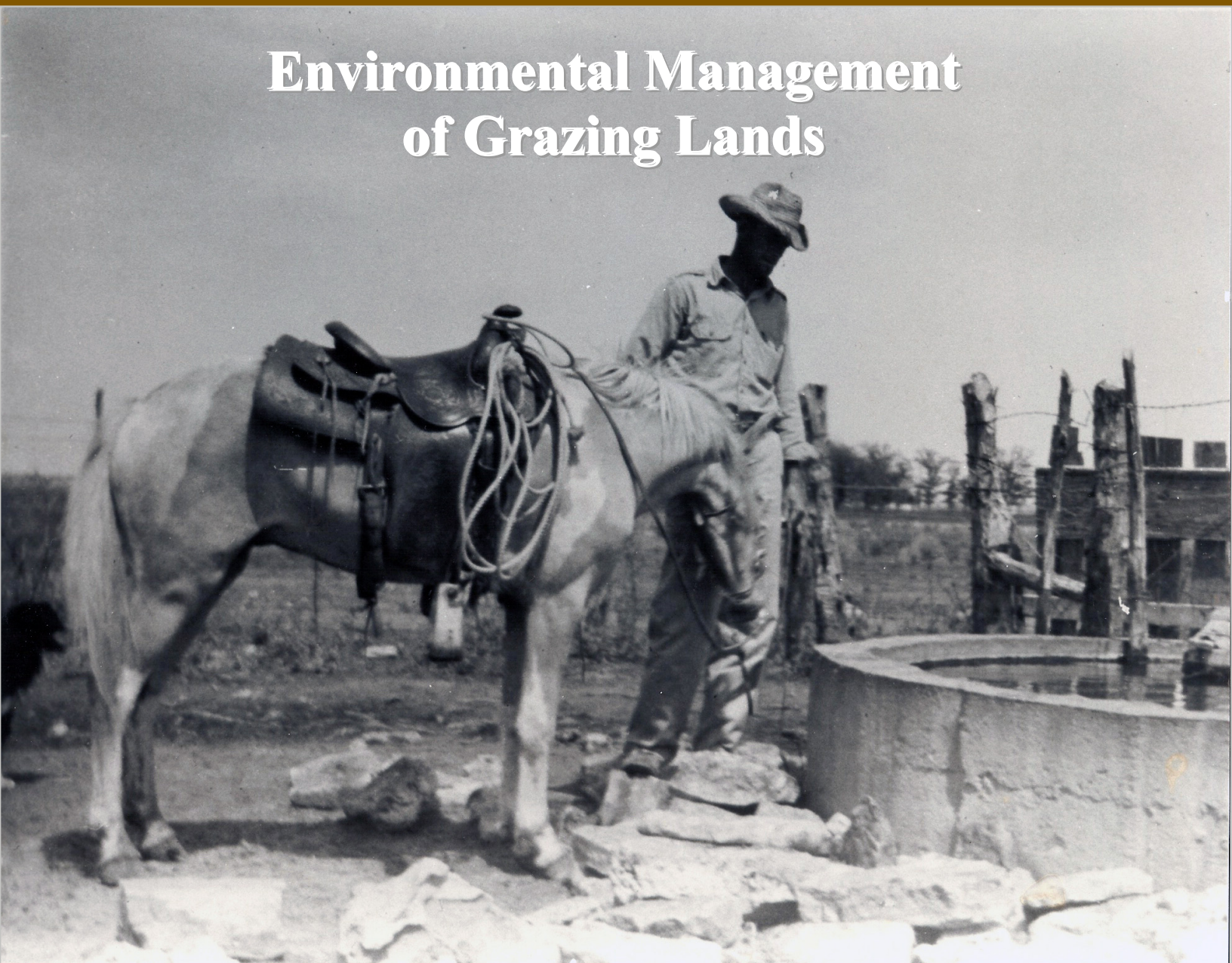


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Environmental Management of Grazing Lands



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Final Report

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(Front cover: Arthur Joseph Wilcox, circa 1940 in Mills County, Texas)

Executive Summary

Bacteria levels are the number one cause of water quality impairment in Texas. Several recent Total Maximum Daily Loads (TMDLs) in Texas, such as those implemented in the Peach Creek and Leon River watersheds, have identified grazing cattle as a contributor to bacterial water quality impairments in those watersheds through both direct deposition and runoff of their fecal matter to streams. To address this issue, the Texas State Soil and Water Conservation Board (TSSWCB) and the Natural Resources Conservation Service (NRCS) funded this project to assist with development and delivery of technical information and support to ranchers on protection and enhancement of the functions and values of grasslands.

A number of best management practices (BMPs) have been identified to reduce bacteria runoff from grazing lands and direct deposition into streams. The primary focus of these BMPs is to maintain adequate ground cover and minimize concentrated livestock areas, especially on sensitive areas such as riparian areas. Maintaining adequate ground cover and plant density improves the filtering capacity of the vegetation and enhances water infiltration into the soil. Minimizing concentrated livestock areas, trailing, and trampling reduces soil compaction, reduces excess runoff and subsequent soil erosion, and enhances fecal matter distribution and ground cover. Specific BMPs identified include grazing management, fencing, alternate water sources, hardened watering points, controlled access, supplemental feed placement, and shade or cover manipulation (NRCS 2007).

This project accomplished several objectives, including: 1) compiling existing information on environmental management of grazing lands, 2) evaluating and demonstrating the effectiveness of proper grazing management in reducing bacterial runoff from grazing lands, 3) initiating evaluation of the effect of complementary practices (i.e. alternative water supplies and shade) on cattle behavior and stream water quality, and 4) promoting adoption of appropriate grazing land management practices.

Evaluation and demonstration of the effect of grazing management on bacteria runoff at the USDA-ARS Riesel Watersheds has produced some interesting results. The site mean concentration of *E. coli* (i.e. flow weighted concentration) at the ungrazed native prairie site was surprisingly high (1.0E+04 cfu/100 ml), greatly exceeding the Texas Surface Water Quality Standards single sample standard for *E. coli* (394 cfu/100 ml) as well as the geometric mean (126 cfu/100 ml). It is important to note that these standards apply to waterbodies, such as streams and reservoirs, but not to edge-of-field runoff as described here. Also, the *E. coli* concentration seen in the runoff from the moderately grazed bermudagrass site (2.3E+04 cfu/100 ml) was significantly higher (more than double) than that observed at the native prairie site. These levels, however, are consistent with the findings of other researchers.

The pre-BMP implementation evaluation of the effectiveness of alternative water supplies and shade on cattle behavior and stream water quality (*E. coli*) has been completed at the 2S Ranch, near Lockhart. This evaluation showed that when alternative water was not available, *E. coli* levels increased as the stream flowed through the ranch. Quarterly evaluation of cattle behavior using GPS collars indicated cattle spent only 4.5% of the time within 35 feet of the stream when alternative water was not available.

When alternative water was provided, however, this percent time that cattle spent within 35 feet of the stream was reduced to 1.1%, a 75% reduction. This reduction is consistent with the findings of other researchers. Post-BMP evaluation has been initiated and will continue for another year now that alternative water and shade has been provided.

Much was done through this project to increase awareness of the bacteria issue and BMPs to address them. AgriLife Extension and TWRI developed fact sheets, provided posters and presentations, conducted site tours, and developed a Web site to help disseminate information. These outreach activities reached local, state, and national audiences. The Web site alone has reached 539 unique visitors during the project.

Much is left to do, however. Evaluation of grazing management, alternative water supplies, and shade will continue. Data on other practices (i.e. using rip-rap to reduce access to riparian areas, providing controlled access points, etc.) and groups of practices is still needed to provide cattlemen with a “toolbox” for addressing the bacteria issue. Modification of water quality standards may also be appropriate to address the high levels of *E. coli* found in runoff from ungrazed sites. Education programs need to be conducted state- and nation-wide to assist cattlemen in addressing bacteria issues.

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List of Acronyms and Abbreviations

ac – acre

AgriLife Extension – Texas AgriLife Extension Service

AgriLife Research – Texas AgriLife Research

ASAE – American Society of Agricultural Engineers

AU – animal unit

AUD – animal unit day

BMPs – best management practices

cfu – colony-forming units

CWA – Clean Water Act

E. coli – *Escherichia coli*

EPA – U.S. Environmental Protection Agency

FCA – Florida Cattlemen’s Association

GPS – global positioning system

ft³ – cubic feet

ha – hectare

kg - kilogram

lbs – pounds

m – meter

m² – square meter

ml – milliliter

mpn – most probable number

PC – Plum Creek

QPRs – Quarterly Progress Reports

SAML – Soil and Aquatic Microbiology Laboratory

SWCD – Soil and Water Conservation Board

TAMU – Texas A&M University

TCEQ – Texas Commission on Environmental Quality

TMDL – Total Maximum Daily Load

TSSWCB – Texas State Soil and Water Conservation Board

TWRI – Texas Water Resources Institute

µm - micrometer

USDA – U.S. Department of Agriculture

USDA-ARS – USDA – Agricultural Research Service

USDA-CSREES - USDA – Cooperative State Research, Education, and Extension Service

USDA-NRCS – USDA – Natural Resources Conservation Service

UV - ultraviolet

WWR – Welder Wildlife Refuge

Introduction

Statement of Need

Bacteria is the number one cause of water quality impairment in Texas (TCEQ 2008a). Several recent Total Maximum Daily Loads (TMDLs) in Texas, such as those conducted in the Peach Creek (TCEQ 2008b) and Leon River (TCEQ 2008c) watersheds, have identified grazing cattle as a contributor to bacterial water quality impairments in those watersheds through both direct deposition and runoff of their fecal matter to streams.

Surface water is often contaminated by low levels of bacteria (Ferguson et al. 2003). Background levels of *Enterococci* have been reported to range from $2.0 \times 10^0 - 2.1 \times 10^5$ cfu/100 mL, while background levels of fecal coliforms range from $1.5 \times 10^1 - 4.5 \times 10^5$ mpn/100 mL (EPA 2001).

However, direct relationships have been observed between the presence of cattle and increased fecal coliform levels (Tiedemann et al. 1987). In New Zealand, elevated *E. coli* concentrations have been observed in streams flowing through grazed pastures (Donnison et al. 2004). Environmental Protection Agency (EPA) (2001) reports that fecal coliform concentrations in runoff from grazed pastures ranges from $1.2 \times 10^2 - 1.3 \times 10^6$ organisms/100 mL, an order of magnitude higher than background levels. According to Edwards et al. (1997), bacteria levels in runoff from four pastures in northwest Arkansas exceeded water quality standards 70-89% of the time. Doran and Linn (1979) found that bacteria runoff from both grazed and ungrazed pastures in eastern Nebraska exceeded water quality standards.

Grazing may also impact groundwater and associated springs as demonstrated by Howell et al. (1995) in two springs in Kentucky. Before cattle were present, only 29% of samples exceeded primary contact standards, while 80% exceeded standards after cattle began grazing the surrounding pasture.

Concerns regarding fecal contamination of waterbodies by cattle arise from documentation of waterborne outbreaks associated with animal-impacted surface waters (Ferguson et al. 2003). *Campylobacter*, one pathogen known to be shed by cattle (Table 1), affects 1 million people annually (University of Wisconsin 2007b).

Table 1. Pathogen prevalence in cattle manure.

Pathogen	Infective Dose (# microorganisms)	Farm Prevalence (%)
<i>Listeria</i>	1000	
<i>Salmonella</i>	15-20	0-13
<i>Cryptosporidium</i>	<10	1-100
<i>Giardia</i>	1	10-100
<i>Campylobacter</i>	500	1
<i>E. coli</i> O157	10	16

Source of Data: University of Wisconsin 2007b

Domestic cattle can also be a major source of *Salmonella*, and enterohemorrhagic *E. coli*. Approximately 13% of healthy cattle have been found to be infected with *Salmonella* (Ferguson et al. 2003) and up to 25% of cattle are infected with enterohemorrhagic *E. coli* (Elder et al. 2000). Other pathogens that may be associated with manure include *Cryptosporidium*, *Listeria* and *Giardia* (University of Wisconsin 2007a and 2007b). Animals infected by *Cryptosporidium* may shed up to 280 million of these organisms per ounce of feces. Ingestion of these pathogens can be dangerous to human health and may cause abdominal pain, nausea, vomiting, fever, diarrhea, and occasionally, renal failure and death (University of Wisconsin 2007b).

Objectives/Work Accomplished

The goal of this project was to assist with the development and delivery of technical information and support to ranchers on protection and enhancement of the functions and values of grasslands. Proper management of grazing lands includes implementation of integrated grazing management practices. These practices sustain forage productivity and soil health, improve air and water quality, and enhance habitats for wildlife. Proper management also increases infiltration and flood protection, sequesters carbon, and provides hunting and other recreational opportunities that contribute positively to the economy of many regions.

This project collaborated with the *Bacteria Runoff BMPs for Intensive Beef Cattle Operations* project, funded through a Natural Resources Conservation Service (NRCS) Conservation Innovation Grant and the *Lone Star Healthy Streams* project, funded through an EPA Clean Water Act (CWA) §319(h) grant that is administered by the Texas State Soil and Water Conservation Board (TSSWCB) and was awarded to Texas Water Resources Institute (TWRI) and Texas AgriLife Extension Service. Together, these projects are developing and delivering current information to landowners on production and environmental management of grazing lands and their associated watersheds to address water quality and other concerns in the state.

This project accomplished several objectives, including: 1) compiling existing information on environmental management of grazing lands, 2) evaluating and demonstrating the effectiveness of proper grazing management in reducing bacterial runoff from grazing lands, 3) initiating evaluation of the effect of complementary practices (i.e. alternative water supplies and shade) on cattle behavior and stream water quality, and 4) promoting adoption of appropriate grazing land management practices.

