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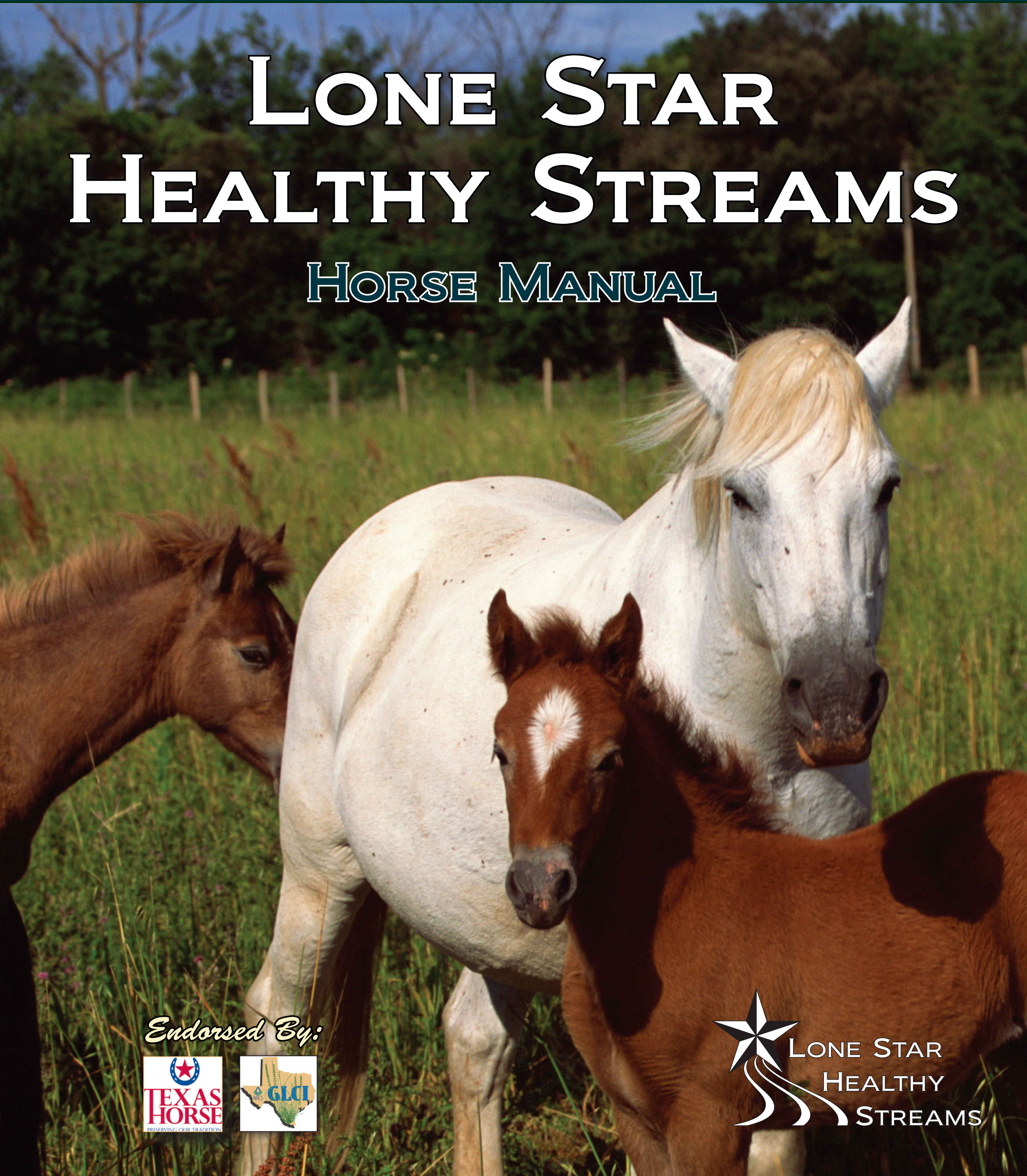
Lone Star Healthy Streams

Horse Manual



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Lone Star Healthy Streams

Keeping Texas Waters Safe and Clean...

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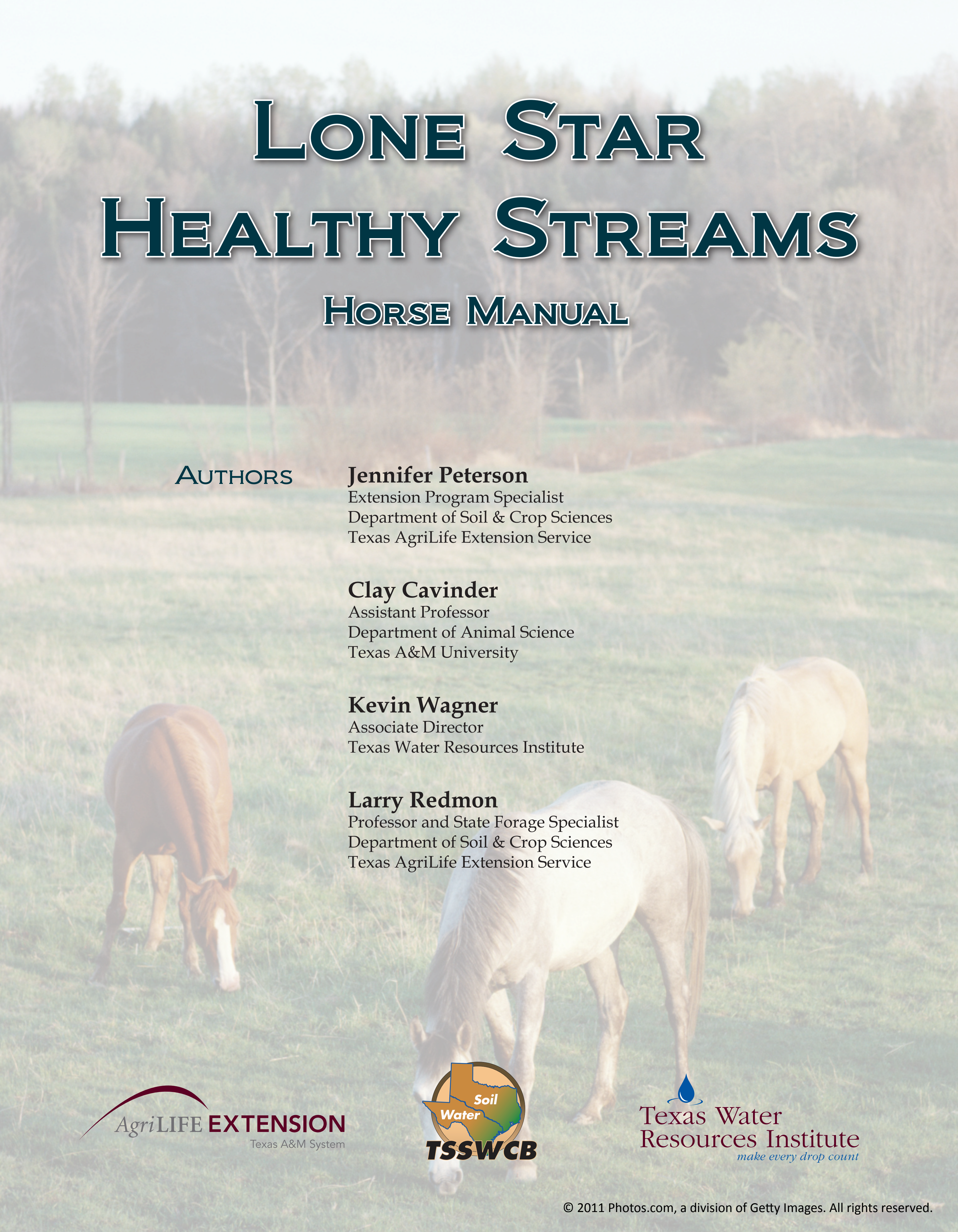

Lone Star Healthy Streams

Horse Manual

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Acknowledgements

Funding Sources

The development of this manual has been supported by a federal grant from the U.S. Environmental Protection Agency's Nonpoint Source Management Program under Clean Water Act Section 319 through the Texas State Soil and Water Conservation Board. The authors are grateful to both agencies for this indispensable support.

Review & Development

The authors would like to thank the following groups and individuals for their assistance:

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- Texas Water Resources Institute (TWRI)
- Lone Star Healthy Streams Program Development Committee
- Lone Star Healthy Streams Steering Committee

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- Texas Commission on Environmental Quality
- Texas Department of Agriculture
- Texas Farm Bureau
- Texas and Southwestern Cattle Raisers Association
- Texas State Soil and Water Conservation Board
- Texas Water Resources Institute
- USDA-Agricultural Research Service (ARS)
- USDA-Natural Resources Conservation Service (NRCS)
- Victoria Soil and Water Conservation District
- Welder Wildlife Foundation
- The 2S Ranch, Caldwell County, TX
- Hall-Childress Soil and Water Conservation Districts

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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

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Water Quality in Texas

Water is a finite resource that can be sWater 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 community can choose to regulate itself through stewardship and conservation practices rather than have the solutions determined by those who may not understand the industry.

Livestock producers should 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.

Livestock 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.

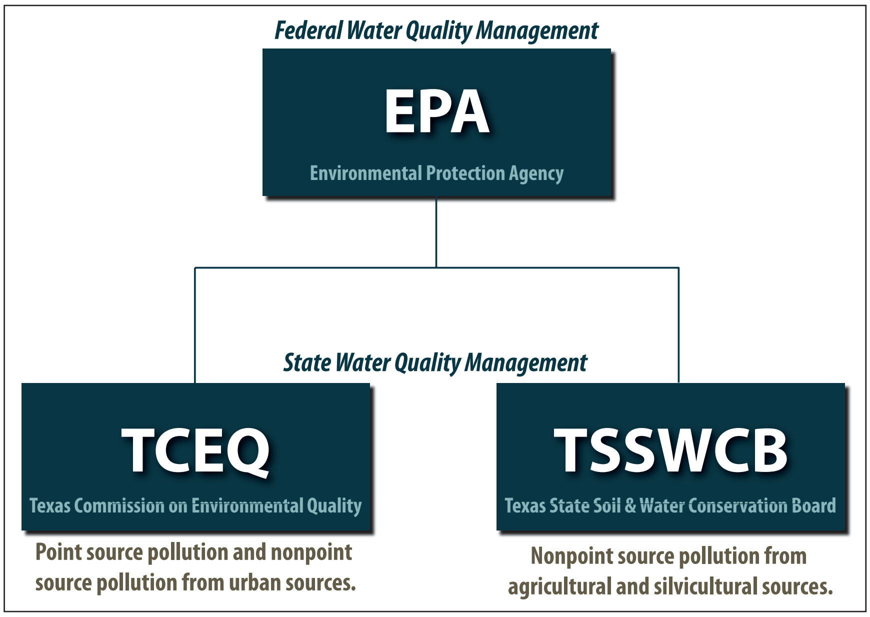

Figure 2. Hierarchy of federal and state agencies involved primarily in water quality management in Texas. Illustration by Jennifer Peterson.

