource-conserving ground covers on eligible farmland. It helps agricultural producers safeguard environmentally sensitive land through practices that improve the quality of water, control soil erosion, and enhance wildlife habitat.

After enrollment, the agency will pay an annual per-acre rental rate and provide up to 50 percent cost-share assistance for practices that accomplish the above goals. The portions of property to be submitted to the program will be under contract for 10 to 15 years and cannot be grazed or farmed.

To be eligible for the program, agricultural producers must have owned or leased the land for at least 1 year before the application. Also, the land submitted must be suitable for these BMPs:

- Riparian buffers
- Wildlife habitat buffers
- Wetland buffers
- Filter strips
- Wetland restoration
- Grass waterways
- Contour grass strips

Conservation Reserve Enhancement Program: This voluntary land retirement program helps agricultural producers protect environmentally sensitive land, decrease erosion, restore wildlife habitat, and safeguard ground and surface water.

Source Water Protection Program: This program helps prevent source water pollution through voluntary practices implemented by producers at the local level.

Conclusion

Texas is projected to have exponential population growth in the near future. Concurrently, our water supply is projected to decline, making water conservation and protection all the more important. As the population increases, more development and fragmentation of large tracts of land are expected. This trend will contribute to runoff and decrease the ability of our land to filter it effectively. Increasing numbers of bacteria will continue to find a way into our surface waters as more livestock are applied to the land whether for recreational or commercial purposes.

This guide is primarily focused on the contribution to nonpoint source pollution from beef cattle operations, but there are other sources such as wastewater treatment facilities, failing septic systems, and urban runoff that contribute to water quality impairments as well. This confirms the need to educate all aspects of society on the importance of maintaining and conserving the quality of water necessary for good health.

As discussed, there are many important aspects to animal care that extend beyond simply owning and feeding livestock. Controlling runoff, managing manure, and maintaining pasture and facilities can take a considerable amount of time and effort, but result in far more benefits not only to the animal and operation, but to the surrounding land. The collective impact of mismanagement of beef cattle facilities can be environmentally harmful. The management practices that minimize these impacts will result in a farm that is healthy, saves money, and is aesthetically pleasing.

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Additional Resources

A Texas Field Guide to Evaluating Rangeland Stream and Riparian Health – B-6157

Alternatives for Cattle During the Drought: Moving Cattle off the Ranch – ASWeb-004

Conservation of Soil Resources on Lands Used for Grazing – SCS-2002-06

Destocking Strategies During Drought – ASWeb-016

Developing and Using a Forage System – SCS-2003-08

Do You Have Enough Forage? – E-392

Forage Establishment, Management, and Utilization Fundamentals – SCS-2003-07

Forages for Texas – SCS-2002-14

Forages: They're Good For Life – SCS-2001-07

Grazing Land Stewardship: A Manual for Texas Landowners – B-6221

Matching Enterprises to Resources – SCS-2003-05

Preparing for the Next Drought – SCS 2007 11

Rangeland Watershed Management for Texans: Are Your Pastures Healthy? – E-107

Routine and Emergency Burial of Animal Carcasses: E-599

Stocking Rate and Grazing Management – E-64

Stocking Rate Decisions – E-152

Testing Your Soil: How to Collect and Send Samples – L-1793

Texas Watershed Steward Handbook: A Water Resource Training Curriculum – B-6203

The Texas Cow-Calf and Stocker Beef Safety and Quality Assurance Handbook

Water Quality: Its Relationship to Livestock – L-2374

Publications are available through the Texas AgriLife Extension Bookstore (https://agrilifebookstore.org/) or by contacting Larry Redmon (lredmon@ag.tamu.edu).

APPENDIX A

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AgriLIFE EXTENSION
Texas A&M System

Testing Your Soil
How to Collect and Send Samples

T. L. Provin and J. L. Pitt*

Soil tests can be used to estimate the kinds and amounts of soil nutrients available to plants. They also can be used as aids in determining fertilizer needs. Properly conducted soil sampling and testing can be cost-effective indicators of the types and amounts of fertilizer and lime needed to improve crop yield.