A literature search was conducted in order to compile existing information on grazing management and impacts on bacteria. This literature search is summarized in Chapter 2.

Evaluation and demonstration of proper grazing management is taking place at (1) the USDA-Agricultural Research Service (ARS) Watersheds near Riesel, (2) the Welder Wildlife Foundation near Sinton, and (3) the Texas A&M University (TAMU), Department of Animal Science, Beef Cattle Systems Center located west of the TAMU campus on Highway 50, along the banks of the Brazos River between College Station and Snook. Three small (1 ha) watershed sites have been established on both the Welder Wildlife Foundation and the TAMU Beef Cattle Systems Center to measure runoff and collect samples.

Three different treatments are being evaluated — no grazing, prescribed grazing, and heavy grazing (double prescribed grazing). In addition, two 1.2 ha sites at Riesel are equipped to measure runoff and suited for achieving the objectives of this study: (1) site SW12, an ungrazed native prairie and (2) site SW17, a grazed bermudagrass pasture. Results to date are reported in Chapter 3.

The evaluation of the complementary practices, alternative water supplies, and shade on cattle behavior and stream water quality was initiated on the 2S Ranch located near Lockhart, Texas, in the Plum Creek watershed. An upstream-downstream, pre-/post-best management practice (BMP) implementation monitoring design was used. Both *E. coli* levels and cattle behavior are being assessed. Findings from the upstream-downstream, pre-BMP implementation monitoring are summarized in Chapter 4.

Finally, a number of programs and activities were completed to promote the adoption of appropriate grazing land management practices. The efforts completed to date are described in Chapter 5.

Project Coordination and Administration

In order to effectively coordinate this project, TWRI prepared project reports, provided technical and financial supervision of the contract, participated in meetings, coordinated activities with ongoing projects, and maintained project files and data.

TWRI prepared and submitted six electronic quarterly progress reports (QPRs) to the TSSWCB documenting all activities performed within each quarter. QPRs were submitted in April, July, and October 2007 and January, April, and July 2008. All QPRs were made available on the *Improving Water Quality of Grazing Lands* Web site. TWRI prepared the final report, as well, summarizing the existing information on environmental management of grazing lands and describing results of research on BMP effectiveness completed to date. Additionally, TWRI participated in regular meetings and teleconferences with the TSSWCB project manager to review project status, deliverables, and discuss related issues. TWRI attended the Association of Texas Soil and Water Conservation District Director's Annual Meeting at the Waco Convention Center on October 22-23, 2007 as well as the State Board Meetings on November 29, 2007 and March 19, 2008.

TWRI performed accounting functions for project funds, ensuring efficient and appropriate expenditure of all project funds. TWRI submitted eight invoices in February, June, August, and November of 2007 and February, May, August, and October 2008.

TWRI closely coordinated this project with the *Lone Star Healthy Streams* project and related USDA-ARS efforts at Riesel. TWRI worked very closely with Dr. Larry Redmon, who leads the *Lone Star Healthy Streams* project, and Dr. Daren Harmel, who oversees USDA-ARS efforts at Riesel. Both helped oversee all research activities conducted through this project. In November 2007, work from this project was presented to the *Lone Star Healthy Streams Steering Committee* of which both are members.

Existing Information

Factors Affecting Water Contamination

The extent and severity to which bacteria from grazing operations affects water quality is a function of (1) the number and size of cattle in the pasture, (2) the location of fecal deposits in relation to waterbodies, (3) site characteristics affecting adsorption and runoff, and (4) bacteria survivability between time of fecal deposition and runoff events (Larsen et al. 1994).

Fecal Matter Production/Deposition

A 1,000-pound (454 kg) cow typically defecates 12 times a day, excreting 4.4 – 6.6 lbs (2-3 kg) per defecation (Larsen et al. 1994), producing a total of 53 – 79 pounds per day on a wet weight basis. This feces is primarily composed of water with the remainder composed of dead bacteria, living bacteria, protein, undigested food residue, waste material from food, cellular linings, fats, salts, and substances released from the intestines and the liver. According to the NRCS Animal Waste Management Handbook (NRCS 2008), beef cattle feces is 88% moisture. As much as 50% (most references indicate ~30%) of the solids (the remaining 12%) is composed of bacteria cells. A large number of bacteria species inhabit the gut of warm-blooded animals. For example, over 400 bacteria species inhabit the human colon. *Bacteroides* is by far the most numerous species. *Bacteroides-Porphyromonas-Prevotella* comprise from 10-60% of the intestinal bacterial population in many animals, while *E. coli* typically comprises about 1% of the total fecal bacterial population.

According to the American Society of Agricultural Engineers (ASAE) (2003), beef cattle produce 58 pounds of total manure per AU (animal unit - 1,000 lb live animal) per day with an average fecal coliform concentration of $4.85E+06$ organisms/ g^{-1} . Based on this, ASAE calculates that daily fecal coliform produced per animal unit is $1.3E+11$. Conversely, Metcalf and Eddy (1991) reported that beef cattle produce 23.5 kg (51.8 pounds) of total manure per AU per day with an average fecal coliform concentration of $2.3E+05$ organisms g^{-1} . Based on this, Metcalf and Eddy (1991) calculate that fecal coliform production for cattle is $5.4E+09$ organisms d^{-1} , almost two orders of magnitude lower than ASAE estimates.

This waste and the millions of bacteria excreted (University of Wisconsin 2007b) may enter waterways through either direct deposition or runoff of manure deposited away from the waterbody and carried by overland flow (Larsen et al. 1994). Bacteria runoff from fresh manure can be as high as 90% (Crane et al. 1983, Coyne et al. 1995). Gary et al. (1983) estimated that about 5% of the total manure produced by cattle contributed to pollution of streams. A number of studies have found that as grazing intensity increases, coliform counts in streams increase (Larsen et al. 1994).

When cattle have access to a stream, a portion of their fecal matter is deposited directly into the stream (Larsen et al. 1988) and can be a significant source of contamination. The majority of the bacteria deposited directly to the stream with the feces settles to the bottom and begins to die off.

However, surviving bacteria can be resuspended at a later time. The manure not deposited directly to the stream is deposited throughout the pasture and can result in approximately 0.4 to 2.0% of a pasture being covered in fecal deposits at any given time. However, fecal pats are not distributed uniformly throughout pastures. Much is concentrated in congregation areas such as near water troughs, fence lines, gates, and bedding areas. Runoff from rainfall can carry viable bacteria from the fecal pats into nearby streams (Larsen et al. 1994).

Feces deposited in the stream, however, have a much greater potential for water quality impact than that deposited even 2 feet away from the stream. Larsen et al. (1994) found that manure deposited 2 feet from a stream contributed 83% less bacteria and manure deposited 7 feet from a stream contributed 95% less bacteria than that deposited directly in a stream.

Site Characteristics Affecting Adsorption and Runoff

The characteristics of the initial site of deposition greatly affect the infiltration, runoff, and retention of microorganisms. Soil type strongly impacts immobilization of bacteria from surface runoff (Ferguson et al. 2003). Microbes readily adsorb to clay and organic matter.

Once adsorbed, *E. coli* survival has been found to increase as a result of availability of organic matter and nutrients (Burton et al. 1987) and protection from UV radiation, pH extremes, desiccation, antibiotics, and predation (Bitton and Marshall 1980). Thus, as long as these soils are kept in place, they effectively immobilize the bacteria; however, if allowed to erode, these soils can deliver bacteria to nearby waterbodies.

Microbial adsorption to particulate matter in aqueous solutions is largely controlled by the morphology of the microbes themselves, including their size and hydrophobic/hydrophilic properties (Ferguson et al. 2003). Fecal bacteria are generally <2 μm in size and behave much like clay in terms of solution transport (Coyne et al. 1995). Particles less than 62 μm in size are generally well mixed throughout the stream profile. If microbes are attached to particles larger than 62 μm in size, however, bacteria levels will vary in the stream profile with higher levels being present near the stream bed and lower levels with distance from the bed (Harmel et al. 2006a). The ability of particulate matter to adsorb microbes is largely a factor of soil type and electrostatic potential of the particle. Other factors controlling adsorption of microbes in solution include the level of salts, organic matter, and pH in the solution the adsorption takes place (Ferguson et al. 2003).

Hydrology of the site is one of the key processes affecting microbial transport and contamination. Peak fecal coliform concentrations in streams are frequently related to runoff events (Larsen et al. 1994). Rainfall depth has been positively correlated with indicator organism concentration and waterborne disease outbreaks. In addition, rainfall intensity has been found to be important to the release of pathogens from fecal matter and transport to surface water (Ferguson et al. 2003).

Because bacteria are living organisms, however, describing their transport is more complex than that reflected by routine hydrologic models. Bacteria levels in overland flow and streams are impacted by adsorption (as discussed previously), straining (i.e. filtration), interception, entrapment, and sedimentation. In addition, bacteria levels in runoff and streams are greatly affected by their survivability in the environment.

Bacteria Survivability and Time between Fecal Deposition and Runoff Events

Time between fecal deposition and runoff events is an important factor affecting microbial transport and contamination. Risk of pollution is greatest immediately after deposition of manure. Conversely, if weather conditions are dry and deposition is on well drained soils, significant losses of microorganisms are greatly reduced (Ogden et al. 2001). Season may play a role as well. Edwards et al. (1997) showed that fecal coliform and fecal strep numbers in runoff from four pastures in Northwest Arkansas were affected by the time of year and more prevalent in warmer months.

Pathogens may survive for long periods in manure and soil (Table 2) depending on the chemical, physical, and biological composition of feces, soil, and water as affected by water/osmotic potential, light, temperature, pH, and inorganic and organic nutrients (Crane and Moore 1986, University of Wisconsin 2007a). Thus, potential for bacteria contamination exists for long periods after cattle are removed from a site (Larsen et al. 1994).

Table 2. Pathogen survival in the environment (in days).

Pathogen	Soil	Cattle Manure	Grass	Water
<i>Listeria</i>	14 – 1460		128	
<i>E. coli</i>	30 – 365	10 – 182	99	35
<i>E. coli O157</i>	2 – 304	61 – 365		14 – 182
<i>Cryptosporidium</i>	30 – 365	28 – 365	30	30
<i>Salmonella</i>	14 – 243	21 – 182	63	16 – 182
<i>Campylobacter</i>	14 – 61	7 – 56		30
<i>Giardia</i>	61	7 – 365		91

Source of data: (University of Wisconsin 2007 a & b)

Water potential, the actual amount of water available in the soil, is vital for pathogen survival in soil and manure in addition to influencing their transport. Gagliardi and Karns (2000) found that between rainfall events, available soil moisture was adequate to allow *E. coli* O157:H7 to survive. Subsequent rainfall events lead to high *E. coli* growth rates in the soil.

Ultraviolet (UV) light is lethal to bacteria, thus protection from sunlight increases its survivability. *E. coli*, however, exhibits a survival adaptation to visible light by developing progressively dormant viable but nonculturable cells (Barcina et al. 1990).

Temperature is one of the most important factors influencing enteric bacteria survival. Enteric bacteria survive longer at lower temperatures and experience more rapid die-off at elevated temperatures, especially when combined with desiccation (Ferguson et al. 2003). Despite this, higher bacteria levels in streams are typically observed during the warmer months (Edwards et al. 1997).

Extremely high or low pH decreases microbial viability (Hekman et al. 1995). High levels of ammonia generated by decomposing manure also reduce bacteria survival by acting as a biocide. Volatilization of ammonia, which increases with temperature, pH, and wind speed, can reduce this effect.

Once microbes enter streams, their interaction with sediments and the availability of nutrients and organic matter greatly influences their survivability. Coliform die-off rates in water are typically 90% in 3-5 days (Gerba and McLeod, 1976). External sources of nitrogen, however, increase survival of *E. coli* in aquatic environments (Lim et al. 1998). Adsorption to sediment/solids increases survivability by providing protection from inactivation by toxins, UV, and microbial antagonism (Ferguson et al. 2003). Because microbial survival in sediment is typically longer, sediments can serve as both a sink and source of bacteria. Sherer et al. (1992) suggested sediment allowed enteric bacteria to survive for months in an aquatic environment. Sediment-bound fecal coliform die-off rates ranged from 0.010 – 0.023 per day, while sediment-bound fecal strep die-off rates ranged from 0.018 – 0.033 per day. Die-off rates increased as organic matter was exhausted.

As long as microbes stay adsorbed to the sediments, they do not present a public health threat. However, this may not be the case if they are resuspended and released. Changes in river discharge and other disturbances may resuspend sediments and release microorganisms (Ferguson et al. 2003). Disturbance of the sediment, whether by animal traffic or increased stream velocities, resuspends sediment bound enteric bacteria (Sherer et al. 1992). Sherer et al. (1988) observed that 1.8 to 760 million fecal coliform organisms were resuspended when 1 m² of bottom sediments in a stream were disturbed. Thus, the peak fecal coliform concentrations observed in streams during runoff events likely result from a combination of resuspension of sediment-bound bacteria and runoff of bacteria resulting from overland flow (Larsen et al. 1994).

BMPs to Reduce Bacteria Loading

A number of BMPs have been identified to reduce bacterial runoff from grazing lands and direct deposition into streams. The primary focus of these BMPs is to maintain adequate ground cover and minimize concentrated livestock areas, especially on sensitive areas such as riparian areas. Maintaining adequate ground cover and plant density improves the filtering capacity of the vegetation as well as soil infiltration. Minimizing concentrated livestock areas, trailing, and trampling reduces soil compaction, excess runoff, and erosion and enhances fecal matter distribution and ground cover. Concentrated livestock areas can be minimized through grazing management, fencing, alternate water sources, hardened water points, controlled access, supplemental feed placement, and shade or cover manipulation (NRCS 2007).