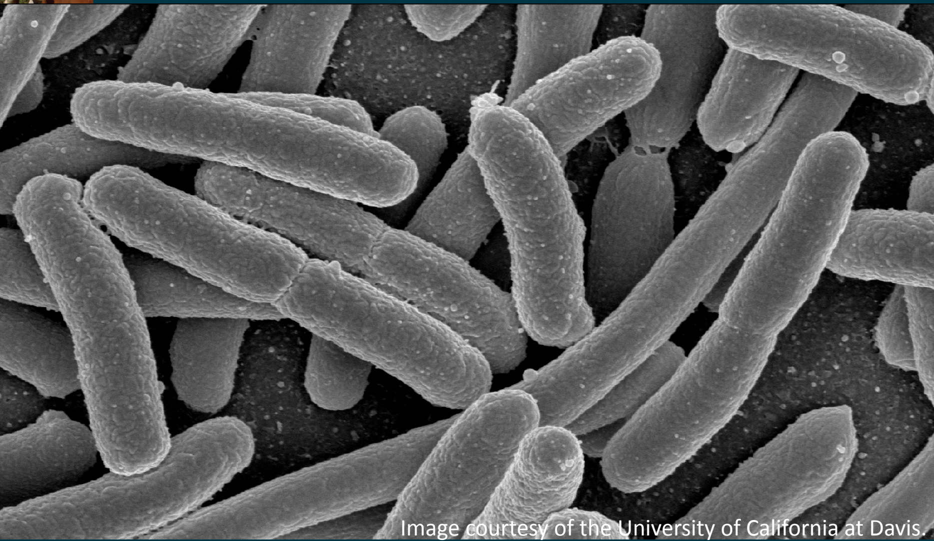

Image courtesy of the University of California at Davis.

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 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 3 people died after consuming spinach contaminated with *E. coli.*

E. coli are important in water quality because they act as indicator organisms - their presence in water can indicate the potential prescence of other harmful pathogens that are capable of causing disease in humans.

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 also imposed regulatory measures on nonpoint sources.

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

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 more appropriate and 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 leading 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 (Table 1)
- 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. 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. In the Copano Bay alone, horses accounted for 36% of the bacterial contamination. Regardless of the source, excess bacteria levels are involved in more than 50 percent of the water quality impairments in Texas (Fig. 4).

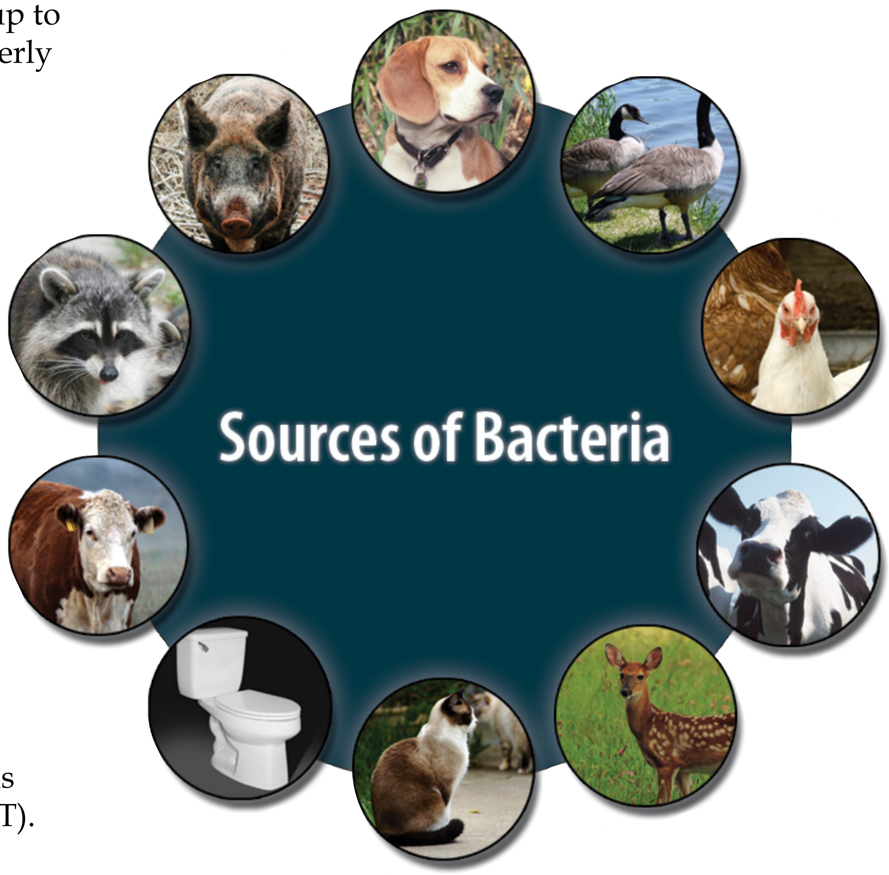

Figure 3. Bacteria in Texas waterways can originate from a variety of sources, including wastewater treatment facilities, wildlife, pets, and livestock. Illustration by Jennifer Peterson.

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

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

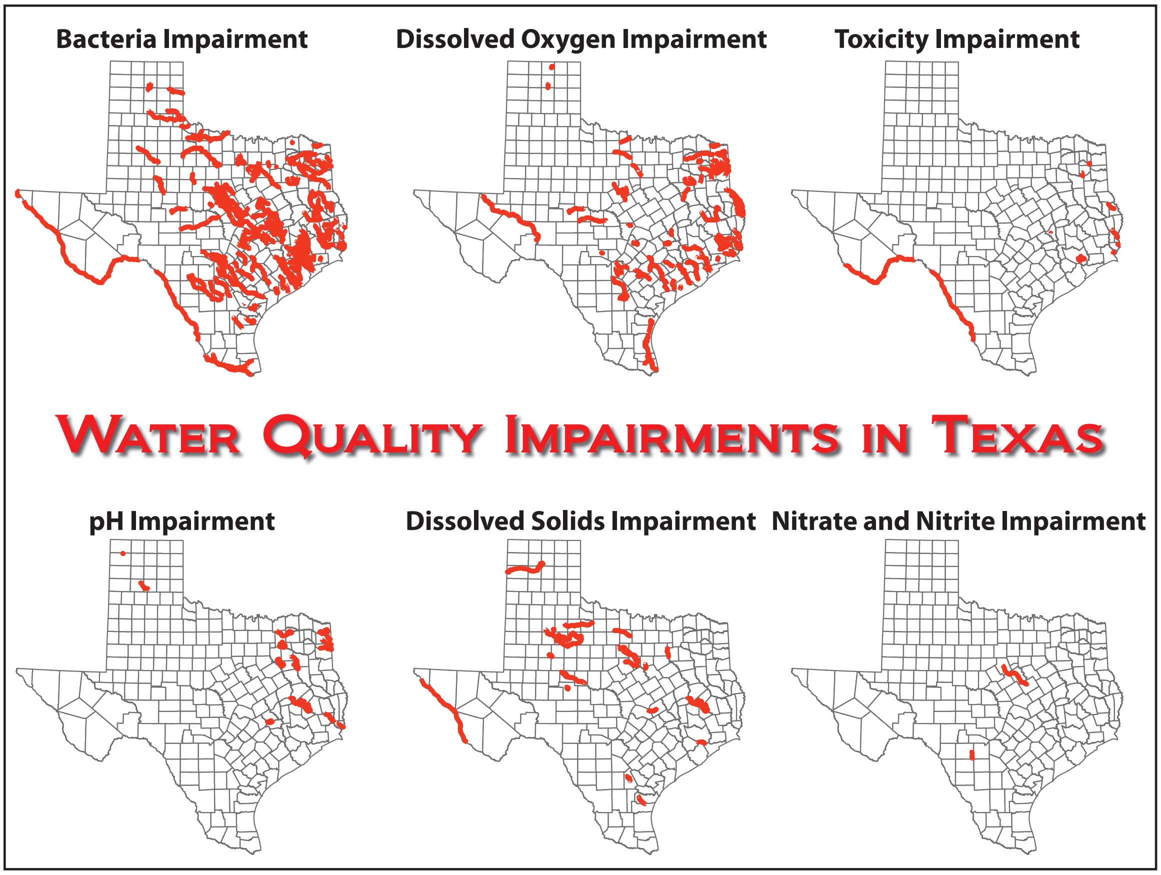

Figure 4. Types and locations of impairments in Texas water bodies. Source: TCEQ, 2008.

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

Although improvements in water quality from producers' efforts can take years to detect, these practices can often result in tangible benefits. In one study, water quality benefits from erosion control on cropland totaled over $4 billion per year. Another study found 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 community to voluntarily do its part to improve water quality.

The Texas Horse Industry

According to the Texas Horse Council, there are about 979,000 horses in Texas, and the state's horse industry produces an estimated $3 billion in goods and services annually. The American Horse Council Foundation estimates that the industry supports more than 32,000 jobs in Texas alone. Annual horse sales total more than $354 million. Texans have invested about $13 billion in barns, towing vehicles, trailers, and related equipment and spend about $2.1 billion annually maintaining their horses.

Chapter 2

Best Management Practices For Horses

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Best Management Practices

As with any other class of livestock, horses can damage the land on which they are kept. Owners have the responsibility of managing them in a way that minimizes their impact on the surrounding environment. Although runoff from equine operations can degrade surface water quality in many ways, most pollution stems from manure, which contains bacteria and nutrients. Sedimentation from erosion and the excessive use of fertilizers and pesticides can also contribute to the problem.

Horses owned for work or pleasure are kept in a restricted area, pasture, or pen. If proper care is not taken, they can concentrate manure, degrade pasture quality, develop digestive and behavioral disorders, and impact surrounding ecological areas and watersheds. Horse owners should adopt best management practices (BMPs) to protect their animals and the land they manage.