The effects of adding a fertilizer often depend on the level of nutrients already present in the soil (Fig. 1). If a soil is very low in a particular nutrient, yield will probably be increased if that nutrient is added. By comparison, if the soil has high initial nutrient levels, fertilization will result in little, if any, increase in yield.

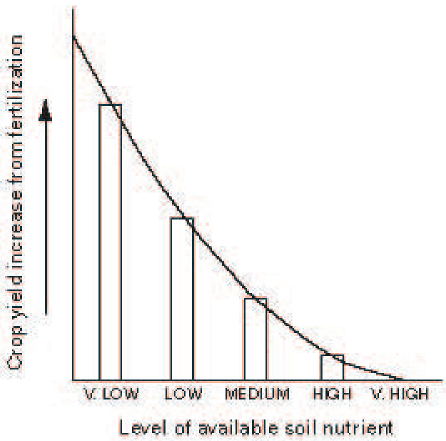

Figure 1. The probability of a crop yield increase resulting from fertilization depends on the initial amount of available nutrients in the soil.

*Assistant Professor and Soil Chemist/Laboratory Director, Program Specialist-Laboratory Manager, Soil, Water, and Forage Testing Laboratory; The Texas A&M System.

There are three steps involved in obtaining a soil test:

1) obtain sample bags and instructions,
2) collect composite samples,
3) select the proper test, and complete the information sheet and mail to the Soil, Water, and Forage Testing Laboratory at 2478 TAMU, College Station, TX 77843-2478 for U.S. mail or 2610 F&B Road, College Station, TX 77845 for commercial deliveries. Contact the lab at (979) 845-4816, FAX (979) 845-5958, or at the Web site *http://soiltesting.tamu.edu* for additional information.

Obtain sample bags and instructions

County Extension offices provide soil sample bags, sampling instructions and information sheets for mailing samples to the Soil, Water, and Forage Testing Laboratory of the Texas Agricultural Extension Service.

Sample bags provided by the Extension service hold a sufficient amount of soil for use in most soil tests. Fill the sample bag or other suitable container with approximately 1 pint of a composite soil sample. Any suitable container can be used for the sample, but it is important to complete the information sheet and follow the instructions for collecting and mailing samples.

Collect composite samples

The objective in sampling is to obtain small composited samples of soil that represent the entire area to be fertilized or limed. This composited sample is comprised of 10 to 15 cores or slices of soil from the sampling area.

To sample a field or pasture, make a map that identifies each area in the field where subsamples were taken (Fig. 2). Fields or tracts of land with differences in past crop ping, fertilization, liming, soil types or land use will require several composite samples. The field identification map should be used each time samples are collected from that field to compare results over time.

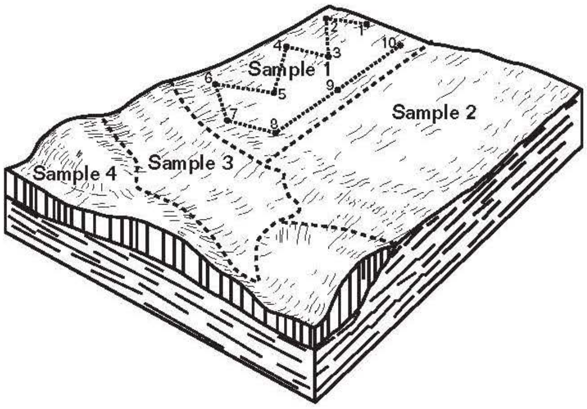

Figure 2. Fields should be subdivided into sampling units as needed and a composite sample should be collected from each unit.

Factors that will affect results include sampling tools, number of subsamples, depth of sampling, and soil compaction and moisture.

Sampling tools

Several tools can be used to collect samples (Fig. 3). The choice depends on soil conditions and sampling depth.