Pasture/Range Planting

Good ground cover begins with proper establishment and maintenance of range and pasture. Pastures should be kept healthy by applying soil amendments and fertilizer according to soil test recommendations (FCA 1999 and Ball et al. 2002). Good vegetative cover minimizes erosion and runoff (FCA 1999) and pastures lacking a good forage stand are more likely to experience erosion and pollutant runoff problems, especially on steep or erodible land (Ball et al. 2002). Healthy pastures have higher infiltration, which promotes soil filtration and the removal of enteric bacteria during soil passage by sorption/ desorption, inactivation, and predation (Ferguson et al. 2003).

Prescribed Grazing

Proper grazing management is essential to maintaining adequate ground cover and minimizing livestock concentration areas and therefore forms the core of the conservation management system to address bacteria loading from grazing lands. Prescribed grazing is the controlled harvest of vegetation with grazing and/or browsing animals for improved or sustained (1) plant community composition and vigor, (2) forage quantity and quality for grazing and browsing animals' health and productivity, (3) soil condition (i.e. reduced soil erosion), (4) surface and/or subsurface water quality and quantity, and (5) riparian and watershed function (NRCS 2007).

Through careful planning of the duration, frequency, intensity, and season of grazing near surface waters, forages can be maintained or improved while also providing water quality benefits (Larsen et al. 1994) and reduced erosion. Proper grazing management includes (1) balancing animal demand with available forage, (2) distributing grazing evenly, (3) avoiding grazing during vulnerable periods, and (4) providing ample rest after grazing (Fitch et al. 2003).

The correct stocking rate is the most important consideration in grazing management (NRCS 2007) and can impact bacteria levels as well. Stream bacteria levels were found by Gary et al. (1983) to be significantly higher under heavy grazing; however, after reduction or removal of cattle, bacterial counts dropped to levels similar to those in an adjacent, ungrazed pasture.

Cross fencing

Cross fencing is a critical component to proper grazing management. Cross fencing helps manage animal access and grazing pressure on a particular area, providing more efficient use of pastures and healthier range conditions. This management of the timing and frequency of grazing can also impact bacteria levels. Sovell et al. (2000) evaluated the effects of rotational grazing on streams in southeastern Minnesota and learned that fecal coliform levels were consistently higher at continuously grazed sites than at rotationally grazed sites. Rotational grazing reduces frequent congregation of animals in the same area.

Livestock congregation areas and waterbody access areas (i.e. riparian areas) have the greatest potential to contribute pollutants to streams because manure accumulates in these areas and compaction by hoof action increases their runoff (Ball et al. 2002). Riparian areas are those areas adjacent to waterbodies that serve as an interface between the land and stream. In grazing systems, properly functioning riparian areas can serve as vegetative filter strips. A vegetative filter strip is an area of permanent vegetation established to intercept contaminants from runoff before the runoff can enter a waterbody.

Filter strips promote runoff infiltration into the soil, slow water flow thus allowing deposition of suspended solids, enhance filtration of suspended solids by vegetation, and encourage adsorption on plant and soil surfaces (Fajardo et al. 2001). Substantial research has been conducted on the application of vegetative treatment areas to runoff from open lot livestock production areas (Koelsch et al. 2006). Filter strips can be an effective practice for reducing bacteria levels in runoff. An extensive literature review conducted by Koelsch et al. (2006) reported that fecal coliform removal resulting from vegetative treatment areas averages 76%; however, observed bacteria reductions have been variable (Table 3). Both Fajardo et al. (2001) and Dickey and Vanderholm (1981) found that vegetative filter strips did not significantly reduce bacterial contamination.

The observed variability likely results from the development of channelized flow in the filter strip which prevents filtering of all runoff. Channelized flow may develop when the filter strip soils are saturated or when runoff rates are high and cause the hydraulic loading rate to surpass the infiltration capacity of the filter strip. In addition, although filter strips are effective at trapping fine particles, they are less effective at trapping particles less than 0.002 millimeters in size (i.e. clay and bacteria).

Table 3. Filter strip effectiveness in reducing fecal coliform levels.

Fecal coliform reduction	Slope	Buffer Length	Runoff Source	Reference
16%	0.5%	91 m	Feedlot runoff	Dickey & Vanderholm 1981
74%	9%	9 m	Poultry litter on no till cropland	Coyne et al. 1995
43%	9%	9 m	Poultry litter on conv. till cropland	Coyne et al. 1995
70%	4%	36 m	Feedlot runoff	Young et al. 1980

Protection of riparian areas can ensure that the bacterial removal function of these vegetative filter strips is maintained and that fecal matter is not deposited directly into or adjacent to streams and other waterbodies. Evidence suggests that direct deposition of fecal matter by cattle into streams may be of similar or greater importance than fecal matter washed in from land, implying that exclusion of livestock from stream channels may appreciably improve water quality (Nagels et al. 2002). Similarly, Tiedemann et al. (1987) suggested that animal access to streams had a greater impact on in-stream bacteria levels than stocking density. Thus, riparian areas should be protected to reduce manure deposition in or near surface waters (Ball et al. 2002). Practices that can be used to protect riparian areas include fencing, developing shade and alternative watering facilities; and keeping salt, mineral and feeding sites at safe distances (greater than 100 feet) from waterbodies to attract cattle away from waterbodies and evenly distribute grazing (FCA 1999).

Riparian fencing

Riparian fencing involves constructing fence along streams or other waterbodies to limit or eliminate livestock access and create a buffer between grazing areas and waterbodies. A riparian buffer zone may be 30 feet or more with more benefits provided the larger the buffer. Brenner et al. (1991) reported that fecal coliforms were reduced in streams when at least 50% of the riparian zone was intact within 30 meters of the stream channel.

Similar to the findings from vegetative filter strips, Line (2003) found that fencing of streams decreased fecal coliform levels by 66% and *enterococci* levels by 57%. In a 1994 study, Brenner found that exclusion of cattle from streams and restoration of wetlands resulted in a 30% reduction in fecal coliforms. In a 1996 study, Brenner found that stream fecal coliform levels were reduced 41% after flowing through a 6.3 km forested riparian buffer zone. In the same study, Brenner also observed that fecal coliform concentrations were reduced by another 42.5% after the stream flowed through an 88 ha wetland. Brenner (1996) concluded that based on his studies, exclusion of livestock from streams and hydric soils and the restoration and maintenance of riparian buffers and wetlands were effective BMPs. Ball et al. (2002) recommends that where possible, fencing should be used to limit livestock access to streams.

Alternative water supplies

An option to complete exclusion of livestock from riparian areas is the use of alternative water supplies. Alternative water supplies are man-made drinking water sources developed to provide livestock another source of drinking water besides streams. Alternative water supplies can be used alone or in conjunction with riparian fencing to minimize the amount of time livestock spend near surface water sources in riparian areas. To achieve optimum uniformity of grazing and greatest use of alternative water sources, cattle should not have to travel more than 200-300 m to water (McIver 2004).

A literature review conducted by McIver (2004) suggests that alternative water sources alone (without use of exclusion fencing) are 90% effective at keeping livestock out of streams (Table 4). As a result of the reductions in time cattle spent in and near streams, Sheffield et al. (1997) found that stream bank erosion decreased 77%, total suspended solids decreased 90%, total nitrogen decreased 54%, and total phosphorus decreased 81%. McIver (2004) noted however, that an alternative water supply alone will not achieve targeted improvements unless it is implemented in conjunction with good grazing management.

Table 4. Alternative water supply effectiveness.

Reduction in Time Spent in Stream	Reduction in Time Spent near Stream	Percent time cattle drank from trough	Reference
90%			Miner et al. (1992)
85%	53%	73.5%	Clawson (1993)
	75%		Godwin and Miner (1996)
		92%	Sheffield et al. (1997)

Other Practices

Other practices can help better distribute grazing and assist in reducing cattle impacts on riparian areas. Providing livestock with shade structures and properly placing salt, mineral, and feeding sites are other options for reducing livestock congregation in riparian areas and better distributing grazing throughout pastures. Providing a stream crossing (i.e. a stabilized area or structure constructed across a stream to provide a travel way for livestock) can reduce streambank and streambed erosion and improve water quality by reducing sediment, nutrient, organic, and inorganic loading.

Pens and other holding areas should also be placed more than 200 feet away from waterbodies and structural controls, such as grassed waterways, filter strips, sediment traps, retention and detention ponds, and other management practices, should be used as needed to reduce runoff (FCA 1999 and Ball et al. 2002). Structural BMPs modify the transport of pollutants to waterways (i.e. vegetated filter strips/riparian buffers). Providing a clean, unstressful environment for cattle along with good herd management and vaccinations reduces disease susceptibility and proliferation of some pathogens in the rumen and thus the amount of pathogens excreted in the feces (University of Wisconsin 2007a). Careful use of these practices will benefit not only water quality, but will also help meet the objectives of the livestock producer.

Final Word

The applicability of BMPs will vary from location to location as a result of site dependent factors such as soil type, slope, drainage patterns, stocking rate, and management (FCA 1999). In addition, the water quality in streams draining agricultural watersheds may exceed water quality criteria for bacteria at some frequency, even when agricultural activities area at a minimum and BMPs are not needed. Studies reviewed stated time and again that runoff from BMPs such as filter strips may not achieve water quality standards (Clausen and Meals 1989, Fajardo et al. 2001, Dickey and Vanderholm 1981, Coyne et al. 1995, Walker et al. 1990). As a result, Dickey and Vanderholm (1981) recommended that additional research be conducted to accurately define bacterial quality for agricultural runoff and assess the practicality of stream water quality standards. Because of the complexity of the fate and transport of bacteria, much additional research is also needed on the (1) inactivation kinetics of pathogens, (2) partitioning of pathogens among various particle sizes, (3) terrestrial transport and attenuation, and (4) inactivation and sedimentation of pathogens in the aquatic environment (Ferguson et al. 2003).

Evaluation of Proper Grazing Management

Evaluation and demonstration of the effect of grazing management on bacteria runoff is taking place at (1) the USDA-ARS Watersheds near Riesel, (2) the Welder Wildlife Foundation near Sinton, and (3) the Texas A&M University, Department of Animal Science, Beef Cattle Systems Center located west of the TAMU campus on Highway 50, along the banks of the Brazos River between College Station and Snook. Rainfall depth, rainfall intensity, and flow are measured for each event. Turbidity and event mean concentrations for *E. coli* are determined for each runoff event. *E. coli* is analyzed by the Soil and Aquatic Microbiology Laboratory (SAML) using EPA Method 1603 (EPA 2006).

USDA-ARS Watersheds near Riesel, Texas

The USDA-ARS Grassland, Soil and Water Research Laboratory in Riesel, TX, has been one of the most intensively monitored hydrological research sites in the country since establishment in the 1930s (Harmel et al. 2007). It is located in the Blackland Prairie region on the border of Falls and McLennan counties (Figure 1). Houston Black clay soils dominate the region. This soil is very slowly permeable when wet; however, preferential flow associated with soil cracks contributes to high infiltration rates when the soil is dry. Mean annual rainfall is approximately 36 inches. Thirteen runoff stations are in operation on the research site to monitor sub-watersheds under both pasture and cropland management.

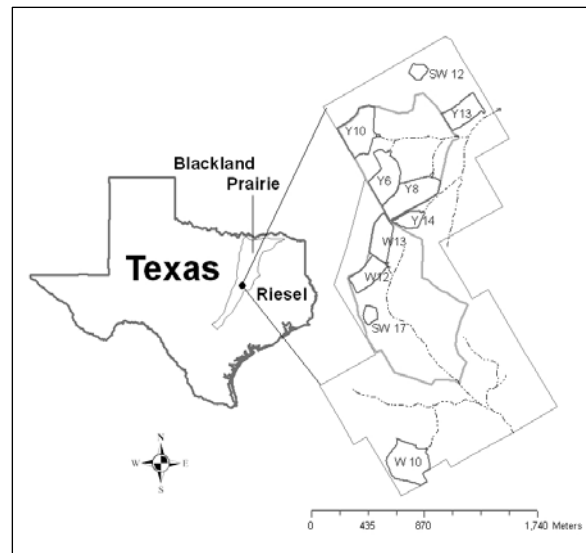


Figure 1. USDA-ARS Grassland, Soil and Water Research Center Laboratory at Riesel.

Two sites are being used to evaluate grazing management, SW12 (2.97 ac) and SW17 (2.99 ac). The average slope of SW12 is 3.8%, while slope averages 1.8% at SW17. Both sites are monitored using 3 foot H-flumes (Figure 2). Site SW12 is an ungrazed native prairie reference site (Figure 2) used for hay production (Harmel et al. 2006b). Site SW17 is a moderately grazed bermudagrass site. Stocking rate at SW17 averaged 4.7 acres per animal unit (AU) between July 2007 and July 2008.



Figure 2. H-flume at site SW17 (left frame). Ungrazed native prairie at site SW12 (right frame).

E. coli monitoring began at Riesel in July 2007. Between July 2007 and July 2008, six runoff events occurred at site SW12 and five runoff events occurred at site SW17 (Table 5). The amount of runoff from site SW12 was almost double that of SW17. The site mean concentration of *E. coli* (i.e. flow weighted concentration) at the ungrazed SW12 (Figure 3) was surprisingly high ($1.0E+04$ cfu/100 ml), greatly exceeding the Texas Surface Water Quality Standards single sample standard for *E. coli* (394 cfu/100 ml) as well as the geometric mean (126 cfu/100 ml). It is important to note that these standards apply to waterbodies, such as streams and reservoirs, but not to edge-of-field runoff as described here. They are noted here for comparative purposes only. Runoff will be diluted after it enters surface receiving waters; thus, the impact of runoff will be less than runoff concentrations suggest (Doran et al. 1981).