Along the eastern and western coasts of the United States, the degradation of surface water quality has caused mandatory regulations to be imposed on horse owners. To prevent or minimize such regulation in Texas, a proactive approach is necessary to prevent contamination.

Whether you breed horses or keep them for pleasure, voluntary best management practices (BMPs) can be adopted to help reduce fecal contamination of Texas streams and rivers. Besides ensuring better water quality for you, your livestock, your neighbors, and Texas, these equine BMPs will also help you maintain better pastures, improve livestock health, and increase property values.

Equine BMPs that can help reduce bacterial concentrations can generally be divided into five categories: pasture management, runoff management, riparian area protection and management, manure management, and mortality management (Table 3). These practices are not mutually exclusive. Often a combination of practices will be most

Table 3. Equine BMPs organized by category.

Pasture Management	Runoff Management	Riparian Area Protection and Management	Manure Management	Mortality Management
Prescribed grazing (NRCS Code 528A)	Filter strips (NRCS Code 393)	Shade structure (NRCS Code 717)	Waste storage structure (NRCS Code 313)	Proper carcass disposal
	Building location	Watering facility (NRCS Code 614)	Waste utilization (NRCS Code 633)	
	Roof runoff structure (NRCS Code 558)	Fencing (NRCS Code 382)	Soil testing and nutrient management (NRCS Code 590)	
	Water harvesting catchment (NRCS Code 636)	Access control (NRCS Code 472)	Composting (NRCS Code 317)	

beneficial to you, your land, your animals, and your watershed.

Specific NRCS conservation practice codes are mentioned throughout the text. More detailed information about these practices can be found in the NRCS Field Office Technical Guide (FOTG), which can be found in all Soil and Water Conservation District Offices, all NRCS field offices, and on the NRCS web page (EFOTG).

Pasture Management BMPs

Prescribed Grazing
The primary pasture management BMP is prescribed grazing (NRCS Code 528A) which can optimize livestock production while protecting and/or enhancing the environment in which the livestock are produced.

Prescribed grazing is the controlled harvest of vegetation by grazing or browsing animals, managed with the intent of achieving a specific objective. Livestock owners set the stocking rate, rest periods, and the intensity, frequency, duration, and season of grazing to promote ecologically and economically stable plant communities. As a result, the land manager's objectives are met and the forage resource is preserved.

A healthy, functional pasture will:

- Reduce wind and water erosion
- Help distribute manure in the field
- Increase animal weight gain and improve health
- Recycle more nutrients
- Increase groundwater recharge
- Help control dust and odor
- Reduce runoff (Kaufmann and Krueger, 1984) and improve runoff filtration (Ratliff et al. 1972)
- Increase the potential for fish production (Bowers et al. 1979)
- Reduce soil compaction (Tate et al. 2004)
- Improve plant diversity (Marty 2005)
- Help control noxious weeds (DiTomaso 2000, Frost and Launchbaugh 2003)

Stocking Rate
Stocking rate is the most critical aspect of livestock production that is related to water quality and that 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 available per animal unit. The stocking rate should be sustainable on a long-term basis without degrading forage, water, or soil resources. A moderate stocking rate typically provides a good balance between plant and animal performance while maintaining enough vegetative cover to protect the soil.

Although moderate stocking rates differ depending on the site and forage species, general guidelines can be obtained from soil surveys produced by the Natural Resources Conservation Service (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:

- Livestock are larger than in the past. Forage intake is related to body size, and many species today are larger than they were two generations ago.
- Woody (brush) species are continually invading and dominating previously productive pastures, reducing the carrying capacity of those pastures. Unless the brush is removed or livestock numbers are reduced, the pastures will be overstocked.
- Inadequate fertilizer and/or weed management have reduced the amount of forage produced on some sites.
- Some producers base their stocking rates 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. 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 4).

Table 4. 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

Because grazing animals are not all the same size, it is 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.

Table 5 lists different kinds and classes of animals, their AUEs, and their estimated daily forage demand. With this information, it is easy to convert different size animals to AUEs to determine the number of animals that could be grazed on a specific pasture for a specific period.

Example: Assume a horse owner has 10 horses on 200 acres for 10 months. The stocking rate of this operation would be calculated as follows:

Example 1: Calculation of Stocking Rate

Step 1. Calculate AU based on AUE:

10 horses x 1.25 AUE = 12.5 AUs

Step 2. Calculate stocking rate using AU:

Total land area ÷ AUs x Grazing season

200 acres ÷ 12.5 AUs x 10 months
= 1.6 acres per AU month (AUM) *or*
19.2 acres per AU year (AUY)

Table 5. 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

You can also estimate the amount of forage required for the number of animals in your operation. Based on the information in Table 5, the average 1,300-pound horse requires 32 pounds of forage dry matter intake per day. In 1 month, an average 1,300-pound horse will require 960 pounds of forage dry matter intake. Over 10 months, as in the example above, one horse will need 9,600 pounds of forage and ten horses will need 96,000 pounds. The horse owner must determine whether the particular pasture can provide that much forage.

Horses should consume at least 1.5 to 3.0 percent of their body weight each day on a dry matter basis. At least 70 percent of this feed should be in long-stemmed forage, whether the horses are in pastures or stalls. This amount of forage decreases the incidence of colic, gastric ulcers, and boredom.

An appropriate stocking rate ensures that the animal has enough forage and that enough groundcover will remain in the pasture to protect the soil and water. Without enough forage, animal performance drops.

Horse owners gain several benefits when horses graze on pastures that are properly managed and stocked:

- Hay costs are reduced by $60 to $100 per month.
- Fertilizer costs are reduced if composted manure is spread on the pasture.
- Land aesthetics are improved for horse owners and neighbors.
- Less time is spent cleaning stalls.
- Bedding costs are reduced.
- Problems with parasites such as worms and flies are reduced.

Grazing Management

Grazing management involves controlling *where, when, how long, and how much* livestock graze. The objective of proper grazing management is to match the availability and nutritional content of the forage with the nutritional requirements of grazing livestock. 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 of growing animals. If a producer is not using a controlled breeding season, this may be a logical place to begin an improved grazing management strategy.

Common grazing systems used in horse farms are continuous, rotational, partial-season, and limited-turnout stocking. However, no single grazing system can meet the requirements of all horse owners. Certain tracts of land lend themselves to one type of grazing system better than others, and the management philosophies and experience levels of the owners will likewise dictate how livestock will be manipulated.

Continuous stocking: A continuous stocking system is one in which horses have access to a pasture all day, every day, for the entire grazing season. Although this system reduces fencing costs and the amount of daily management required, it is difficult to manage the timing and intensity of grazing because horses tend to be very selective in the forage they consume. As a result, plants can become stressed if never given a chance to recover from grazing pressure. In time, pastures can become dry, overgrazed lots where only weeds will grow.

The continuous stocking system can enhance forage utilization, however, if appropriate stocking rates are used along with good pasture management practices. This type of grazing system is appropriate where ample pasture land is available to support the number of horses. Increased management may be needed during periods of rapid or slow forage growth.

Rotational stocking: Forage plants are healthier and more productive if given a chance to rest and regrow between grazing periods. You can incorporate this concept into your grazing system by dividing your pasture into separately fenced paddocks (using electric fence) and rotating your horses among them (Fig. 5). With a rotational stocking strategy, horses are allowed to graze one paddock at a time.

Begin grazing a paddock when the grass is about 6 inches to 10 inches high, and rotate the horses to the next paddock when the grass has been grazed down to about 1 ½ inches to 2 inches. The previously grazed paddock is then allowed to recover, which

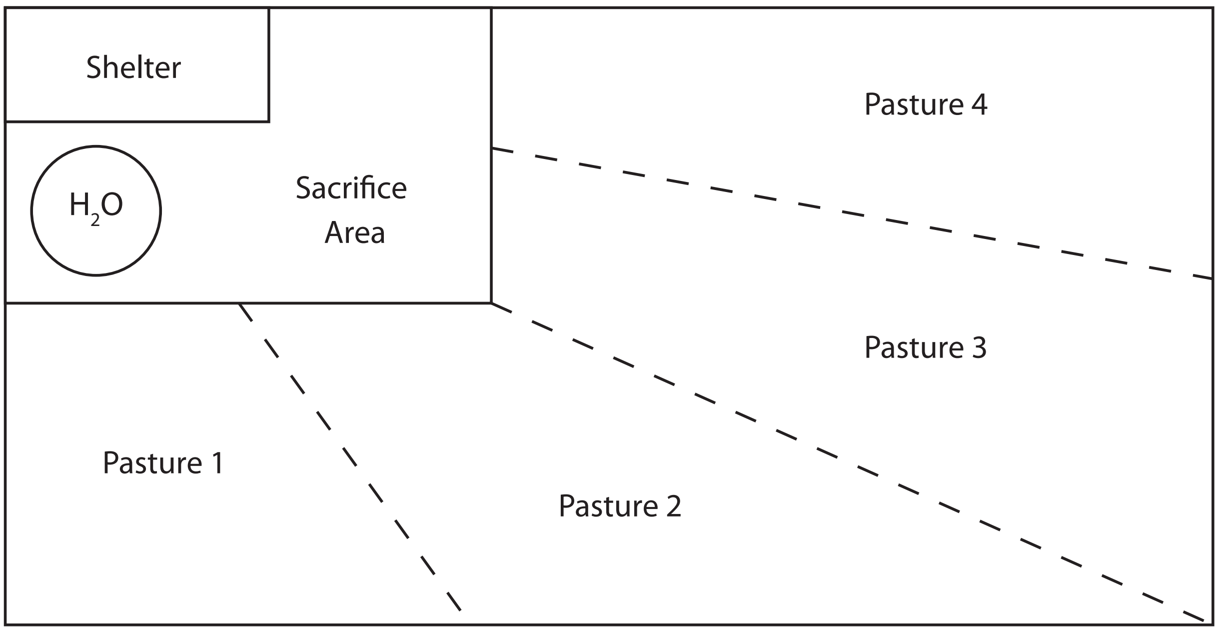


Figure 5. A sample rotational stocking system.

can take 10 to 60 days depending on the environmental conditions (such as rainfall and temperature).

Paddock size and number depend on the available acreage, the number of horses, the productivity of the pasture, and the length of time horses graze each paddock. Ideally, each paddock should contain enough grass to sustain the horses for 3 to 7 days. Grazing for longer than 7 days may compact the soil, especially in high-traffic areas.