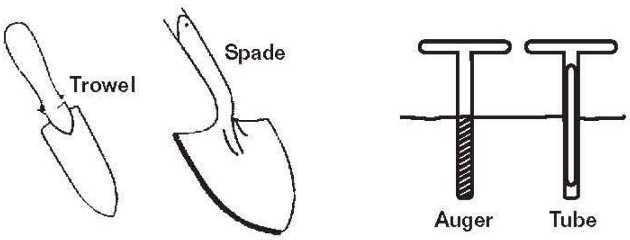

Figure 3. These tools can be used to collect soil samples.

The selected tool must be able to cut a slice or core through the desired layer of soil as illustrated in Figure 4. The objective is to obtain a cross section of the plowlayer or layer being subsampled.

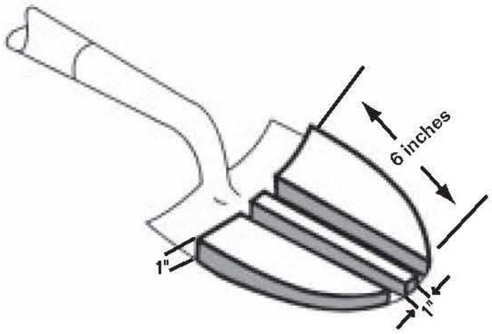

Figure 4. Collect a slice or core of soil to the desired depth.

Number of samples

In fields up to 40 acres, collect at least 10 to 15 cores or slices of soil per composite sample. Composite samples should represent the smallest acreage that can be fertilized or limed independently of the remaining field or acreage.

The development of precision agriculture has allowed some producers and fertilizer suppliers to manage soil fertility levels on 1- to 3-acre parcels. In small gardens and lawns, five to six cores may be adequate. Because soils are variable, it is important to obtain enough subsample to ensure a representative composite sample. A greater number of cores makes the sample more representative of the field.

Unusual problem areas should be omitted or sampled separately. To properly diagnose the causes of poor crop production, collect separate composite samples from the good and poor growth areas. Do not include soil from the row where a fertilizer band has been applied.

Depth of sample

Traditionally, soil samples are collected to a depth of 6 inches. This depth is measured from the soil surface after non-decomposed plant materials are pushed aside. This sampling depth can be significantly altered based on tillage or fertilization practices.

Stratification (accumulation at the surface) of phosphorus and lime from prior surface applica-tions can dramatically alter soil test data. Stratification is of particular concern in reduced tillage and nonirrigated fields that receive limited rainfall. In these instances, subsurface sampling depths may vary from 2 to 8 inches or 3 to 9 inches below the surface. Also, deviations from the traditional 6-inch sampling depth may be required if fertilizer has been placed deeper in the soil.

Deep rooted perennial crops can require deeper subsurface sampling. The slow movement of most plant nutrients prevents any dramatic manipulation of subsurface nutrient levels, however sampling data can be useful to assess pH or salinity problems. Subsurface sampling is illustrated in Figure 5.

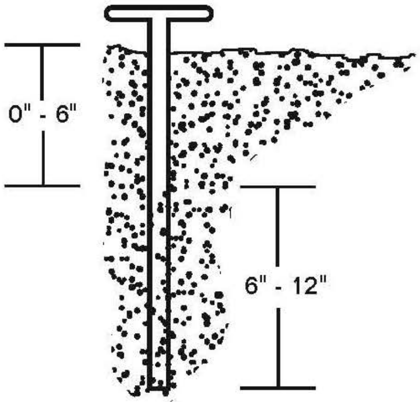

Figure 5. A sampling tube or auger is needed to collect subsurface samples.

When sampling perennial sod crops, sample to a depth of 4 inches. Discard the surface ½ inch of soil before mixing the subsamples. Use this sampling method in all established lawns, golf greens and similar turf applications.

The Texas Natural Resource Conservation Commission (TNRCC) requires extensive soil sampling for some land uses. Individuals sampling soil for TNRCC compliance should follow TNRCC protocols and directions.