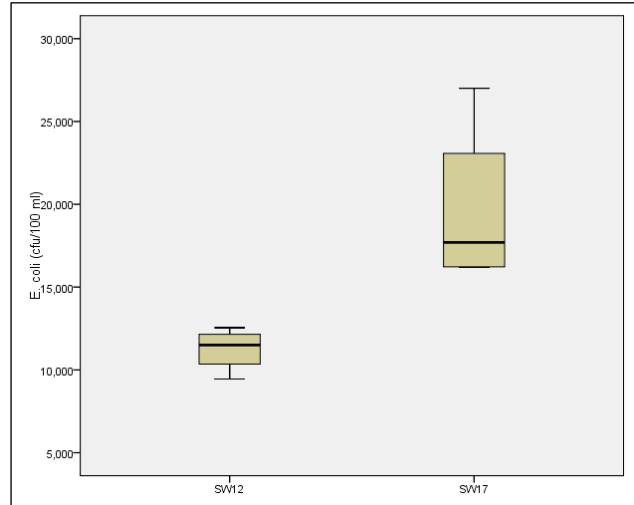
These levels, however, are consistent with published values. According to Overcash and Davidson (1980), background fecal coliform levels can range from $1.5E+01$ to $4.5E+05$ mpn/100 ml. EPA suggests that *E. coli* comprise 63% of the total presumptive fecal coliform concentration (Hamilton et al. 2005). Thus, using Overcash and Davidson's data, we can estimate that background *E. coli* levels range from $9.4E+00$ to $2.8E+05$ mpn/100 ml.

Table 5. Runoff volumes and *E. coli* levels at sites SW12 and SW17 between July 2007-2008.

Storm Date	Site SW12 - Ungrazed			Site SW17 - Moderately Grazed		
	Total Runoff Volume (ft3)	<i>E. coli</i> (cfu/100ml)	<i>E. coli</i> (cfu/ha)	Total Runoff Volume (ft3)	<i>E. coli</i> (cfu/100ml)	<i>E. coli</i> (cfu/ha)
3/6/2008	1666	11250	4.42E+09	1136	16200	4.31E+09
3/10/2008	5666	9450	1.26E+10	1696	16250	6.45E+09
3/18/2008	5066	11750	1.40E+10	2826	19150	1.27E+10
4/10/2008	1666	4600	1.81E+09			
4/17/2008				566	11300	1.50E+09
5/14/2008	10766	12550	3.18E+10	8486	27000	5.36E+10
5/15/2008	4566	4450	4.79E+09			
Total	29395		6.95E+10	14710		7.85E+10

The site mean concentration at the moderately grazed site SW17 was 2.3E+04 cfu/100 ml for the period of July 2007-2008. The *E. coli* concentration seen in the runoff from the moderately grazed bermudagrass site SW17 was significantly higher than that observed at the native prairie site SW12 (Figure 3).

Figure 3. Boxplots of *E. coli* levels (July 2007-2008) at sites SW12 and SW17. (The bottom and top of the box are the 25th and 75th percentile (the lower and upper quartiles, respectively), and the band near the middle of the box is the 50th percentile (the median). The “whiskers” extending from the boxes indicate values between 1.5 and 3 times the interquartile range. The individual points above the “whiskers” are extreme cases with values greater than 3 times the interquartile range.)



The levels at SW17, however, fall well within the range published in current scientific literature (Table 6). Doran et al. (1981) reported that fecal coliform levels from grazed pastures ranged from 1.2E+02 to 1.3E+06 organisms/100 ml. This range converts to *E. coli* levels of approximately 7.6E+01 to 8.2E+05 cfu/100 ml.

Table 6. Bacteria levels in runoff from ungrazed and moderately grazed pastures.

Study	Ungrazed		Moderately Grazed	
	Fecal coliform (cfu/100 ml)	<i>E. coli</i> (cfu/100 ml)	Fecal coliform (cfu/100 ml)	<i>E. coli</i> (cfu/100 ml)
This paper		10,032		22,815
Doran et al. (1981)	13,280	8,366 ¹	113,700	71,631 ¹
Robbins et al. (1972)	10,000	6,300 ¹	30,000	18,900 ¹

¹*E. coli* levels estimated by multiplying reported fecal coliform levels by 0.63.

Welder Wildlife Foundation near Sinton, Texas

The Rob and Bessie Welder Wildlife Foundation, established in 1954, is a non-profit, 501(c)(3) foundation. It is located on a 7,800-acre native wildlife refuge 8 miles north of Sinton, Texas, in the Coastal Bend region of the state (Figure 4). The Welder's research and educational priorities are in the field of wildlife management and conservation and closely related disciplines. This site was selected because (1) it is in the Copano Bay watershed, site of an ongoing bacteria TMDL, (2) three 2.4-ac watershed sites had previously been established to monitor runoff and (3) the foundation was willing to participate.



Figure 4. Welder Wildlife Foundation Entrance on Highway 77 between Sinton and Refugio.



Figure 5. Site WWR-3 on February 26, 2007 prior to initiation of work to refurbish sites.

The three 2.4-ac watershed sites had been established on the Welder by the Texas A&M University Rangeland Ecology and Management Department in 2000 to conduct a study on the effect of shrub management techniques on water quality and quantity on Coastal Bend rangeland. Unfortunately, since the conclusion of that study in 2002, the watershed sites had fallen into disrepair (Figure 5). Instrument housing had become colonized by bees (Figure 6), which significantly delayed installation of the new, updated monitoring equipment.

The Welder is typical of South Texas rangelands. It is located in the transition zone between the Gulf Prairies and Marshes and the South Texas Plains and contains many plants of tropical or subtropical origin. The Welder has never been cultivated and has historically been managed for livestock (Stewart 2003). The three watershed sites are located on chaparral-mixedgrass communities on the east and west sides of Paloma draw, approximately 4 miles from the foundation headquarters. Victoria clay (0-1%) underlay the upper one-quarter to one-third of the watershed sites and Monteola clay (5-8% slopes) underlay the remainder. Both soils are classified as Hydrologic Soil Group D soils.



Figure 6. The sign at the entrance to the Foundation was not kidding (right frame). Bee hives completely filled old sampling equipment housing (left frame).

Each watershed site (Figure 7) is equipped with berms and v-notch weirs to aid in collection and measurement of runoff. At each site, an ISCO bubble flow meter and sampler was installed to measure flow and collect runoff (Figure 8). An ISCO rain gage was installed at WWR-2 to measure rainfall depth and intensity. The ISCO samplers are programmed to collect flow-weighted composite samples allowing determination of event mean concentrations (EMCs) for *E. coli* for each rain event. Site WWR-1 will be ungrazed throughout the study. Site WWR-2 will receive moderate grazing (1 animal unit / 14 acres). Site WWR-3 will receive heavy grazing (1 animal unit / 7 acres).



Figure 7. Welder Foundation Sites.



Figure 8. Installation was not finished in time for this 9/4/07 runoff event at WWR-1 (left frame). ISCO installation began in August 2007 (right frame – site WWR-3).

Considerable work was needed to prepare the sites for this study. During the runoff event on September 4, 2007, it was observed that the berms were not fully functioning. Thus, in November 2007, brush clearing was conducted around the perimeters of each site to improve accessibility and the berms were reconstructed to better control runoff (Figure 9). Fences were also constructed around each site so that cattle grazing could be controlled (Figure 9).



Figure 9. Brush clearing and berm reconstruction at WWR-3 on November 7, 2007 (left frame). Fence construction at WWR-1 on February 13, 2008 (right frame).

Beginning December 1, 2007, cattle were excluded from WWR-1 (the ungrazed site). To date, two grazing treatments have been conducted in WWR-2 and WWR-3. To meet the stocking rate goal of 14 acres/AU on the moderately grazed site (WWR-3) and 7 acres/AU on the heavy grazed site (WWR-2), it was calculated that grazing for a total of 78 animal unit days (AUD) would be needed on WWR-3 and 156 AUD would be needed on WWR-2. From December 1, 2007 through February 13, 2008, both sites were grazed approximately 36 AUD. From April 18 – 28, 2008, WWR-2 received 52.5 AUD grazing and WWR-3 received 30 AUD (Figure 10). Future grazings are planned to meet the target total AUDs.

On May 5, the forage remaining at each site was determined by clipping ten 0.5 square meter frames. The average weight clipped was 88.9 g at WWR-1, 39.4 g at WWR-3, and 12.1 g at WWR-2. This equates to a standing crop of 1586, 703, and 216 pounds per acre, respectively. Monthly measurements of grass height (based on 10 points in each watershed) were initiated in May following the grazing. Grass height (Figure 11) generally follows rainfall (Figure 12).



Figure 10. Grazing on WWR-3.

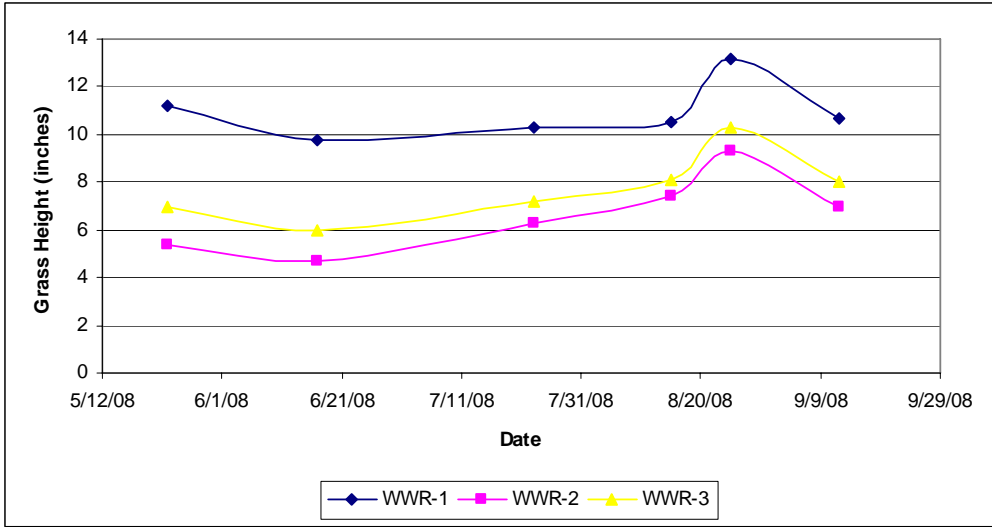


Figure 11. Grass height measurements at WWR-1, 2, and 3.

Unfortunately, no runoff has been collected to date at the Welder Wildlife Foundation since the ISCOs were initialized. Despite two hurricanes hitting the Texas Coast in 2008, only 14.9 inches of rain were received at site WWR-2 between October 30, 2007 (when the ISCOs were activated) and August 31, 2008 (Figure 12). This is well below normal rainfall for this area, which ranges from 25.6 – 31.5 inches.

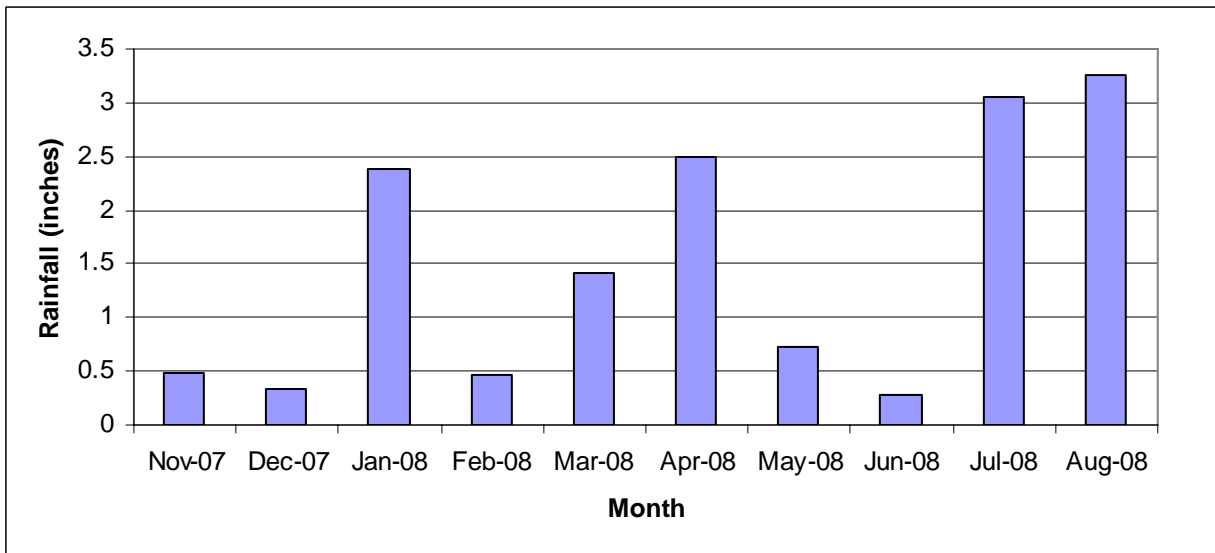


Figure 12. Rainfall at WWR-2 between November 2007 and August 2008.

Monitoring will continue at least through October 2009. Should these drought conditions continue, rainfall simulators will be used to evaluate bacteria runoff from each treatment.

Texas A&M University, Department of Animal Science, Beef Cattle Systems Center

The final site for the evaluation of the effects of grazing management on bacteria runoff is the Texas A&M University, Department of Animal Science Beef Cattle Systems Center. The Beef Cattle Systems Center is located on the west side of the Brazos River between College Station and Snook, right off of Highway 50.

On October 23-26, berms were constructed around each watershed site and slope was modified so that each site would drain to the watershed outlet. Following berm construction, all sites were sprigged with Tifton 85 (Figure 13).



Figure 13. Berm construction (left pane) and sprigging Tifton 85 (right pane) in October 2007.