Confining horses to smaller paddocks for a defined period reduces selective grazing and uses the forage more uniformly. It also helps maintain desirable plant species and reduces weed infestation. Over time, the amount and quality of the forage increase so that more horses can be supported by the same acreage.

Partial-season stocking: A partial-season stocking system allows horses to graze a pasture for only a certain part of the year. For example, some horse owners take advantage of the rapid plant growth in the spring and summer and graze their animals only during this time. In the fall and winter, the horses are removed from the pasture and hand-fed to avoid overgrazing. Horses do not return to the pasture until the following spring.

Other horse owners, especially those busy with shows during the spring and summer, defer grazing during these months and put horses on pasture only in the fall, when they can graze forage that has been stockpiled over the summer. This stocking strategy reduces the risk of overgrazing and leaves enough vegetation to protect water quality and watershed health.

Limited-turnout stocking: This stocking strategy limits the access that horses have to pasture each day. Grazing time can be as short as 30 minutes or as long as 12 hours. This approach is ideal for small-acreage landowners who might have more horses than their pastures can support for longer periods of grazing. Even a limited grazing time provides exercise, and it may also reduce feed costs over the long term.

Potential bacterial reductions with prescribed grazing: 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). The studies were conducted on land where beef and/or dairy cattle were present. It is assumed that similar reductions in pollutants would occur on land grazed by horses.

Additional Pasture Management Practices

Additional pasture management BMPs include providing a sacrifice lot, testing the soil, and mowing, dragging, and burning pastures.

Sacrifice lot: Regardless of the grazing system you choose, it is important to have a sacrifice lot, which is a dry lot, pen, corral, or stall run where horses can be housed and hand-fed whenever the pastures need a rest from grazing during critical times such as

winter, summer, heavy rainfall, rejuvenation time, and drought.

The sacrifice lot should be in an area with good drainage (preferably with less than a 5 percent slope) and should never drain into a surface water body. It should have at least 600 square feet per horse. When not in use, a sacrifice lot can double as an arena, turnout, or storage area. Put horses in your sacrifice lot when:

- The grass has not had adequate time to regrow to a height where it can tolerate grazing again.
- You are short on pasture acres and you use limited-turnout stocking to extend the number of days the animals can use the pasture.
- Your pasture is wet, and putting animals out on it will compact the soil and damage the grass for the rest of the season.
- You are in a drought; grazing below minimum recommended heights may kill the grass; and the cost of reestablishing the pasture and the value of future lost forage production exceed the cost of buying hay.

You should also use the sacrifice lot in the winter when grass has minimal nutritional value. Hoof traffic and continuous grazing all winter can cause considerable damage, leaving weak plants or bare spots in the pasture the following spring and summer. During the winter, keep the horses in a sacrifice area where they are fed hay and have water and shelter.

Soil testing: An inexpensive soil test can help determine the type and amount of fertilizer and lime needed for good pasture growth. Applying fertilizer at the appropriate rate and time will save money because only the amount needed is applied. It will also help protect water quality by preventing nutrient runoff from over-fertilized pastures.

Have your soil tested at least once every 3 years. The Texas AgriLife Extension office in your county (http://agrilifeextension.tamu.edu/) can assist you with this process.

Mowing/clipping pastures: Horses are notorious spot grazers. Left uncontrolled, spot grazing can create an uneven growth pattern in a pasture. Mow or clip pastures occasionally during the growing season to encourage the horses to graze more uniformly, discourage weed growth, spur new grass growth, and prevent grass from becoming too mature. Pastures may need to be clipped three or more times per year.

Dragging pastures: Horses usually avoid areas where excessive manure has collected, which contributes to uneven grazing. Chain or link harrows can be used to distribute the manure more evenly across the pasture. This practice also kills parasites and bacteria by exposing them to air and sunlight and smoothes over areas horses have dug up with their hooves. A good time to drag a pasture is immediately after it is 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/.

Consequences of Improper Pasture and Grazing Management

Poor pasture and grazing management can increase soil erosion, reduce forage production, and reduce water conservation.

Soil erosion: Erosion displaces topsoil and washes it away. Often the runoff ends up in waterways, where it deposits sediment and 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 (Brady 1990, Branson et al. 1981). Dislodged soil particles become suspended in the water and are washed away by overland flow (runoff).

Dislodged soil particles can also seal the soil surface by plugging the tiny pores between soil particles (micropores). This plugging reduces water infiltration rates and increases runoff.

Vegetative groundcover can dramatically reduce erosion. Plants intercept the raindrops, absorbing the energy of impact and protecting the integrity of the soil surface. Groundcover also reduces erosion by diminishing the energy of runoff water (Fig. 6).

After a raindrop makes impact, one of three things can happen (Holechek et al. 1998):

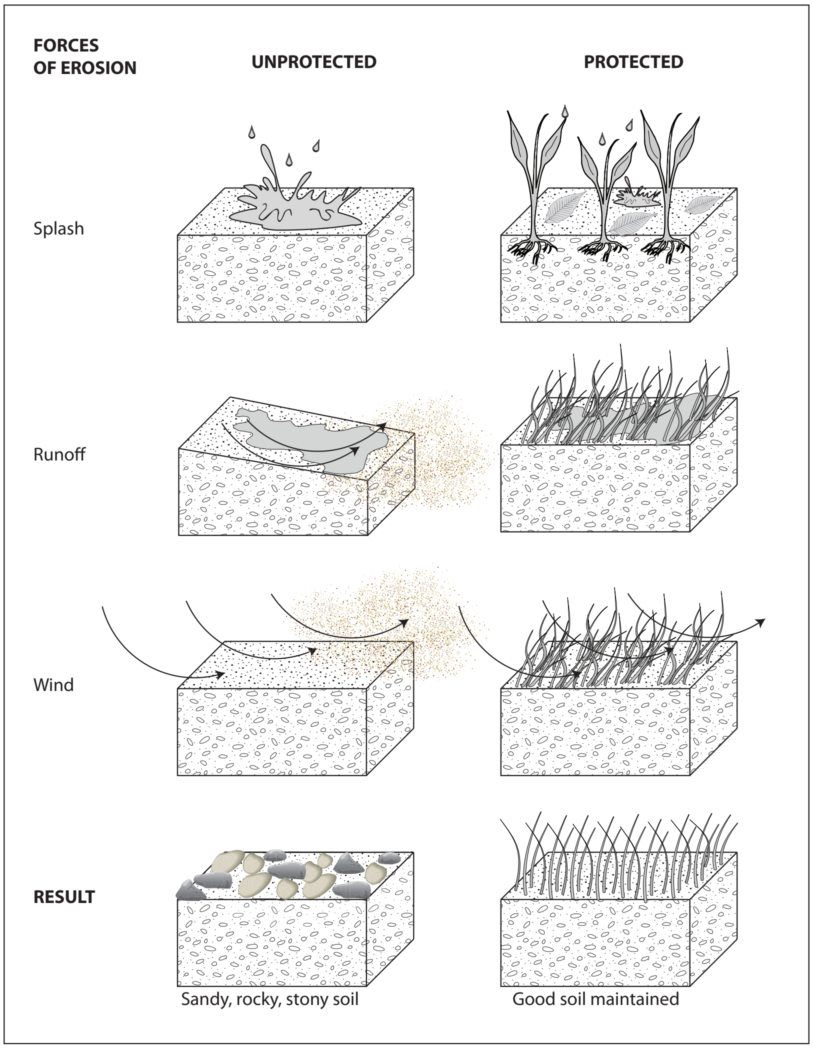


Figure 6. Vegetation effects on reducing soil erosion. Illustration by Jennifer Peterson (adapted from Nebel 1981 as used by Holechek et al. 1998).

- **Infiltration**, or 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.
- **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.

Figure 7. Typical erosion due to unprotected soil. Photo by Lynn Betts, USDA–NRCS.

Soil is lost when it is detached and transported from the site in runoff (Fig. 7). This can occur uniformly as sheet, or interrill, erosion. Extreme interrill erosion can create soil pedestals around areas covered by materials (such as rock) that resist raindrop impact. 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.

Overstocking pastures reduces the vegetative groundcover and makes the land vulnerable to rainfall erosion. Water flows rapidly over the land, carrying sediment, bacteria, and pesticides into nearby waterways. Eventually, sediment reduces the capacity of surface water reservoirs.

When proper stocking rates are used, the ground always has enough plant cover to reduce runoff and soil erosion and to protect water quality.

<u>Forage production</u>: Heavy grazing pressure and high stocking rates decrease the vigor and viability of forage plants on rangeland and pastures. If horses remove more than 50 percent of the aboveground plant, photosynthesis is slowed, which in turn reduces root development and the amount of moisture and soil nutrients that plants can take up (Fig. 8). Over the long term, forage plants become weaker and less abundant, undesirable plants take over, and the amount of bare ground increases. Ultimately, the rangeland or pasture is completely degraded.

If the stocking rate is not reduced, carrying capacity will diminish, animal performance will decrease, and the potential for profit will be eliminated. Input costs will rise—for more herbicides and winter feeding, for instance—making the bad situation worse.

<u>Water conservation</u>: Perennial groundcover increases the amount of precipitation captured by the soil and decreases the amount lost in runoff. When a pasture is overused, undesirable plant species move in. These species generally do not provide the type of groundcover necessary to reduce

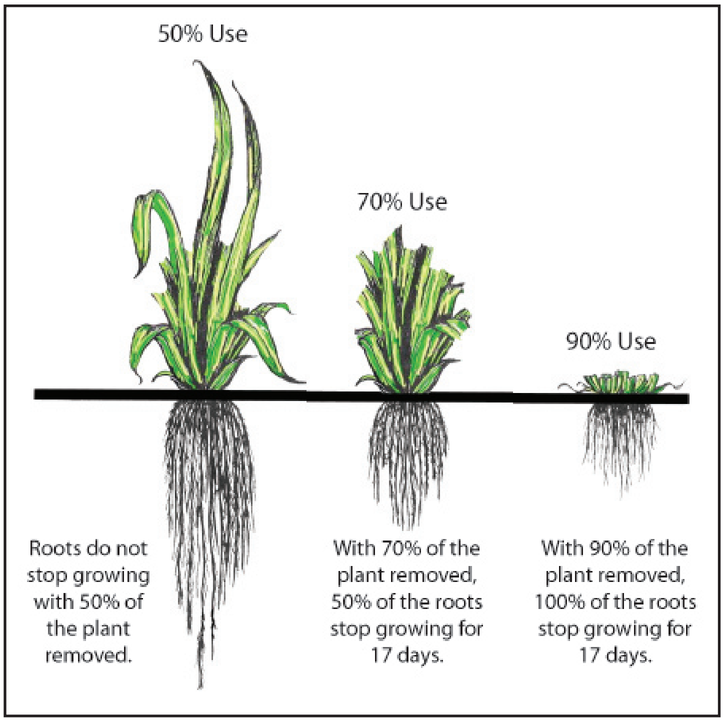


Figure 8. Effect of intensity of defoliation on root production. Illustration courtesy of the Texas USDA–NRCS.

runoff and increase infiltration. As a result, much of the precipitation is lost from the site, reducing forage production (Fig. 9) and minimizing the recharge of underground aquifers. In clayey soils, the soil becomes compacted, which further reduces the infiltration rate.