Select the proper test

Several different soil tests are available at the Extension Soil, Water, and Forage Testing Laboratory. These include tests for routine nutrients, micronutrients, boron, detailed salinity, lime requirement, texture and organic matter. After taking the soil sample, select the appropriate test to obtain the desired information.

The **routine** test determines the soil pH, salinity, nitrates (NO_3-N), and levels of the primary nutrients (P - phosphorus, K - potassium, Ca - calcium, Mg - magnesium, Na - sodium, and S - sulfur) available to plants. The routine test will provide the basic N-P-K fertilizer recommendation for selected crops. This test meets most application needs.

The **micronutrient** test estimates the levels of zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) in the soil that are available to plants. Conduct this test for specialty crops, in soils with high pH on which corn or sorghum is being grown, or to provide general guidelines for troubleshooting deficiencies.

The **boron** test determines the level of water extractable boron (B) in the soil. Conduct the test where clover, alfalfa or other legumes are grown on sandy soils or when soils are being irrigated and water quality is of concern.

The **detailed salinity** test uses a saturated paste extract to measure the pH, electrical conductivity and water soluble levels of the major cations in the soil. From these levels, the Sodium Adsorption Ratio (SAR) is calculated. Conduct this test when water quality is of concern; in soils in the western part of the state where the rate of evaporation or transpiration exceeds the rainfall; when previous soil tests have shown an increase in sodium or salinity; or in areas where brine and salt water spills have occurred. Some TNRCC permits also may require a detailed salinity test.

The **lime** requirement determines the amount of lime needed to raise the soil pH to a desired level. This determination is needed on very acidic (pH <5.2) or acidic soils (pH <6) where alfalfa or other legumes are grown.

Texture and organic matter are specialty tests for specific applications. The texture determines the amount of sand, silt and clay in the soil. This test may be requested when installing a septic system. The organic matter may be requested for general information. Both tests often are requested for environmental or research purposes.

The information form, obtained from the county Extension office, requests information about soil conditions, acreage sampled, past cropping, fertilization and an estimate of the expected yield. All information is important in relating soil test results to suggested fertilization and liming. The expected yield is an indication of intended management, past production levels and local environmental factors that control yields. Uncontrolled production factors such as nematodes and disease should be considered in estimating a yield goal or expected yield. In areas where samples are collected from problem fields, the condition of plants should be described along with observations that would aid in relating soil test results to the problem.

Soil samples should not be stored for long periods of time prior to shipping to the laboratory. The levels of nitrate-nitrogen in the soil may change if the samples are stored wet. In addition, the nitrate-nitrogen data from properly dried samples may be of little value if environmental conditions and plant growth have altered levels in the soil. Air drying samples in the shade on clean brown paper is strongly recommended. Do not oven dry the samples because high drying temperatures can alter test results.

Instructions for mailing are provided with the sampling instructions. The fee for each sample should be noted and payment should accompany the samples. The information sheet and payment should be attached to the sample package. Between 5 and 7 days are required to obtain results for routine analyses from the laboratory. In-depth analyses of samples require additional testing and processing time. Therefore, it is important to conduct sampling early in the season. This will ensure that test results are available in time to make necessary fertilizer and lime applications.

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APPENDIX B

AgriLIFE EXTENSION
Texas A&M System

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop sciences

Manure and Effluent Sample Collection

Manure and litter samples

- Collect at least 5, and preferably 10, subsamples from piles. Be sure to sample throughout the pile, not just the outside surface.
- Mix subsamples thoroughly in clean plastic bucket.
- Transfer sample to suitable container (see below).
- Label sample container using a permanent marker.
- Separate samples should be taken for each type or age of manure and litter.

Effluent samples

- Collect at least 5, and preferably 10, subsamples from the lagoon.
- Sample the lagoon using a plastic cup (8 ounce) secured to an aluminum rod (6 to 10 feet long).
- Samples collected with depth will better represent effluent.
- Collect subsamples and mix in clean plastic bucket.
- Transfer sample to suitable container (see below).
- Label sample container using a permanent marker.
- Separate samples should be taken for each lagoon.