This site was selected to evaluate intensively managed forages (i.e. irrigated bermudagrass pastures). The site is under a ½-mile center pivot irrigation system (Figure 14), which affords the opportunity to determine the levels of bacteria in runoff water under very intensive management scenarios involving irrigated forages. This site, along with the Welder rangeland assessment, provides a broad spectrum of grazing management for evaluating bacteria runoff.



Figure 14. Irrigating sites after planting.

The site is comprised of Belk clay (0-1% slopes), a heavier-textured alluvial soil found along the Brazos River. As with the other sites being assessed, Belk clay is classified as a Hydrologic Soil Group D soil. Slope averages only 0.2% (Figure 15).

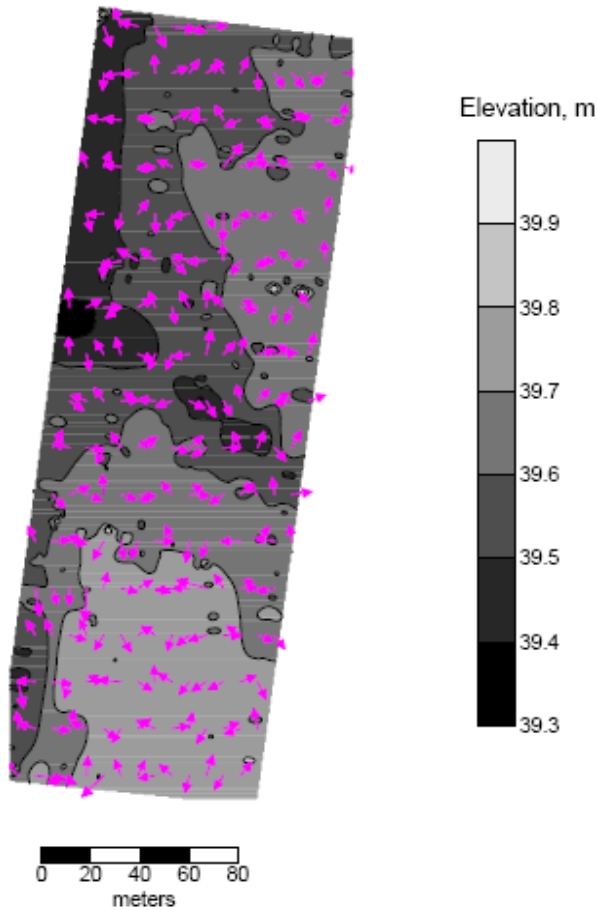


Figure 15. Elevation map of Brazos Bottom watersheds (arrows indicate predicted water flow).

Fence construction and weir installation have been completed; however, monitoring equipment has not yet been installed. Additional work is needed on the weirs as well (Figure 16).



Figure 16. Electric fence and weirs installed on September 15, 2008 (left pane). Seepage under weir following a 4.25" rain from Hurricane Ike (right pane).

Evaluation of Complementary Practices

Evaluation of the effectiveness of alternative water supplies and shade (Figure 17) on cattle behavior and stream water quality (*E. coli*) is being conducted at the 2S Ranch, near Lockhart. An upstream-downstream, before-after BMP-implementation monitoring scheme is being used to evaluate these practices. During the first year (July 2007 – July 2008), no alternative water or shade was provided with the exception of a two week period during January 2008. During the second year (July 2008 – July 2009), alternative water and shade is being provided.



Figure 17. Shade structure prototype.

The inflow (Site PC-1) and outflow (Site PC-2) of Clear Fork of Plum Creek on the cooperating ranch are monitored on the first and third Thursday of each month (Figure 18). Flow depth is also measured to determine flow. Because water sampling occurs on a routine schedule and captures dry and runoff-influenced events at their natural frequency, there will be no prejudice against rainfall or high flow events. A permanent cross section has been established and is measured semi-annually to assess impacts of BMP implementation on streambank stability. In addition, cattle behavior is assessed quarterly to evaluate the impacts of BMP implementation on the percent time that cattle spend within the stream and its riparian zone.

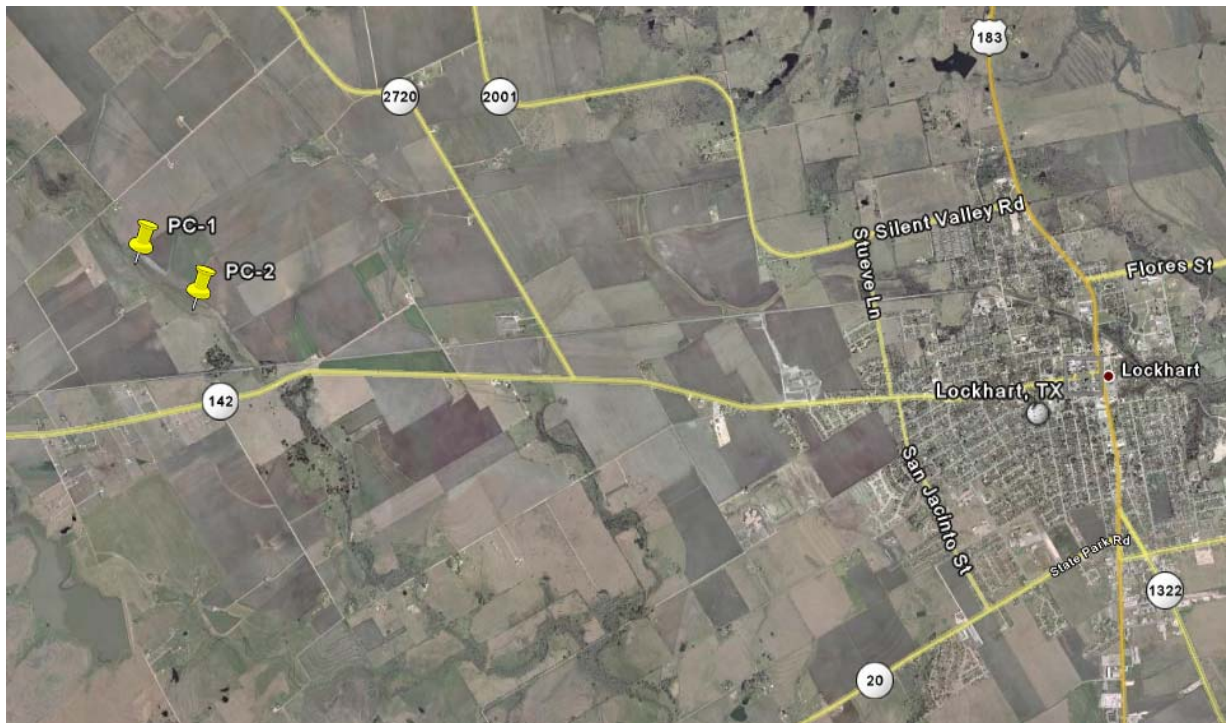


Figure 18. 2S Ranch sampling sites (PC-1 and PC-2) on Clear Fork of Plum Creek.

Evaluation of Pre-BMP Implementation of *E. coli* Levels

The results of the bi-monthly water sampling for *E. coli* levels are shown in Figure 19. For 75% of the sampling dates, the water leaving the property was higher in *E. coli* than the water entering the property. For 33% of the sampling dates, the level of *E. coli* in the water leaving the property exceeded the state single sample maximum water quality standard for primary body contact (394 cfu/100 ml). In comparison, on only 12.5% of the sampling dates did the *E. coli* entering the property exceed the standard.

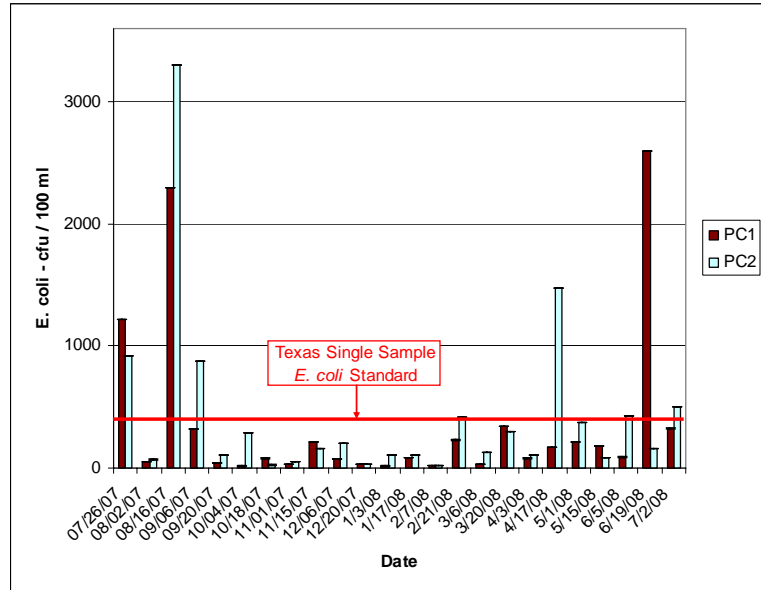
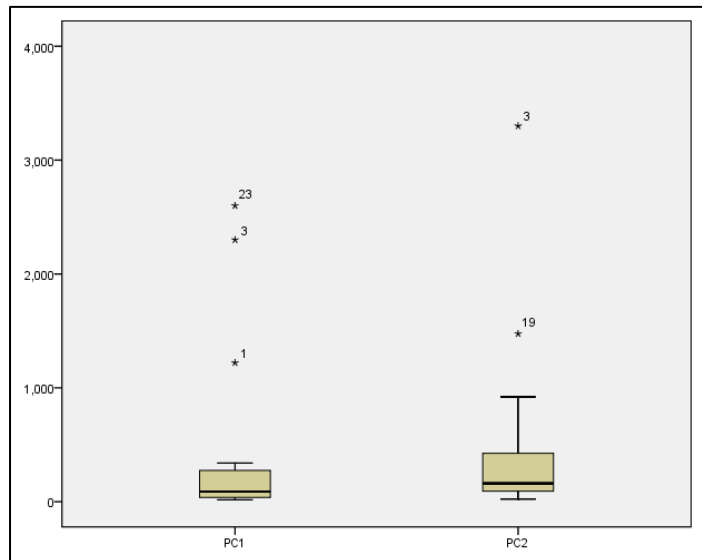


Figure 19. Year 1 *E. coli* levels at sites PC1 and PC2.

The median *E. coli* levels in the creek during year 1 were over 80% higher at the outflow (PC2) than the inflow (PC1). The median year 1 pre-BMP implementation *E. coli* levels were 89 cfu/100 ml at PC1 and 161 cfu/100 ml at PC2 (Figure 20).

Figure 20. Boxplots of *E. coli* levels at PC1 and PC2 during year 1. (The bottom and top of the box are the 25th and 75th percentile (the lower and upper quartiles, respectively), and the band near the middle of the box is the 50th percentile (the median). The “whiskers” extending from the boxes indicate values between 1.5 and 3 times the interquartile range. The individual points above the “whiskers” are extreme cases with values greater than 3 times the interquartile range.)



GPS Tracking of Cattle

Each quarter, cattle at the Clear Fork of Plum Creek cooperating ranch are collared with Lotek® GPS 3300LR collars (Figure 21). Cattle movement is tracked for 21-23 days and then the collars are removed. At a 5 minute fixed schedule, up to 6,624 locations are recorded by each collar each quarter. The percent time the GPS-collared cows spend in close proximity to the stream is shown in Figure 22. On average, cows spent approximately 7% of their time within 50 feet of the stream. Of considerable interest is the January 2008 data.



Figure 21. Installing GPS collars at 2S Ranch.

In January, several calves became ill with bovine respiratory disease and the water troughs were activated for a period of two weeks. It was during this time that the January GPS data was collected. There was a significant ($P < 0.05$) reduction in the time cattle spent in close proximity to the stream (1.75% versus 7%) compared with the other sampling dates. This 75% reduction is consistent with the findings by Godwin and Miner (1996).

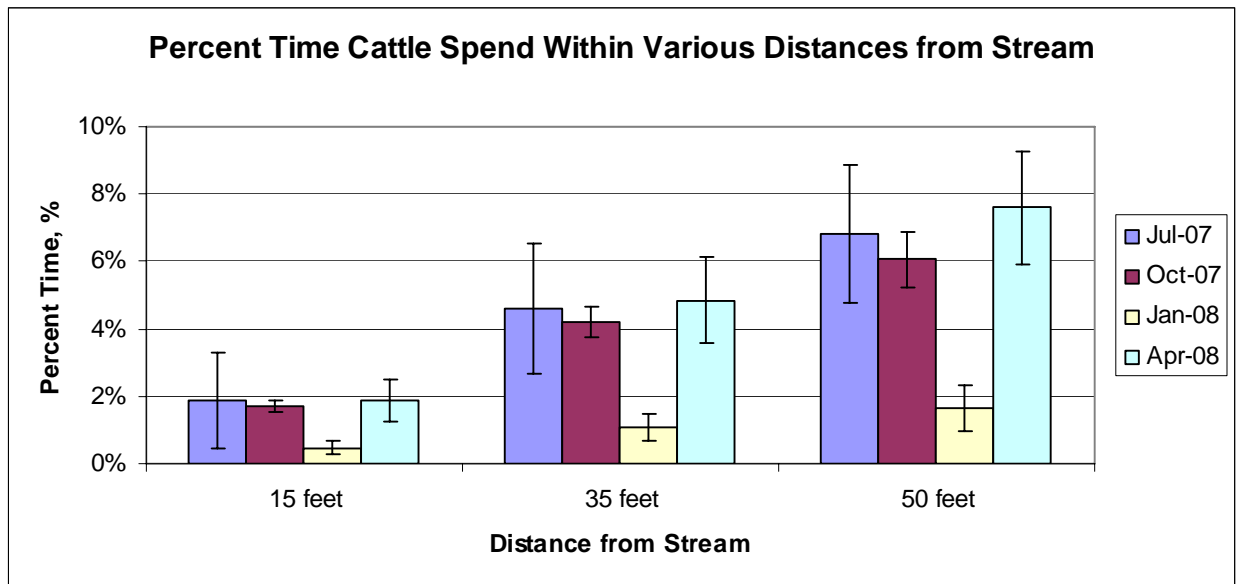


Figure 22. Percent time cattle spent in close proximity of the creek during year 1.