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 do grazed plots.
- Lands that are moderately or lightly grazed have similar infiltration rates.
- Heavily grazed land has lower infiltration rates than does moderately and lightly grazed land.

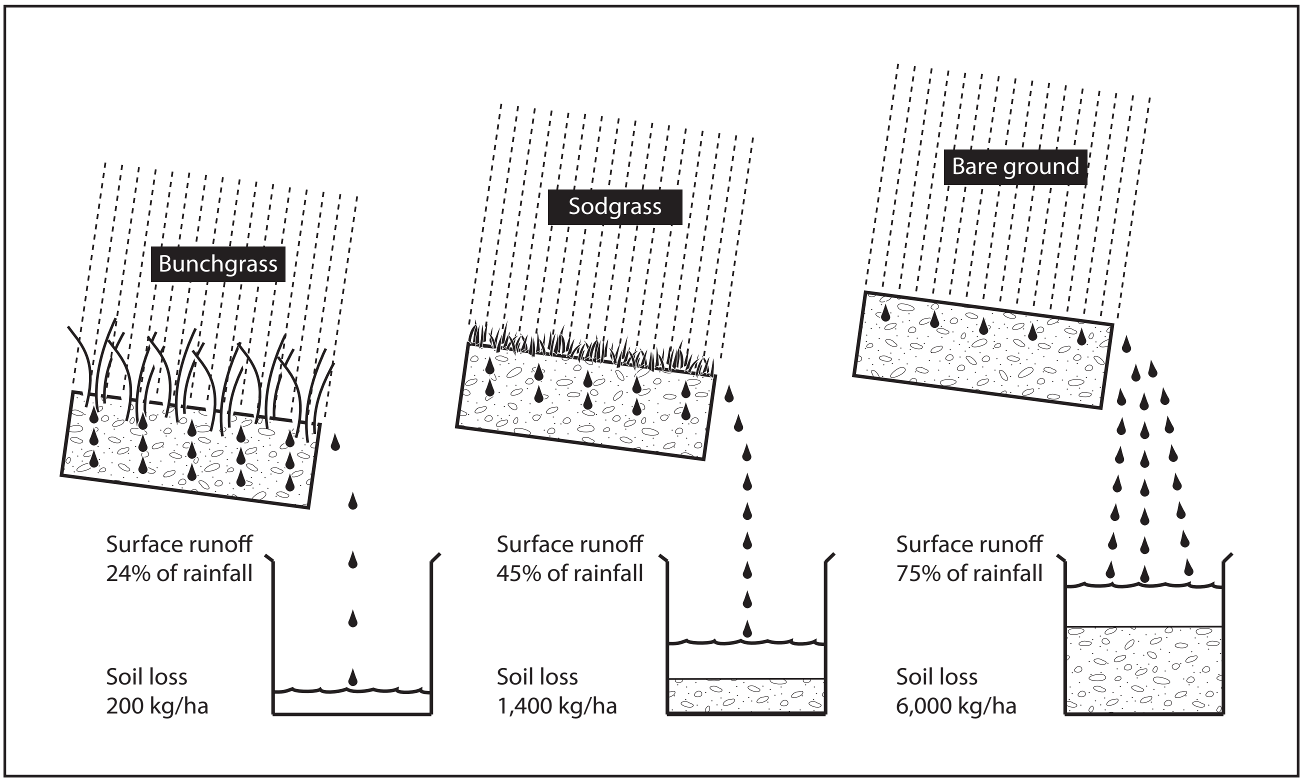


Figure 9. Influence of vegetation type on sediment loss, surface runoff, and rainfall infiltration from 4 inches (10cm) of rain in 30 minutes (adapted from Blackburn et al. 1996, by Knight 1993, and as used by Holechek et al. 1998).

Summary of Pasture Management BMPs
A properly managed pasture and grazing system provides adequate nutrition as well as the safest and most economical care for horses. The simple, inexpensive, low-maintenance practices discussed in this section will help ensure the health of your animals, the pasture, and the environment by reducing soil erosion and preventing bacterial contamination of surface water and groundwater.

Runoff Management BMPs

Runoff management BMPs help control the amount of water moving across the landscape. These practices are vital to minimizing bacterial contamination of surface water bodies and keeping watersheds healthy. Reducing the flow of water across the landscape will cause fewer pollutants to be picked up and deposited into the water body itself.

Several BMPs help manage runoff, including filter strips (NRCS Code 393), building location, and roof runoff structures/rainwater harvesting (NRCS Codes 558 and 636).

Filter Strips
A filter strip is an area of herbaceous vegetation that is established between a body of water and cropland, grazing land, or disturbed land. It is designed to remove sediment, bacteria, organic material, nutrients, and chemicals from overland flow. A filter strip works by slowing runoff, which allows the contaminants to settle out, infiltrate, and be dispersed across the width of the filter strip (Fig. 10).

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 (Green and Haney 2005). If riparian areas are protected from overstocking and overgrazing, they will naturally develop effective vegetative filter strips that further protect the stream from runoff containing bacteria, nutrients, pesticides, and sediment.

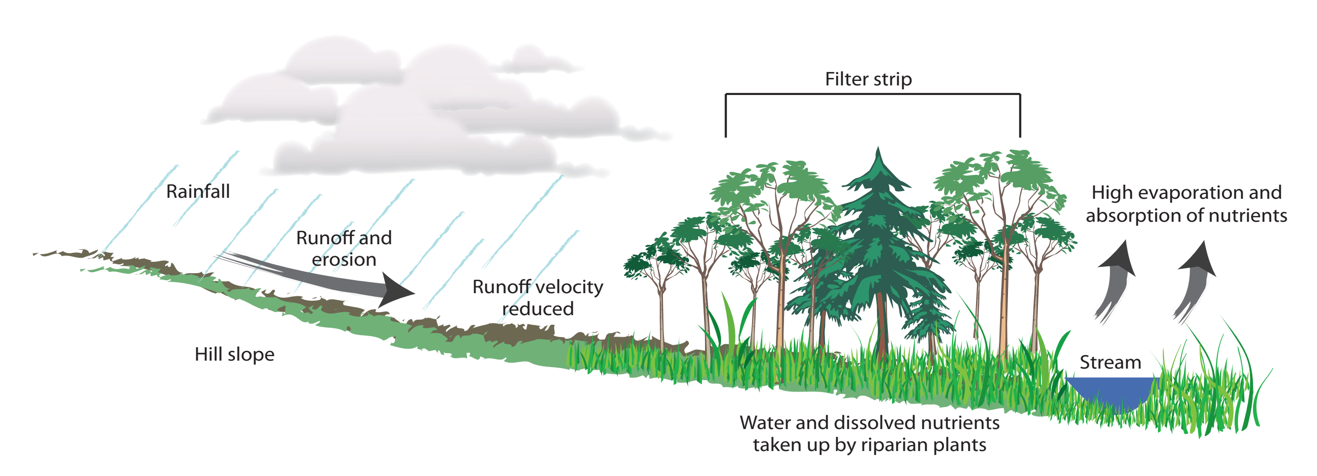


Figure 10. Conceptual model of how vegetative filter strips protect a stream from contaminants and the riparian area from erosion. Illustration by Jennifer Peterson.

For adequate protection, filter strips should have specific minimum widths, which vary according to the slope of the land (Table 6).

Their effectiveness 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 7). It is assumed that filter strips would be just as beneficial on land grazed by horses. In addition, filter strips are effective in removing other contaminants, including atrazine, herbicides, nitrate-nitrogen, sediment, soil, and total phosphorus (Fig. 11). 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.

Table 6. 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

The cost of establishing a filter strip depends on the seed and fertilizer selected and the associated labor and equipment

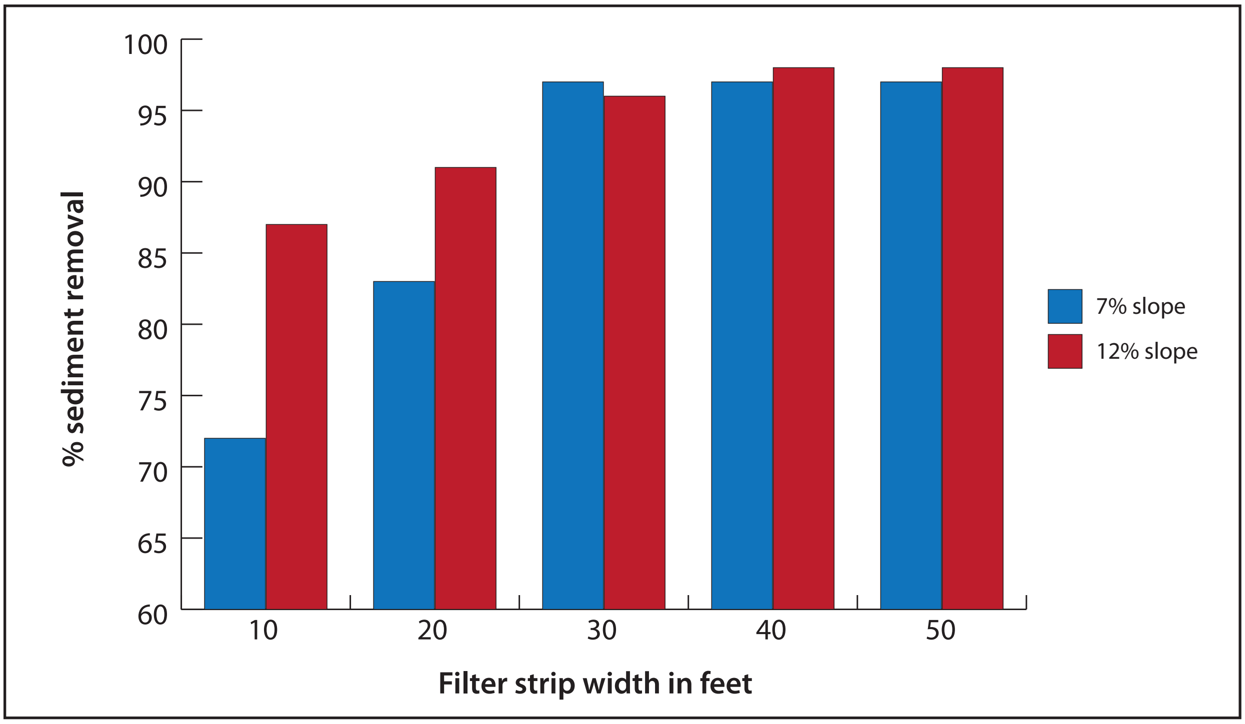


Figure 11. Percent sediment removed by a vegetative filter strip based on the width of the filter strip (Schultz et al. 1992).