Sample containers

- Biosolids, manure and litter samples should be collected in sealable plastic bags.
- Liquid samples (i.e., lagoon or effluent samples) should be collected in plastic bottles (16 ounce) with at least 50% headspace. Failure to provide adequate headspace may result in rupture of container.
- Do not use cola bottles or other containers containing phosphorus or nutrients to be analyzed.

APPENDIX C

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Disposal of Domestic or Exotic Livestock Carcasses

RG-419, PDF version
(revised 3/05)

This document is a summary of suggested guidelines from the Texas Commission on Environmental Quality (TCEQ) and the Texas Animal Health Commission (TAHC) for disposal of farm or ranch animals.

This document does not explain requirements that apply to veterinarians or commercial chicken or duck operations. For information about chicken or duck carcass disposal, see TCEQ publication RG-326, How to Dispose of Carcasses from Commercial Chicken or Duck Operations.

For rules that apply to veterinarians disposing of carcasses, refer to Title 30 Texas Administrative Code (30 TAC) Section 111.209(3).

By planning in advance how you will dispose of carcasses, your facility will be better prepared to deal with environmental and health issues. Emergency cases may be handled differently. Contact your regional TCEQ office in the event of an emergency.

Why is disposal of carcasses regulated?

On-farm disposal of dead animals should always be done in a manner that protects public health and safety, does not create a nuisance, prevents the spread of disease, and prevents adverse effects on water quality.

Who is responsible for making sure the carcasses are properly disposed of?

The owner or operator of the farm or facility is responsible for disposal in a timely and sanitary manner. Please be aware that under 30 TAC Section 335.4 this means there can be no discharge into or adjacent to waters in the state. There can be no creation or maintenance of a nuisance and there can be no endangerment of public health and welfare.

How soon must they be disposed of?

TAHC rules require that animals that die from a disease recognized as communicable by the veterinary profession must be disposed of within 24 hours by burial or burning. Animals dying from anthrax or ornithosis must be killed, then burned on-site within 24 hours.

How can I dispose of the carcasses?

There are several options including on-site burial, composting, or sending the carcass to a municipal solid waste landfill, renderer, or commercial waste incinerator. TCEQ rules allow animals to be burned when burning is the most effective means to control the spread of a communicable disease. The animal must be burned until the carcass is thoroughly consumed. The cover requirements described in 30 TAC Chapter 330, Section 136(b)(2) should be adequate for burial of farm and ranch animals in most cases. Some diseases are reportable, and you are required to contact the TAHC at 1-800-550-8242 prior to disposing of animals with these diseases. TAHC can also provide a list of reportable animal diseases.

Where can I bury?

If you decide to bury the animal, the burial site should not be located in an area with a high water table or with very permeable soils. The TCEQ suggests that animals be buried far enough from standing, flowing, or ground water to prevent contamination of these waters, and in an area not likely to be disturbed in the near future.

Suggested Setbacks for Burial

- Drinking water wells - At least 300 feet from the nearest drinking water well.
- Surface water - At least 300 feet from the nearest creek, stream, pond, lake, or river, and not in a floodplain.
- Neighbors - At least 200 feet from adjacent property lines.

Where can I burn?

When burning, do not do so in an area where a nuisance or traffic hazard would be created.

Suggested TCEQ Setbacks for Burning

- Adjacent properties - Downwind of, or at least 300 feet (90 meters) from, occupied structures.
- Weather conditions - If possible, burn during the day when the wind speed is > 6 mph or < 23 mph. Monitor the fire, and complete the burn the same day.