Streambank Stability Measurements

A permanent cross-section was established at the 2S Ranch on Clear Fork of Plum Creek to allow evaluation of changes to streambank stability as a result of BMP implementation. At least semi-annually, a stream cross-section is measured using a laser level in an area used by cattle for crossing located approximately 55 feet above the permanent stream crossing (Figure 23). Between March and July 2008, there was little change in stream morphology as a result of erosion.

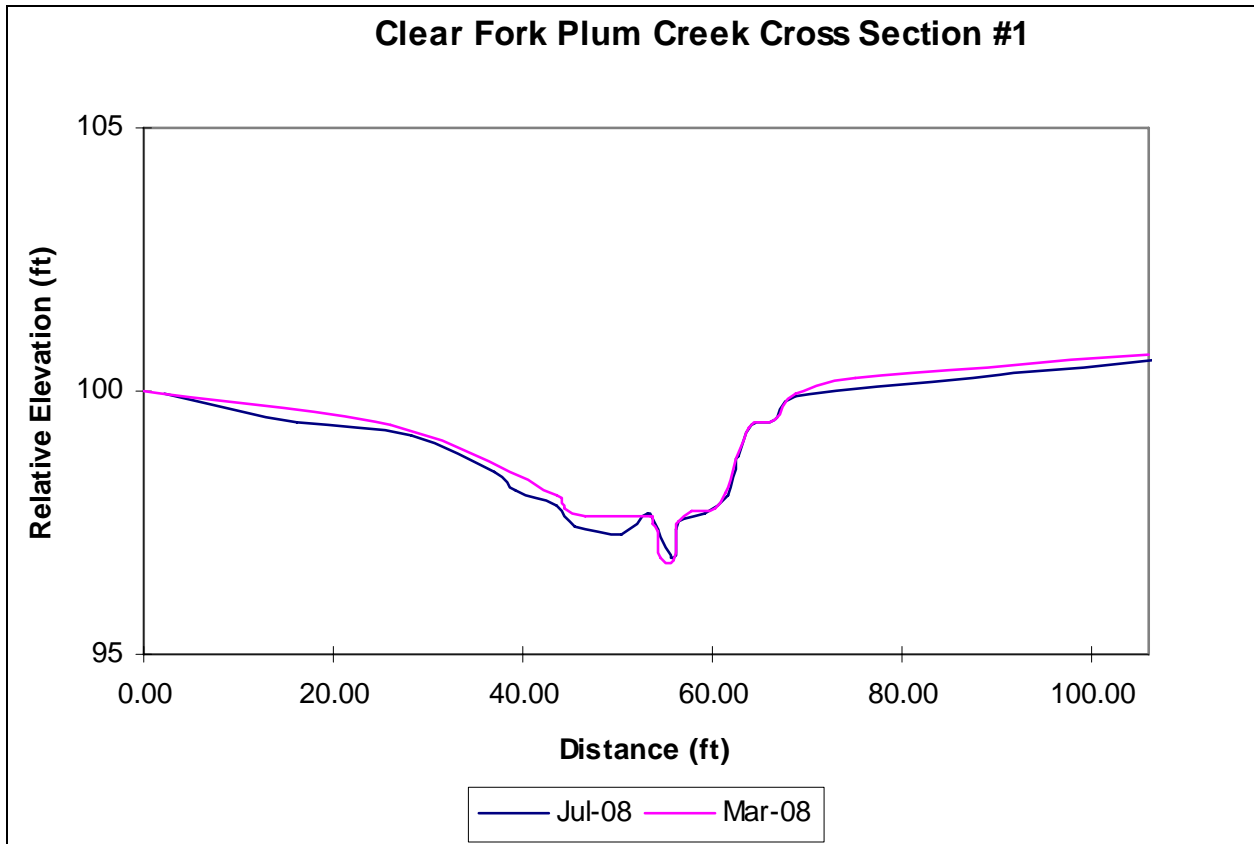


Figure 23. Stream cross-sections measured during year 1.

Technical Transfer

AgriLife Extension and TWRI, in coordination with the TSSWCB, NRCS, local soil and water conservation districts (SWCDs) and other groups, worked diligently to deliver information on the management of grazing lands to address water quality and other natural resource concerns to a wide array of audiences in the state and beyond.

From February 27-31, 2007, the TWRI Project Manager participated in the USDA-CSREES National Water Conference presenting the poster titled “Reducing Bacterial Contamination in Texas Watersheds.” This poster highlighted the efforts of this project and others to reduce bacteria contamination from grazing lands. http://grazinglands-wq.tamu.edu/docs/2007-01-26_NationalWQConferencePoster.pdf

The TWRI Principal Investigator and Project Manager were interviewed by “The Cattleman” magazine on March 13, 2007 for an article on bacteria TMDLs. The article was published in the May 2007 edition. On page 23 of the magazine, the evaluation and demonstration of BMPs conducted by this project was discussed, increasing awareness of bacteria issues. The article can be viewed at: <http://thecattlemanmagazine.com/issues/2007/0507/On%20the%20Ground.pdf>.

A fact sheet titled “Improving Water Quality of Grazing Lands” was also developed by TWRI describing the project’s background, objectives, collaborators, and sources of funding. The fact sheet may be viewed at: <http://twri.tamu.edu/projects/ImprovingWQGrazingLands.pdf>. This fact sheet has been distributed at TMDL meetings for the Copano Bay watershed as well as at meetings of the Lone Star Healthy Streams Steering Committee.

A number of tours have been conducted, the first of which was conducted on April 16, 2007. AgriLife Extension, TSSWCB, and the Welder toured the grazing management evaluation sites at Welder and discussed bacteria issues in Copano Bay and around the state (Figure 24).



Figure 24. Tour of Welder Wildlife Foundation sites on April 16, 2007.

In September 2007, TWRI developed the Web site titled “Improving Water Quality of Grazing Lands” describing ongoing projects evaluating bacteria BMPs and developing bacteria education programs. It can be found at the following address: <http://grazinglands-wq.tamu.edu/index.php>. The Web site was viewed by 539 unique visitors from September 2007 – September 2008 (Figure 25).

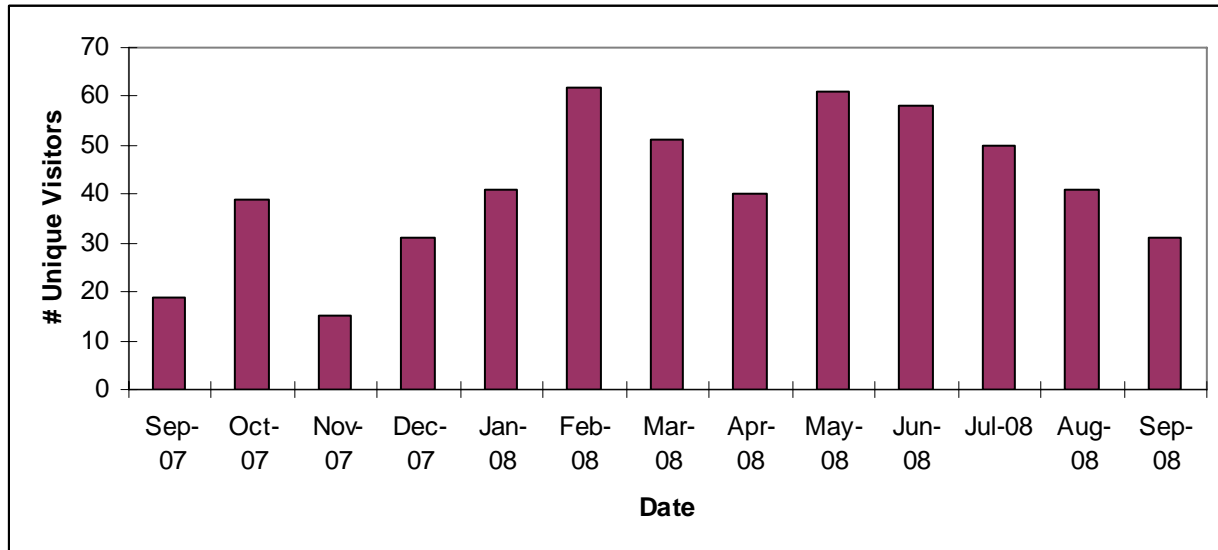


Figure 25. Number of “unique visitors” to *Improving Water Quality of Grazing Lands* Web site.

On November 29, 2007, the project was presented to the Lone Star Healthy Streams Steering Committee. This steering committee is composed of state and federal natural resource agencies, soil and water conservation districts, and leaders in agriculture from throughout Texas (Table 7).

Table 7. Members of Lone Star Healthy Streams Steering Committee.

Name	Organization
Ben Weinheimer	Texas Cattle Feeders Association
Bill Hyman	Independent Cattlemen's Association
Bill Steubing	Rancher (Plum Creek)
Bob McCan	Victoria SWCD
Curtis Scrivner	Hall-Childress SWCD
Daren Harmel	USDA-Agricultural Research Service
Jason Skaggs	Texas & Southwestern Cattle Raisers Association
John Foster	Texas State Soil and Water Conservation Board
Kevin Wagner	Texas Water Resources Institute
Larry Redmon	Texas AgriLife Extension Service
Lynn Drawe	Welder Wildlife Foundation
Mark Mosely	Grazing Lands Conservation Initiative
Ned Meister	Texas Farm Bureau
Richard Eyster	Texas Department of Agriculture
Susan Baggett	USDA-Natural Resources Conservation Service
Terry Gentry	Texas AgriLife Research
Wilson Scaling	Little Wichita SWCD

In the fall of 2007, TWRI featured “Managing Bacteria Pollution in Texas Waters” in the txH₂O. This magazine is distributed to over 2800 water and natural resource professionals throughout Texas and the region. The work of this project and others to address bacteria issues were featured.

On December 2, 2007, information on the project was provided to stakeholders at the Copano Bay TMDL Meeting in Refugio during the poster session prior to the meeting. The following day, on December 3, TWRI coordinated a tour of the Welder and watershed sites of the ongoing evaluation of grazing management being conducted there (Figure 26) for staff from TSSWCB, AgriLife Research, the Welder, and Texas Commission on Environmental Quality (TCEQ.)



Figure 26. Site tour for TSSWCB, TCEQ, the Welder, and AgriLife Research staff.

On January 16, 2008, TWRI presented “Water Concerns in Texas” at the Texas Ag Industries Association Annual Membership Conference. Bacteria issues and the efforts of this project were one of many topics discussed.

During the Farm Bureau Ag Leadership Conference in College Station on January 29, 2008, AgriLife Extension provided a presentation providing information on bacteria issues and this project to those in attendance. On February 6, 2008, TWRI discussed water concerns in Texas with the Texas Farm Bureau AgLead Class VIII, a group of young agricultural leaders from across the state. Bacteria concerns were the primary topic of interest.

AgriLife Extension presented a poster on the project at the Annual Meeting of the Southern Branch of the American Society of Agronomy held in Dallas on February 3-5, 2008.

TWRI provided a presentation on “TMDL and BMP Update” to the Texas and Southwestern Cattle Raisers Association Natural Resource Committee Meeting on March 15, 2008. This presentation was attended by nearly 100 landowners and leaders from throughout Texas including the State Comptroller and former Chairman of the TCEQ. Discussions of this project were a primary focus of this presentation.

Finally, educational programs containing information on the project were provided to audiences in Harris, Victoria, Bosque, McClennan, Hamilton, Coryell, Henderson, San Augustine, and Wharton counties.

Conclusion

Existing publications show the extent and severity to which bacteria from grazing operations affects water quality are a function of (1) the number and size of cattle in the pasture, (2) the location of fecal deposits in relation to waterbodies, (3) site characteristics affecting adsorption and runoff, and (4) bacteria survivability between time of fecal deposition and runoff events. To minimize these effects, a number of BMPs have been identified. The primary focus of these BMPs is to maintain adequate ground cover and minimize concentrated livestock areas, especially on sensitive areas such as riparian areas. Maintaining adequate ground cover and plant density improves the filtering capacity of the vegetation as well as water infiltration rates into soils. Minimizing concentrated livestock areas, trailing, and trampling reduces soil compaction, excess runoff, and erosion and enhances fecal matter distribution and ground cover. Specific BMPs identified include grazing management, fencing, alternate water sources, hardened water points, controlled access, supplemental feed placement, and shade or cover manipulation.

Evaluation and demonstration of the effect of grazing management on bacteria runoff at the Riesel Experiment Station has produced some interesting results. First, the site mean concentration of *E. coli* (i.e. flow weighted concentration) at the ungrazed native prairie site was surprisingly high ($1.0E+04$ cfu/100 ml), greatly exceeding the Texas Surface Water Quality Standards single sample standard for *E. coli* (394 cfu/100 ml) as well as the geometric mean (126 cfu/100 ml). It is important to note that these standards apply to waterbodies, such as streams and reservoirs, but not to edge-of-field runoff as described here. Secondly, the *E. coli* concentration seen in the runoff from the moderately grazed bermudagrass site ($2.3E+04$ cfu/100 ml) was significantly higher (more than double) than that observed at the native prairie site. These levels, however, are consistent with the findings of other researchers.