Table 7. 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

costs. According to the NRCS, filter strip installation can cost from $275 to $310 per acre.

Often, simply changing the stocking rate and/or grazing management will encourage filter strips to develop naturally. Riparian areas that are protected from overstocking and overgrazing will naturally develop effective vegetative filter strips.

The NRCS offers technical and financial assistance programs to offset 50 percent of the cost of implementation. For more information on these programs, contact the NRCS office at the local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app).

Building Location
All barns, storage areas, and compost piles should be located on higher ground with well-drained soils and away from streams, ponds, wetlands, and other bodies of water (Fig. 12; Bamka 2001). Direct storm water away from the structures and toward filter strips or vegetated water retention systems by grading the land and constructing berms and terraces.

Before building any equine facilities, survey the drainage patterns, soil types, and water bodies on your land. Note any low spots that might not drain well. Look for higher, better drained land that might be good locations for foundations of buildings.

If you do not know what soil types you have on your property, check your County Soil Survey (http://soils.usda.gov/survey/online_surveys/) or use the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm). These free resources provide detail on soil types, drainage patterns, and erosion potential.

Because barnyard structures often contain large amounts of manure, locate them away from streams and rivers. Check with a local construction official to determine setback requirements for livestock and equine structures.

Selecting proper building locations does not add to the cost of construction. The benefits of properly locating equine facilities include:

- Reduced runoff and soil erosion
- Improved drainage from the barnyard
- Improved property aesthetics and increased property value
- Improved water quality by reducing the amount of sediment, nutrients, and bacteria that enter the stream
- Stabilized stream banks and reduced the erosion caused by trampling and overgrazing of banks

If possible, grade the areas around buildings to divert runoff away from the facilities and neighboring bodies of water. Doing this in conjunction with installing filter strips will protect water quality.

Figure 12. Properly locating all stables, barns, compost piles, and other facilities will help protect water quality. Photo courtesy of Jupiter Images.

Roof Runoff Structure/Water Harvesting Catchment
Roof runoff structures are gutters, downspouts, and outlets that collect, control, and transport precipitation from roofs (Fig. 13). During heavy rains, large amounts of water drain off the roofs of farm houses, barns, and other buildings and can cause flooding, erosion, and pollution problems. These problems can be greatly minimized simply by keeping roof rainwater

away from buildings and other important areas on the farm.

The first step is to install gutters and downspouts on houses, barns, and other large buildings. Downspouts should direct rainwater away from the building and to a vegetated area such as a filter strip. Minimize the water's force by protecting the ground directly below downspouts with rocks, splash blocks, or surface drains (Fig. 14).

The cost of installing roof runoff structures can range from $6.70 per linear foot for gutters and downspouts to $20.60 per linear foot for collection pipes (Table 8). Rather than simply directing roof runoff away from buildings, direct it to rain barrels, cisterns, or storage tanks (Fig. 15). This harvested rainwater can be stored temporarily and then used for irrigation, livestock, fish, wildlife, recreation, and other activities.

Horses typically drink 3 to 8 gallons of water per day. When you factor in the water used for baths, cleaning equipment, landscaping, and other activities, it makes sense to collect as much rainwater as possible to help lower your water bill.

It is estimated that 1 inch of rain can yield at least 0.6 gallons of water for every square foot of collecting surface such as a roof. The roof of a 2,000-square-foot house or barn, then, can collect almost 1,200 gallons of water from a 1-inch rain. This water can be stored and used as needed.

Many designs are available for rainwater harvesting systems, from small structures for watering wildlife to large roof catchments with filters and treatment systems to make water useable throughout

Figure 13. A roof runoff structure like the one pictured helps collect, control, and transport precipitation from roofs. Photo courtesy of the King Conservation Disctrict.

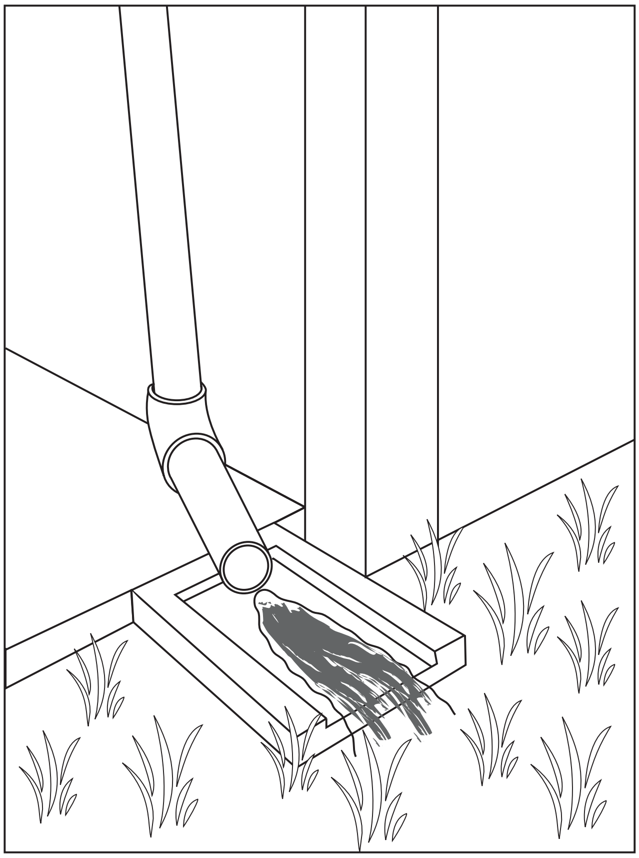


Figure 14. Protect the soil surface below the downspout from the water's force by having water fall onto splash blocks, into a surface drain, or into a stable rock outlet. Illustration courtesy of the USDA–NRCS.

Table 8. Costs for different types of gutters and downspouts (Krishna 2005).

Material	Cost	Comments
Vinyl	$.30/foot	Easy to install and attach to PVC trunk lines
Plastic	$.30/foot	Leaking, warping and breaking are common problems
Aluminum	$3.50-6.25/foot	Must be professionally installed
Galvalume	$9-12/foot	Mixture of aluminum and galvanized steel; must be professionally installed

the home or barn. Do some research to find the system that will best meet your needs, while factoring in the associated costs and benefits of installing the system. If installed properly, even the simplest rainwater harvesting systems will provide long-term benefits.

For more information, see the Texas Water Development Board's Manual on Rainwater Harvesting (http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf). Several publications on rainwater harvesting are also available from the Texas AgriLife Extension Service at https://agrilifebookstore.org/.

The cost of installing a rainwater harvesting system depends on the type of system you choose and the materials used. The largest expense is usually the storage tank, and the cost of the tank is based on its size and the material from which it is made. Table 9 shows different tank materials and the costs per gallon of storage. The tank size and the intended end use of the water will dictate which materials are most appropriate.

Costs range from about $0.50 per gallon for large fiberglass tanks to $4.00 per gallon for welded steel tanks. The larger the tank, the lower the storage cost per gallon. A system to provide drinkable water will be more expensive because it will require other components such as a roof washer, pressure tank, pump, and a filtering/disinfection system.

An economical water source is a water harvesting catchment. In some areas of Texas, the cost of drilling a well can be as high as $20,000, with no guarantee of hitting a reliable water source. Also, well water can contain high levels of total dissolved solids (TDS), resulting in "hard" water. Rainwater, on the other hand, is naturally "soft" and may be preferred. The cost of a substantial rainwater harvesting system is no higher than the cost of drilling a well in some parts

Figure 15. These four 2,500-gallon water harvesting tanks capture rainwater from the barn's roof and help save more than 162,000 gallons of water a year that would otherwise be pumped from the groundwater aquifer. Photo courtesy of Yamhill Soil and Water Conservation District.

Table 9. Costs for different types of water storage tanks (Krishna 2005).			
Material	**Cost**	**Storage**	**Comments**
Fiberglass	$0.50-2.00/ gallon	500-20,000 gallons	Can last for decades without deterioration; easily reparied; can be painted
Concrete	$0.30-1.25/ gallon	Usually 10,000 gallons or more	Risks of cracks and leaks but these are easily repaired; immobile; smell and taste of water somtimes affected but the tank can be retrofitted with a plastic liner
Metal	$0.50-1.50/ gallon	150-2,500 gallons	Lightweight and easily transported; rusting and leaching of zinc can pose a problem but this can be mitigated with a potable-approved liner
Polypropylene	$0.35-1.00/ gallon	300-10,000 gallons	Durable and lightweight; black tanks rsult in warmer water if tank is exposed to sunlight; clear/translucent tanks foster algae growth
Wood	$2.00/gallon	700-50,000 gallons	Aesthetically pleasing, sometimes preferable in public areas and residential neighborhoods
Polyethylene	$0.74-1.67/ gallon	300-500 gallons	
Welded Steel	$0.80-4.00/ gallon	30,000-1 million gallons	
Rain Barrel	$100	55-100 gallons	Avoid barrels that contain toxic materials; add screens for mosquitoes

of Central Texas, and weather patterns are generally reliable enough to provide adequate water.

The NRCS offers technical and financial assistance to help offset the cost of installing roof runoff structures and rainwater harvesting systems. Contact the NRCS office at your local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app). The Texas Legislature has passed bills to encourage this practice. Some local taxing entities give tax exemptions for these systems, and some public utilities offer rebates.

Collecting roof runoff or diverting it to vegetated areas keeps it from flowing across impervious surfaces and waste areas where it can pick up pollutants (such as sediment, nutrients, bacteria and organic matter) and carry them into water bodies. Using roof runoff structures in conjunction with other practices such as fencing, filter strips, and the protection of heavy-use areas, has been shown to reduce the concentrations of bacteria in surface water.