Notification Requirements

Notify the TCEQ by letter if you expect to bury animal carcasses on your farm. Your letter should contain your full name and address, the type of animals, and a short description of the locations on your farm where the carcasses will be buried. Information on the anticipated capacity of the burial areas as well as the use of daily and/or final cover should be included, and a map showing the general location of the area would be useful. This letter will be considered as your compliance with 30 TAC Section 335.6 and will be acknowledged by the TCEQ. Mail your notification to the address listed under the "Additional Information" section of this document.

Once you notify us, do not send additional letters. However, if you have more than 10 animals die at one time, it is recommended that you contact the TCEQ regional office near you since multiple mortalities are handled on a case-by-case basis. If the location of burial changes, or if additional burial areas are used, then an updated Section 335.6 notification should be provided.

Disclaimer

This document is intended as guidance to identify the requirements for the disposal of animal carcasses; it does not supersede or replace any state or federal law, regulation, or rule. It is the responsibility of the owner to be knowledgeable and to remain abreast of guideline or regulation developments. Please refer to the "Additional Information" and "Recommended References" sections for more specific information.

Additional Information

Rules regarding carcass disposal: Rules that are directly related to carcass disposal are in 30 TAC Chapters 335 and 111 including Sections 335.4 – 335.6, which deal with general waste disposal requirements, and 111.209(2) "Exception for Disposal Fires"

Rules for poultry disposal: 30 TAC Chapter 335—including Section 335.6, "Notification Requirements," and especially Section 335.25, "Handling, Storing, Processing, Transporting, and Disposing of Poultry Carcasses"

Disposal rules that apply to veterinarians:
30 TAC Section 111.209(3)

Water quality rules for concentrated animal feeding operations (CAFOs): 30 TAC Chapter 321, Subchapter B; For composting operations: 30 TAC Chapter 332; For municipal solid waste (landfills): 30 TAC Chapter 330

Nuisance Rules, General Rules: 30 TAC Chapter 101 Section 4 and CAFO Rules: 30 TAC Subchapter B Section 321.31

Public Health Rules: Sections 81.081-81.086 of the Texas Health and Safety Code

Texas Animal Health Commission: Texas Agriculture Code Chapters, 161 to 168. Contact: 1-800-550-8242 prior to disposing of diseased animals. TAHC also can provide a list of reportable animal diseases.

Notification for onsite burial of carcasses: Industrial and Hazardous Waste Permits Section, MC-130, TCEQ, P.O. Box 13087, Austin, Texas 78711-3087 ; Phone: 512/239-6595 Fax: 512/239-6383. It is recommended you contact your TCEQ Regional Office if you have more than 10 animals die at one time and you plan to dispose of them on-site.

TCEQ Rules: Rules and publications are available at www.tceq.state.tx.us or 512/239-0028

TAHC Rules: Rules and publications are available at www.tahc.state.tx.us

Recommended References

How to Dispose of Carcasses from Commercial Chicken or Duck Operations (TCEQ RG-326; April 2000) explains carcass disposal rules and options for anyone who hatches, raises, or keeps chickens or ducks for profit.

Catastrophic Animal Mortality Management (Burial Method), Technical Guidance, USDA/Natural Resources Conservation Service, Texas State Soil and Water Conservation Board, February 11, 2002

NRCS TX Conservation Practice Standards: Code 316 - Animal Mortality Management

OSHA Construction rules: www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1926.html

OSHA Excavation Rules: www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1926_SUBPART_P.html

Title 2, Texas Water Code, Chapter 26,
Subchapter H, Poultry Operations: www.capitol.state.tx.us/statutes/statutes.html

Senate Bill 1339, and House Bill 3355 (77th Legislature, 2001): www.lrl.state.tx.us/isaf/lrlhome.cfm

Texas Occupations Code, §801.361, Disposal of Animal Remains (78th Legislature, 2003):
www.capitol.state.tx.us/statutes/oc.toc.htm

CALL BEFORE YOU DIG

Call 1-800-344-8377 to make sure you will not accidentally hit a gas or utility line on your property when digging a hole to bury animal carcasses.

Lone Star Healthy Streams

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