The pre-BMP implementation evaluation of the effectiveness of alternative water supplies and shade on cattle behavior and stream water quality (*E. coli*) has been completed at the 2S Ranch near Lockhart. This evaluation showed that when alternative water was not available, *E. coli* levels increased as the stream flowed through the ranch. Quarterly evaluation of cattle behavior using GPS collars indicate that cattle spent only around 4% of the time within 35 feet of the stream when alternative water was not available. When alternative water was provided, however, this was reduced to 1%, a 75% reduction. This reduction is consistent with the findings of other researchers. Post-BMP evaluation has been initiated and will continue for another year now that alternative water and shade have been provided.

To increase the awareness of the bacteria issue and possible BMPs for addressing them, AgriLife Extension and TWRI developed fact sheets, provided posters and presentations, conducted site tours, and developed a Web site to help disseminate information. These reached local, state, and national audiences. The Web site alone has reached 539 unique visitors during the project.

Much work remains to be done. Water quality standards should be evaluated in light of the findings of this study, continued evaluation of BMPs is needed, and transfer of this information to cattlemen throughout Texas must continue.

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Appendix

Improving Water Quality of Grazing Lands



Grazing lands are the dominant land use throughout most of Texas. Until recently, little attention was paid in Texas to the effect that livestock grazing on these lands may have on water quality. Bacteria source tracking conducted as a part of the Texas Commission on Environmental Quality's Total Maximum Daily Load program has recently identified cattle as significant contributors of excessive bacteria in several impaired water bodies. Texas has now initiated a major effort to improve the management of grazing lands to reduce nonpoint source pollution.

With an increasing focus on more holistic watershed management, three projects, the *Lone Star Healthy Streams*, *Environmental Management of Grazing Lands* and *Bacteria Runoff Best Management Practices (BMPs) for Intensive Beef Cattle Operations*, are expanding the overall knowledge of beef cattle producers regarding watershed management and measures for reducing bacteria contamination of streams. These projects are a partnership among federal and state natural resource agencies and industry groups.

Project cooperators are testing the effectiveness of a variety of BMPs. Based on this evaluation of BMPs, personnel will develop and test an educational program through *Lone Star Healthy Streams*. After the pilot program, the *Lone Star Healthy Streams* program will be delivered statewide to needed areas.

Implementation of watershed management principles and practices on grazing lands are critical to the success of water resource protection efforts in the state for years to come.

Objectives

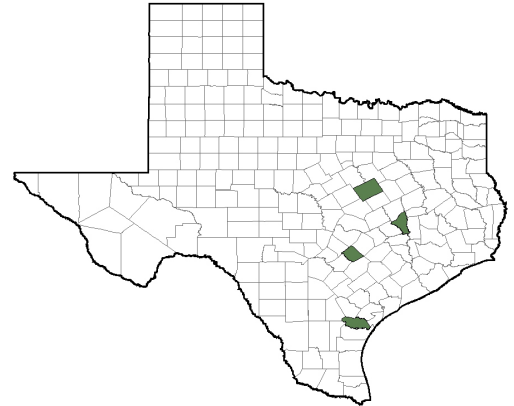
- Evaluate and demonstrate the effectiveness of value-added BMPs in reducing bacterial contamination
- Develop educational curriculum that provides production and environmental management training concerning grazing lands in association with watersheds
- Test and modify education program based on results of pilot program
- Promote statewide adoption of appropriate grazing land management practices

Accomplishments

- Developed project Web site: <http://grazinglands-wq.tamu.edu>
- Initiated grazing management evaluation at Welder Wildlife Refuge and Riesel
- Began alternative water evaluation at 2S Ranch near Lockhart, TX

Collaborators

- Texas Water Resources Institute, Texas A&M AgriLife
- Texas AgriLife Extension Service
- Texas AgriLife Research
- USDA Agricultural Research Service
- Welder Wildlife Refuge

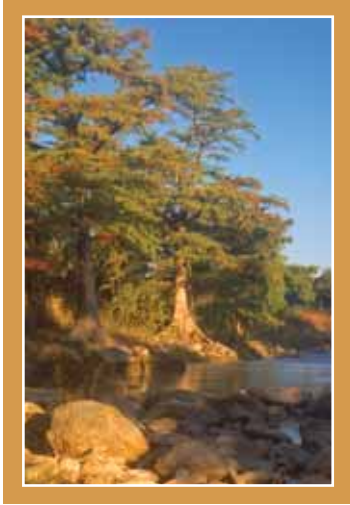


Funding Agencies

- Texas State Soil and Water Conservation Board
- U.S. Environmental Protection Agency
- USDA Natural Resources Conservation Service



On The Ground



Two program managers say practical techniques and personal involvement will influence water quality for the better.

Kevin Wagner, project manager with the Texas Water Resources Institute, knows why livestock producers should be concerned with total maximum daily loads (TMDLs) and bacterial contamination in Texas' water bodies. "Bacteria is the No. 1 cause of water quality impairment in the whole United States," he explains. Wagner works with Dr. Allan Jones and has been actively involved in the work of the task force on bacteria TMDLs formed by the Texas Commission on Environmental Quality (TCEQ) and the Texas State Soil and Water Conservation Board (TSSWCB or Soil Board).

"Why should cattlemen be concerned?" he asks. "Because there are potential requirements that could come out of the TMDL process," that could end up as regulations, he explains.

"I agree with Dr. Jones that at the beginning, right now, we have an opportunity to take care of the problem voluntarily. But, if water quality continues to be a problem and ... we're not taking care of bacterial contamination and non-point source pollution voluntarily, then there's a good

potential for an increasing amount of regulation. The more proactive a stance cattlemen can take, the better," he encourages.

Wagner has several suggestions on what those proactive actions could be. "No. 1, be involved in the water quality standards process. That is one of the biggest issues we have to address.

"If there is a TMDL study going on, participate in those meetings," he says. "The decisions on what direction the TMDL study goes in and what actions are implemented are made at those meetings. If cattlemen aren't there, then they may be the ones

Bacteria is the No. 1 cause of water quality impairment ...

stuck with all work of reducing the daily loads of contamination going into the water."

Wagner says if the TMDL study participants are limited to just urban and agency people, they may find it easier to shift the work to their rural neighbors rather than take on responsibilities themselves. "Cattlemen need to make sure their voices are heard," he stresses.

Brian Koch with the TSSWCB in Wharton agrees. He has seen the stakeholder process at work in developing a plan to address water

quality impairment along part of the Plum Creek Watershed, which runs from Lockhart to Kyle.

Plum Creek is listed on the Texas Water Quality Inventory and 303(d) List as having bacteria impairment from Kyle to Lockhart and nutrient concern for nitrates, nitrites, ammonia and total phosphorous – from Lockhart to Luling.

Koch says the Soil Board and Texas Cooperative Extension-Soil and Crop Sciences have held three initial meetings to introduce the Plum Creek Watershed Protection Plan in April of 2006, in the watershed area, followed by

monthly steering committee or workgroup meetings since then. Word about the meetings was distributed by invitation, news releases in the local papers and a monthly

newsletter Koch publishes on the TSSWCB Web site.

"The Luling paper carried everything we gave them," he says, and *Country World News* published a good deal of information on the meetings, but other local papers were less generous with space for meeting announcements.

"We have met monthly in the watershed since April 2006. We haven't done any bacterial source tracking in Plum Creek yet," he says. "The stakeholders haven't decided that they want to do it

yet.” They are using other methods to research the problem and options for Plum Creek.

“We run everything through the stakeholders, nothing is done without their approval,” Koch explains. “We ran models and showed the stakeholders the results and they gave us their feedback and input,” in which they asked for additional monitoring of water quality. “We’ll put the data from that additional monitoring into the plan,” he says.

Koch doesn’t expect the Plum Creek implementation plan to ever be a finished document. The stakeholders recognize the land use from Lockhart to Kyle will change in the coming years, and expect their implementation plan to be adapted to those changes. “It will be a living plan,” he explains. “If a new issue comes up, we can implement that into the plan and make adjustments as we go.”

Out on the ranch, Wagner says good grazing management “will go a long way toward taking care of a lot of these water quality issues. A lot of the bacteria come from direct deposition into the streams or right along the streams. Anything you can do to minimize that, especially during periods when there is a lot of recreation, is beneficial,” he points out.

Wagner is studying some practical techniques in livestock management to see what impact they have on reducing bacterial loads. One technique is installing alternative water supplies for livestock to draw them away from the creek. “We’re looking at what kind of load reductions you can get from implementing a simple practice like that.” He points out that an alternative water supply is a benefit to any herd at any time because it provides a reliable water supply, particularly during drought.

Wagner is also researching the effects of techniques such as grazing management, adjusting stocking rates, moving mineral feeders to upland areas, and ro-

tating stock out of creek pastures during seasons of active water recreation on water quality.

Wagner and Koch both advocate stakeholder involvement. Early and active involvement helps identify the problem, track the source and choose the techniques to make improvement with cost efficiency and effectiveness in mind.

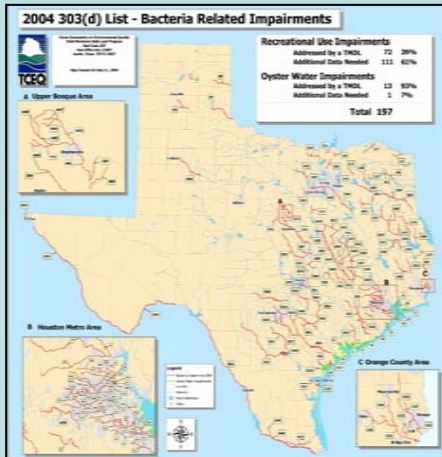
Koch says, “That process of giving the stakeholders a choice, voicing their concerns, eases the process and makes everyone want to work together better.” ■

Reducing Bacterial Contamination in Texas Watersheds

Kevin Wagner, Dr. Terry Gentry, Dr. Larry Redmon, and Dr. Allan Jones
Texas A&M University, College Station, Texas

Bacteria – Texas #1 Water Quality Issue

The leading cause of water quality impairment in Texas and much of the nation is contamination with fecal bacteria from human and animal sources. Currently, 197 Texas waterbodies do not meet bacterial standards established by the state.



Bacteria TMDL Task Force

To address bacterial impairments, Texas is completing TMDLs to restore these waterbodies. To provide guidance to the state on establishment of bacteria TMDLs and implementation plans (I-plans), the Texas State Soil and Water Conservation Board (TSSWCB) and Texas Commission on Environmental Quality (TCEQ) established a seven-member Bacteria TMDL Task Force. This Task Force, was led by Dr. Allan Jones and assisted by an Expert Advisory Group of approximately 50 stakeholders.

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Task Force Recommendations

The Bacteria TMDL Task Force outlined the following recommendations for development of bacteria TMDLs and guide future research. All Task Force documents are available at: <http://twri.tamu.edu/bacteriatmdl/>.

Proposed Three-Tier Approach for Bacteria TMDL Development

Year 1 - Required for all bacteria TMDLs.

Decision 1 (D1) Are data and analysis adequate?
Yes → Go to D2.
No → Go to T2.

Decision 2 (D2) Are needed load reductions socially and economically attainable?
Yes → Complete and submit draft TMDL for agency approval.
No → Request evaluation of designated use (i.e. Use Attainability Analysis).

Year 2 - Implemented for most bacteria TMDLs. May be adequate for I-Plan development for non-controversial TMDLs.

Decision 3 (D3) Are data and analysis adequate?
Yes → Go to D4.
No → Initiate a "phased TMDL" and go to T3.

Decision 4 (D4) Are needed load reductions socially and economically attainable?
Yes → Complete and submit draft TMDL (or I-Plan) for agency approval.
No → Request evaluation of designated use (i.e. Use Attainability Analysis).

Year 3 and 4 - Normally used for I-Plan development. May be required for development of complex "phased TMDLs."

Decision 5 (D5) Are needed load reductions socially and economically attainable?
Yes → Complete and submit draft I-Plan (or revise "phased TMDL") for agency approval.
No → Request evaluation of designated use (i.e. Use Attainability Analysis).

Overview of Identified Research Needs

1. **Quantify bacteria loads from animal / non-animal sources and major land uses**
2. Characterize fate & transport mechanisms (e.g. buildup & mobilization of fecal bacteria from the landscape, dominant environmental factors affecting transport, and effect of sedimentation and resuspension)
3. Enhance bacteria models by improving linkages of BST and modeling and develop spatially-explicit tools to assess bacterial sources, distribute estimated loads, and generate bacterial load input parameters for watershed-scale simulation
4. Investigate & refine library-dependent & independent BST & define appropriate sampling protocols & watershed size for its use
5. **Determine effectiveness of agricultural & urban control measures & BMPs**
6. Quantify uncertainty & develop means to communicate uncertainty to stakeholders

Addressing Bacteria From Grazing Lands

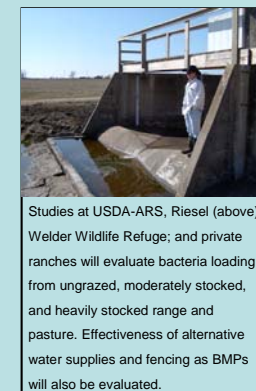
Bacteria source tracking completed in conjunction with several TMDLs has identified grazing cattle as a significant source of bacteria loading. Grazing lands, which represent the dominant land use in the majority of watersheds in Texas, have received little attention until now regarding the effect of grazing livestock on water quality. Implementation of watershed management principles and practices on grazing lands will be critical to the success of water resource restoration and protection efforts.



Education and Assessment of BMPs

Landowner education and voluntary adoption of BMPs are needed to reduce bacteria contamination of waterbodies as well as the likelihood of increased regulatory oversight of production. To develop science-based Extension education programs, evaluation of the effectiveness of grazing management and complimentary practices such as providing alternative water supplies and fencing is needed to provide producers the information necessary for making sound management decisions.