Roof runoff structures also:

- Improve property aesthetics and increase property value
- Reduce soil erosion and improve soil condition
- Improve water quality
- Prevent water from flowing into barns, stables, and animal waste areas
- Protect buildings from foundation damage
- Increase the infiltration of rainwater into the soil
- Improve livestock health by reducing mud around barns and other areas where animals stand

Adding a rainwater catchment system will:

- Provide a clean source of water for livestock
- Reduce the need for horses to climb steep, unstable stream banks to reach water, which contributes to erosion and overgrazing of these areas
- Reduce the concentration of salt in the soil (Waterfall 2006)
- Lower water bills (Sewell 2008)
- Reduce sedimentation in streams and mitigate floods (Forasté and Hirschmann 2010).

Summary of Runoff Management BMPs
The use of filter strips, proper building locations, and roof runoff structures/ rainwater harvesting systems will help control runoff across your property, protect the health of your horses, and minimize the level of contaminants that enter surface water. Some, or all, of these practices might be suitable for you and your land. Assess your situation and your goals, and implement the practices that work best for you.

Riparian Area Protection and Management BMPs

Riparian areas are environmentally sensitive areas along streams and rivers that require special protection from grazing livestock. To protect these areas, adopt BMPs that control the amount of time animals spend in and near riparian areas. These practices range from strategies for modifying animal behavior to total exclusion from the riparian area.

BMPs for riparian area management include shade structures (NRCS Code 717), watering facility (NRCS Code 614), exclusionary fencing (NRCS Code 382), and access control (NRCS Code 472).

Shade Structures
A shade structure is a permanent or portable structure that provides shade for livestock away from the riparian area and improves grazing distribution. Some studies indicate that animals perform better when there is shade in grazing areas during hot weather (Paul et al. 2000). Studies have shown that horses are highly sensitive to temperatures above 77°F (Morgan 1998), at which feed intake decreases while body core temperature, sweating, and metabolic rate increase (Ott 2005).

Natural shade is generally most abundant in riparian areas, so horses and other animals tend to congregate there and may defecate directly into the waterways. This increases the fecal coliform levels in the stream. Building shade facilities or, better yet, having trees in the pasture to provide natural shade can reduce the amount of time that horses spend in the riparian area.

Grown horses need about 60 square feet of shade per animal (NRCS 2008), and the structure needs to be at least 8 feet tall. The shade facilities may be permanent or temporary. Portable structures should be moved periodically to prevent the destruction of vegetation in the immediate area.

Structures can be framed with treated lumber or steel (Fig. 16) and roofed with tin or shade cloth. Shade cloth transmits about 80 percent of light but blocks most of the sun's rays and heat; it also allows heat to dissipate through the weave of the cloth and is relatively inexpensive and easy to repair. To make the cloth last longer, remove and store it during winter.

Although horse behavior related to shade structures has not been studied, shade structures have been shown to reduce the amount of time that cattle spend in riparian areas. They are recommended in most states and by the EPA as an effective BMP.

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

Shade structures also have been found to:

- Help horses maintain proper body temperatures (Thesing 2006)
- Decrease the amount of water and minerals/electrolytes that horses lose through sweating (Thesing 2006)
- Improve animal health and appetite (Thesing 2006, Porr 2007)
- Increase the animals' use of stored fat (Thesing 2006)
- Improve grazing distribution (McIlvain and Shoop 1970)

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.

For more information, contact the NRCS office at your local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app).

Figure 16. 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.

Watering Facility
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 the horses.

Even when horses 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 horses spend in and near a stream (Brown 2006, Clawson 1993, Franklin et al. 2009, Godwin and Miner 1996, Miner et al. 1992, Sheffield et al. 1997). In a study done with cattle, Wagner and Redmon (2011) demonstrated with GPS data that cattle spent 43 to 57 percent less time in streams when provided an alternative water source.

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. 17) or solar-powered pumps (Fig. 18) 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.

Figures 17 and 18. 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.

Because animals spend less time in riparian areas if other sources of water are available, this BMP can reduce bacteria levels in the water from 51 to 94 percent (Table 10). It also reduces stream bank erosion (Sheffield et al. 1997), reduces the risk of colic, and improves animal health and condition (Richards 2007).

Animals prefer to drink from water troughs rather than streams, possibly because the quality of water from alternative water sources is better. Studies done on cattle have found that with access to alternative water sources, cattle spend much more time drinking from troughs than they do from streams and calves gain 9 percent more weight from cows drinking clean water than from cows drinking pond water (Willms et al. 2002). Therefore, clean water from alternative water sources not only helps protect riparian areas and waterways but may also improve animal performance. An alternative water supply alone, however, will not achieve targeted improvements unless implemented in conjunction with good grazing management (McIver 2004).

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:

Table 10. Bacterial 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.

- **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

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

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 (Fig. 19) may not completely protect the riparian area unless adequate vegetative filter strips are maintained along the waterway. As long as the land is not overstocked and overgrazed, the filter strips will protect streams from runoff that might carry bacteria, nutrients, pesticides, and sediment after heavy rains.

Producers should carefully plan the length of the stream segment to be fenced out and be prepared to maintain the fence, especially in areas subject to periodic flooding. Many ranchers place exclusionary fences above flood-prone areas. The fenced-out area could be used for hay production. Exclusionary fencing can reduce bacteria levels from 30 to 94 percent (Table 11). Although the data in Table 11 refer mostly to studies conducted with cattle, similar results are expected when fencing is installed on land where horses graze.

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)
- 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)

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

Figure 19. A barbed wire fence separates a riparian buffer on the right from a grazed pasture on the left. Photo courtesy of the USDA–NRCS.

Table 11. 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.

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.

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). For more information contact the NRCS office at the local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app).

Access Control

Closely related to exclusionary fencing is the practice of access control, which simply means excluding livestock, people, or vehicles from environmentally sensitive areas. Access control tools include fences, gates, signs, or other barriers.

One type of barrier is rip-rap (large rocks), which can be used to restrict livestock from riparian areas, trails, stream crossings, or other sensitive parts of a ranch (Fig. 20). Livestock tend to avoid areas where large stones comprise 30 percent or more of the ground cover (Hohlt et al. 2009), so rip-rap can alter animal movement patterns away from riparian areas.

Preliminary data from research 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 equine 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).

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.

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).

Figure 20. This stream bank has been stabilized from erosion with rip-rap. Photo courtesy of the USDA–NRCS.

Implementation costs for access control measures depend on the method used. Fencing will cost about $1.80 to $3.05 per foot. 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). For more information on access control practices and financial assistance programs, contact the NRCS office at your local USDA Service Center (http://offices.sc.egov.usda/gov/locator/app).

Summary of Riparian Area Protection and Management BMPs

If you own land next to a body of water, it is critical that you protect the riparian area along the waterway to prevent erosion and pollution problems. The best line of defense against contaminants is properly maintained vegetation along the shoreline.

To help protect the riparian area from excessive use and erosion, install shade structures, watering facilities, and fencing and control direct access to the waterway. As always, assess your situation and goals and implement the practices that work best for you and your land so its resources can be maintained for future generations to enjoy.

Manure Management BMPs

Manure is a good soil amendment and a valuable source of nutrients for plant growth. However, horse manure contains bacteria and other pathogens; if the manure is not managed properly, it can contaminate waterways and harm people and horses. Pathogens in horse 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 horse produces about 51 pounds of manure per day, which adds up to 8 to 10 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. 21). 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

Figure 21. Dry stack horse manure storage area. Photo courtesy of the Livestock and Poultry Environmental Learning Center.

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 12 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).

Although the information in Table 12 comes from land where beef and/or dairy cattle grazed, it is assumed that manure storage would be equally beneficial for horse manure. However, indicator bacteria loads in surface runoff do vary. 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.

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)

Table 12. 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.

- 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 13 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 13. 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. 22). 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.

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.

Figure 22. 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.

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 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.

Figure 23. 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 horse manure to determine its nutrient content. This analysis will help ensure that manure application meets but does not exceed plant nutrient requirements.

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. 23). 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).

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,

Table 14. 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

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 14). 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 horse owners is to compost manure. Composting reduces the volume of the material and makes it more useful on-site (Fig. 24). 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 horse manure can take 30 to 60 days; adding bedding to the manure may require as long as 6 months to compost. Although composting requires extra time and expense, the benefits far outweigh the costs.

Figure 24. Multiple bin horse compost system. Photo courtesy of O_2 Compost.

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 this ratio, although it can be altered depending on the amount and type of bedding material used (Table 15).

An on-farm composting system can be designed in several ways, and no single design is appropriate for all sizes and types of equine facilities. Tailor your composting system to accommodate the number of horses, the space and

Table 15. Carbon to nitrogen ratios for manure and bedding materials (Warren and Sweet 2003).

Material	C:N Ratio
Horse manure	20-40:1
Grass clippings	25:1
Horse manure with bedding	30-60:1
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 horse 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 horse manure and straw might have a C:N of 30:1 ((20 + 40)/2 = 30).

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 horse owner. Manure must be stored, handled, recycled, and disposed of properly to protect water quality and keep animals, people, and the surrounding environment healthy. 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 to manage horse mortality include rendering, composting, incineration, burial, and sanitary landfills (Gould et al. 2002).

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 horses 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 horse carcass, it might not be an option for all horse 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 horse 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, and those that do may not take horses. Some landfills that accept horse 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. Consider contacting a local equine veterinarian for burial recommendations.