Projects Addressing Grazing Lands



Studies at USDA-ARS, Riesel (above); Welder Wildlife Refuge; and private ranches will evaluate bacteria loading from ungrazed, moderately stocked, and heavily stocked range and pasture. Effectiveness of alternative water supplies and fencing as BMPs will also be evaluated.

Three projects are being implemented to evaluate the effectiveness of BMPs in reducing bacteria runoff and to develop and deliver education programs to cattle producers and other livestock owners. Initial funding for these activities was provided by the TSSWCB and USDA-NRCS through the (1) *Environmental Management of Grazing Lands* project. The bulk of the funding is provided by the TSSWCB and EPA with CWA 319(h) funds. The (2) *Lone Star Healthy Streams* program and (3) *Education Program for Improved Water Quality in Copano Bay* are currently being initiated and expected to be completed in 2009.

Introduction

According to the *DRAFT 2006 Water Quality Inventory and 303(d) List*, 306 water bodies are impaired in Texas with a total of 419 impairments (Fig. 1). Of these, approximately half of the impairments are due to excessive bacteria.

Bacterial source tracking work in a number of water bodies has identified a contribution from grazing cattle to the bacteria loading of these streams. Grazing lands, which represent the dominant land use in the majority of watersheds in Texas, have received little attention until recently regarding the effect of grazing livestock on water quality. Thus, implementation of watershed management practices on grazing lands are critical to the success of water resource protection efforts in the state.

Landowner education and voluntary adoption of best management practices (BMPs) could substantially reduce bacterial contamination of streams and water bodies and reduce the likelihood of increased regulatory oversight. The Texas State Soil and Water Conservation Board (TSSWCB), local Soil and Water Conservation Districts (SWCDs) and the USDA-NRCS support producers through technical assistance and cost-share programs enabling implementation of BMPs. For such measures to be effective, however, they must be properly implemented and managed to ensure sustainability. In addition, these practices must be compatible with the overall management system and not result in additional economic burden to agricultural producers.

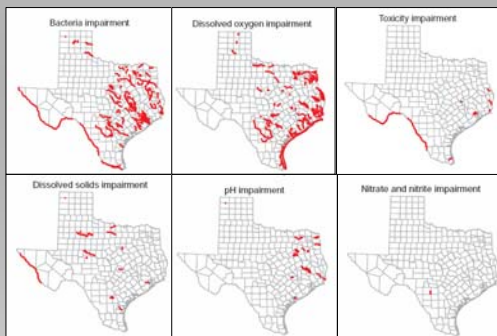


Figure 1. Water quality impairments in Texas, 2006, TCEQ.

Objectives

The goal of *LONE STAR HEALTHY STREAMS* is to reduce levels of bacteria in Texas watersheds from grazing beef cattle (Fig 2). This goal will be accomplished by:

- Developing an educational curriculum delivering current knowledge in production and environmental management of grazing lands and their associated watersheds,
- Evaluating and demonstrating effectiveness of value-added BMPs in reducing bacteria of streams in a pilot watershed,
- Testing the functionality of the education program and making necessary changes and program modifications based on the results of the pilot project,
- Promoting Statewide adoption of appropriate BMPs and other watershed/water quality protection activities through education, outreach and technology transfer.

General Project Description

This project is funded with 319 funds provided by the TSSWCB and will be a partnership among the primary federal and state agencies that interface with beef cattle producers relative to environmental management.



Figure 2. Management strategies and educational programs are needed to reduce bacteria levels in water bodies due to grazing livestock.

Among the main partners, AgriLife Extension's role in the project will be to assess and compile current knowledge regarding BMPs that protect grazing lands watersheds from bacteria contamination, demonstrate and evaluate value-added BMPs in the pilot watershed, and determine the efficacy of the BMPs. Texas Water Resources Institute will be responsible for project management and making timely reports to TSSWCB and EPA.

A Project Steering Committee providing input into curriculum development and program delivery will be established that includes representatives from:

- Texas State Soil and Water Conservation Board,
- Soil and Water Conservation Districts,
- USDA-NRCS and Farm Services Agency,
- Texas Water Resources Institute,
- Texas AgriLife Extension Service,
- Texas AgriLife Research,
- Texas Department of Agriculture,
- Grazing Lands Conservation Initiative,
- Other state and federal agencies as appropriate,
- Representatives from key commodity groups including:
 - > Texas Farm Bureau,
 - > Texas and Southwestern Cattle Raisers Association,
 - > Independent Cattlemen's Association of Texas.

Additionally, local producers will be asked to serve on the Project Steering Committee.



The BMP evaluated during the first project will be an alternative water source. Extension will assess effects of this BMP on cattle behavior, bacteria levels, and other water quality parameters (e.g. nutrients and sediment), and the economic impact for beef cattle producers.

Based on results of the initial education program and BMP demonstration/evaluation in the pilot watershed, an educational program will be developed and delivered state-wide to grazing lands owners and managers to bring heightened awareness of the issue regarding bacteria contamination of watersheds by grazing animals and to encourage adoption of BMPs designed to reduce bacterial loading to Texas streams and water ways.

Results to Date

Beginning in July 2007, twice-monthly sampling of a perennial stream in an impaired watershed began. Water to existing troughs was turned off, thus forcing existing cattle to water in the stream. Water both entering and exiting the project ranch was sampled for *E. coli*. Results thus far for *E. coli* levels are shown in Figure 3. Also in July 2007, random cattle in the project herd were fitted with GPS collars for three weeks to document movement patterns. Data points were collected every five minutes to attempt to determine cattle movements. Cattle were subsequently re-collared during October 2007 and January 2008.

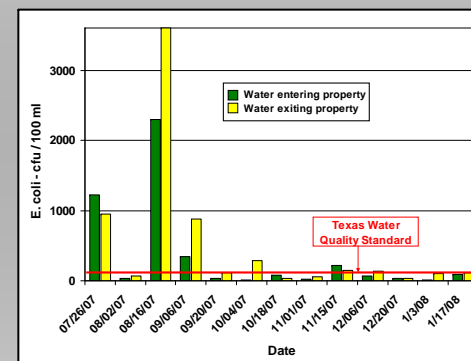


Figure 3. *E. coli* levels entering and leaving project grazing management unit.

GPS data for July and October has indicated that, although cattle are being forced to water in the project stream, only 6.8% and 6.1% of the cattle's time was spent within 50' of either side of the stream for July and October, respectively. Once YR 1 benchmark data is obtained, water to the troughs will be made available and water sampling for *E. coli* and GPS data describing cattle behavior will be repeated to determine the value of alternative water development in altering cattle movement away from the stream. Additional information will be obtained in YR 3 to validate the first two years of results.

Summary

AgriLife Extension education programs are designed to target specific audiences and to deliver current, unbiased, science-based information and technology. With an increasing focus on more holistic watershed management, however, there is an opportunity for AgriLife Extension personnel to use the *LONE STAR HEALTHY STREAMS* Program as a vehicle to expand the overall knowledge base of beef cattle producers regarding watershed management and BMPs for reducing bacteria contamination of streams. Through linkages with existing programs, the burden on producers and County Extension faculty could be minimized, while the knowledge base and potential for producers to participate in, and ultimately affect changes in watershed protection, could be realized.

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A Project to Reduce Bacteria in Texas Waterways: Lone Star Healthy Streams

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Introduction

According to the *DRAFT 2008 Water Quality Inventory and 303(d) List*, 386 water bodies are impaired in Texas (Fig. 1). Of these, approximately half of the impairments are due to excessive bacteria.

Bacterial source tracking work in a number of water bodies has identified a contribution from grazing cattle to the bacteria loading of these streams. Grazing lands, which represent the dominant land use in the majority of watersheds in Texas, have received little attention until recently regarding the effect of grazing livestock on water quality. Thus, implementation of watershed management practices on grazing lands are critical to the success of water resource protection efforts in the state.

Landowner education and voluntary adoption of best management practices (BMPs) could substantially reduce bacterial contamination of streams and water bodies and reduce the likelihood of increased regulatory oversight. The Texas State Soil and Water Conservation Board (TSSWCB), local Soil and Water Conservation Districts and the USDA-NRCS support producers through technical assistance and cost-share programs enabling implementation of BMPs. For such measures to be effective, however, they must be properly implemented and managed to ensure sustainability. In addition, these practices must be compatible with the overall management system and not result in additional economic burden to agricultural producers.

Materials and Methods

A perennial stream segment, the Clear Fork of the Plum Creek, in Caldwell County, TX, was selected to evaluate alternative water sources as a relevant BMP that could reduce the time grazing livestock spend in or near riparian areas. The Clear Fork, as well as Plum Creek, are listed on the state of Texas 303(d) list as impaired due to bacteria.

Water to existing water troughs was terminated to force the cattle to obtain water from the stream segment. Water samples from the stream segment were then obtained twice monthly. One sample was obtained where the creek entered the cooperating landowner's property and a second sample was obtained just as it left the landowner's property. Water was analyzed for *E. coli* and expressed as colony forming units per 100 ml of water.

Concurrently, during the middle of each season of the year (summer, autumn, winter, and spring), eight randomly selected beef cows residing on the property were fitted with GPS collars (Fig. 2). The collars remained on the cows for approximately 21 days. Data points regarding the location of each cow was collected each five minutes. The data was analyzed to determine how much time the cows spent within close proximity to the stream.



Figure 2. Fitting GPS collars to cattle to evaluate behavior and movement patterns.

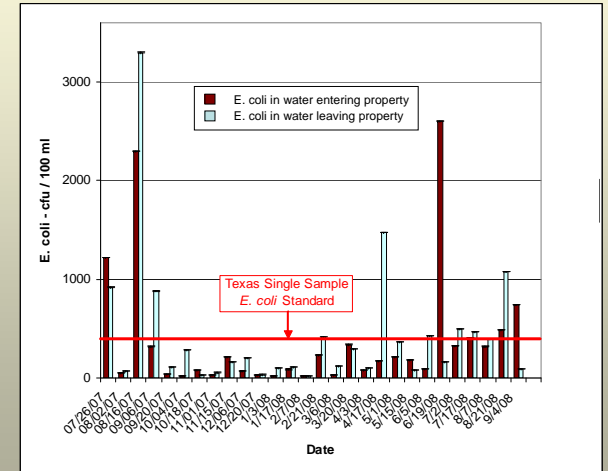


Figure 3. *E. coli* levels entering and leaving the project unit.

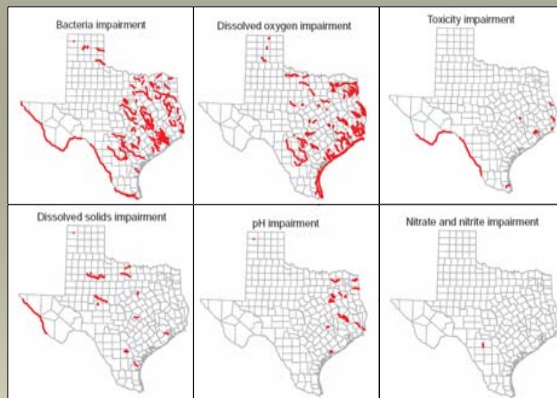


Figure 1. Water quality impairments in Texas, 2008, TCEQ.

The goal of *LONE STAR HEALTHY STREAMS* is to reduce levels of bacteria in Texas watersheds from grazing beef cattle (Fig 2). This goal will be accomplished by:

- Developing an educational curriculum delivering current knowledge in production and environmental management of grazing lands and their associated watersheds,
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Funding for this project was provided by the TSSWCB with EPA 319 funds.

Results

Levels of *E. coli* from the twice-monthly water sampling are shown in Figure 3. For 32% of the sampling dates, the level of *E. coli* in the water leaving the property exceeded the state standard for contact. For 79% of the sampling dates, the water leaving the property was higher in *E. coli* levels than the water entering the property. The time the GPS-collared cows spent in close proximity to the stream is shown in Figure 4. On average, cows spent approximately 7% of their time within 15 m of the stream.

Of considerable interest is the January 2008 data. Several calves became ill with bovine respiratory disease. In order to entice the cattle to the working pens where they could be medicated, the water troughs were activated. It was during this time the January GPS data was collected. There was a significant ($P < 0.05$) reduction in the time cattle spent in close proximity to the stream (1.75% versus 7%) compared with the other sampling dates. This may indicate the effectiveness of altering cattle movement away from riparian areas using alternative water sources.

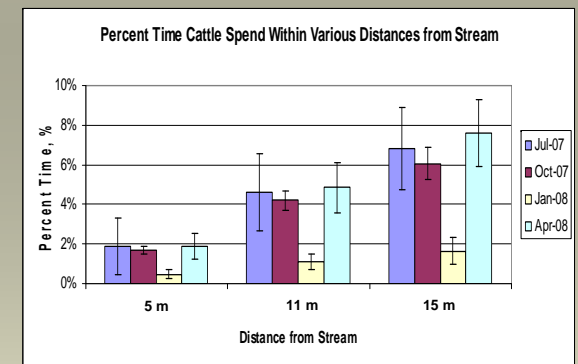


Figure 4. *E. coli* in water leaving property

Summary and Future Efforts

During July 2008, water to the troughs was made available on a continuous basis and water samples for *E. coli* continued to be obtained on a twice-monthly basis from the stream segment. Likewise, cattle movement and behavior patterns are continuing to be monitored using GPS collars. Year 2 data will be contrasted with Year 1 data to determine the efficacy of the presence of alternative water sources on reducing the time cattle spent near the riparian area. We will also contrast the difference between Year 1 and Year 2 in *E. coli* values obtained from the stream. If the alternative water source provides the same dramatic decrease in time spent near the stream as was observed for the January 2008 sample date, the data may serve to validate the use of alternative water sources as a proactive measure with which beef cattle producers may use to reduce *E. coli* levels in Texas waterways. Additional BMPs need to be evaluated in the same manner.

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