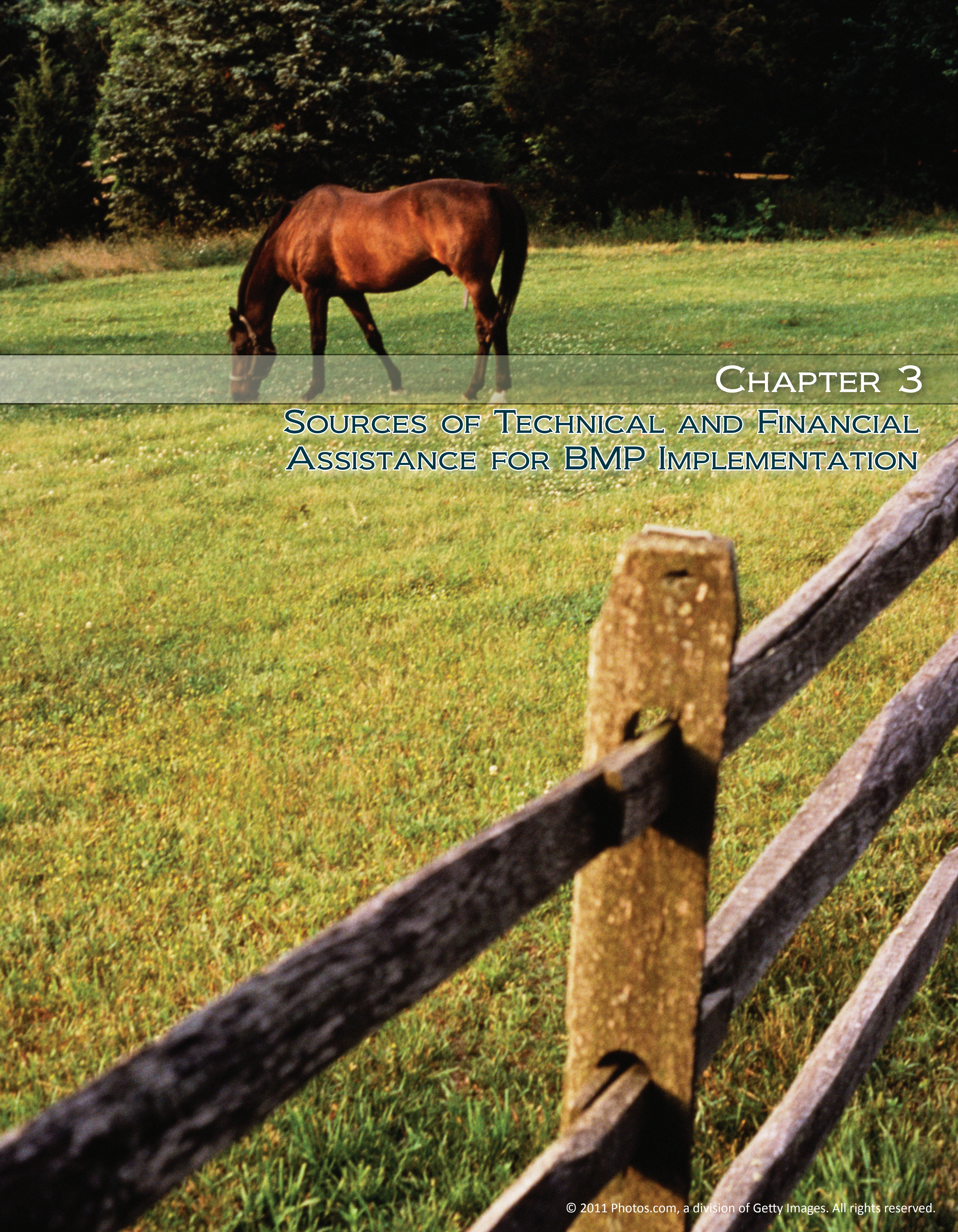
Texas law requires notification 48 hours prior to any excavation to assure utilities are properly marked. To locate all your utility services before you dig, call 1-800-dig-tess. In addition, deeds must be marked with burial sites according to TCEQ as well.

<u>Potential bacterial reductions with proper mortality management</u>: 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 horse 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 horses, 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

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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. 25) 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.

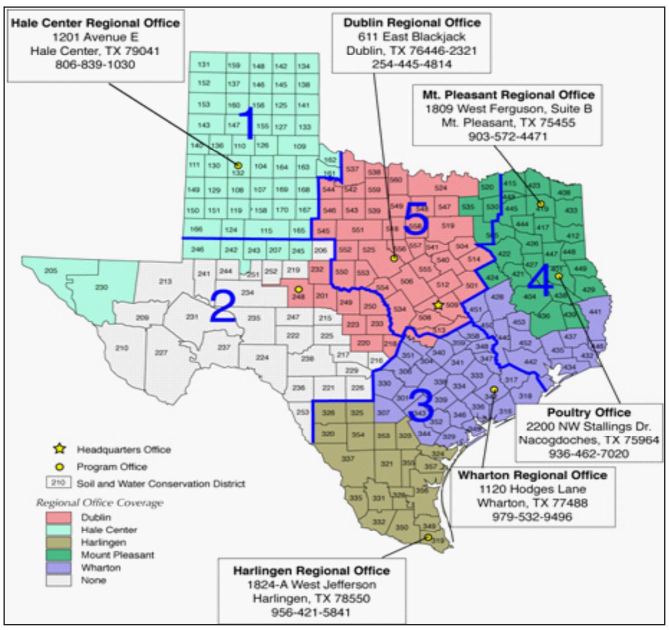

Figure 25. Map showing the five regions of the Texas State Soil and Water Conservation Board. Illustration courtesy of the Texas State Soil and Water Conservation Board.

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

Many important responsibilities accompany horse ownership: controlling runoff, managing manure, maintaining pastures and facilities, and others. Although these activities can take much time and effort, the benefits to water quality are far-reaching. The collective impact of mismanaging Texas's equine facilities would be environmentally harmful. Implementing BMPs that protect the environment will result in a healthy farm or ranch that saves money and is aesthetically pleasing.

Texas is projected to have explosive 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 land will be developed and more large tracts will be divided. These changes will increase the amount of rainfall runoff and decrease the ability of our land to filter runoff effectively.

While this guide focuses on equine operations as a potential nonpoint source of pollution, there are many other sources such as wastewater treatment facilities, failing septic systems, and urban runoff. Therefore, all members of society must be educated on the importance of maintaining and conserving the quality of water in Texas.

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Additional Resources

Best Management Practices for Equine Disease Prevention: B-6214, Texas AgriLife Extension Service

Composting Horse Manure: B-6084, Texas AgriLife Extension Service

Feeding the Arena Performance Horse: B-6143, Texas AgriLife Extension Service

Feeding Young Horses for Sound Development: B-5043, Texas AgriLife Extension Service

Mature, Senior, and Geriatric Horses: Management, Care, and Use: B-6161, Texas AgriLife Extension Service

Routine and Emergency Burial of Animal Carcasses: E-599, Texas AgriLife Extension Service

Selection and Use of Hay and Processed Roughage in Horse Feeding: B-5033, Texas AgriLife Extension Service

What Texas Horse Owners Need to Know about Equine Piroplasmosis: E-260, Texas AgriLife Extension Service

APPENDIX A

E-534
8/99

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.

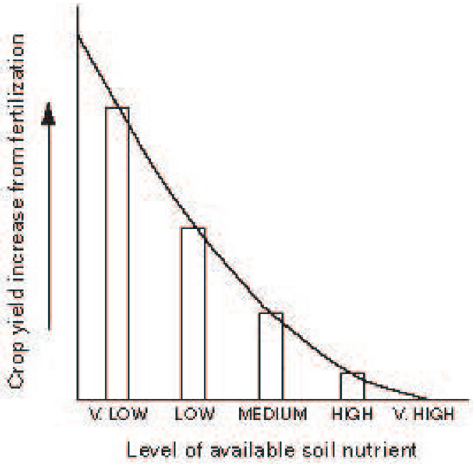

Figure 1. The probability of a crop yield increase resulting from fertilization depends on the initial amount of available nutrients in the soil.

*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.

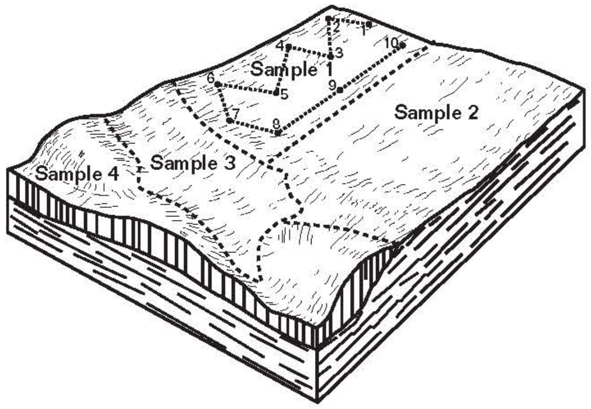

Figure 2. Fields should be subdivided into sampling units as needed and a composite sample should be collected from each unit.

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.

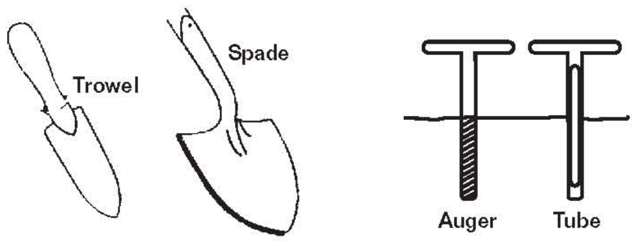

Figure 3. These tools can be used to collect soil samples.

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.

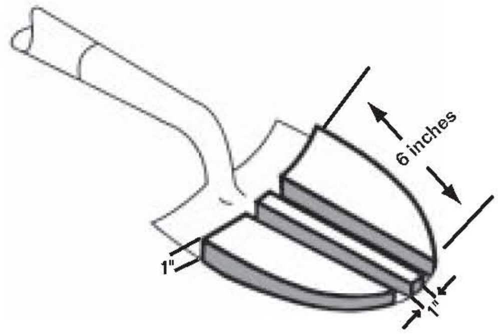

Figure 4. Collect a slice or core of soil to the desired depth.

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.

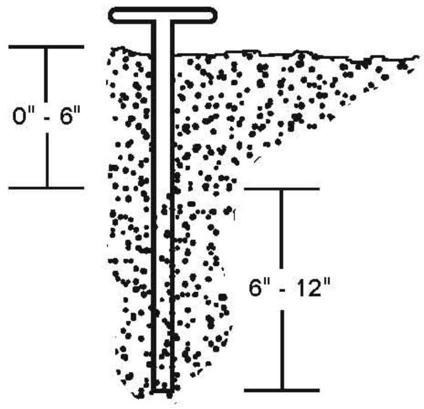

Figure 5. A sampling tube or auger is needed to collect subsurface samples.

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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Visit the Texas AgriLife Extension Service at *AgriLifeExtension.tamu.edu*

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Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, Texas AgriLife Extension Service, The Texas A&M System.

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

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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

Funding for this publication came from a Clean Water Act §319(h) nonpoint source grant from the Texas State Soil and Water Conservation Board and the U.S. Environmental Protection Agency.

Produced by the Department of Soil and Crop Sciences and AgriLife Communications, The Texas A&M System.
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Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, the Texas AgriLife Extension Service, Texas A&M System.

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