# OFF-STREAM WATER SOURCES FOR GRAZING CATTLE AS A STREAM BANK STABILIZATION AND WATER QUALITY BMP

by

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Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Biological Systems Engineering

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April, 1996
Blacksburg, Virginia

Key Words: Off-Stream Water Sources, Water Quality, Erosion, Cattle Behavior, BMP

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(ABSTRACT)

A study was conducted in order to evaluate cattle behavior, stream bank erosion and water quality due to the installation of off-stream water sources for grazing cattle as an alternative to stream bank fencing. The study was located on two commercial cow-calf operations in southwest Virginia which utilized rotational grazing. The presence of an off-stream water source for grazing cattle greatly reduced the negative impact which grazing cattle have upon stream bank erosion and water quality. Field observations of cattle behavior indicated that cattle preferred to drink from an off-stream water source over that of an adjacent stream 92% of the time. The installation of an off-stream water source reduced the total time which cattle spend within the stream area by 58% and the amount of stream bank erosion by 76%.

Due to the installation of off-stream water sources, concentrations of total suspended solids, total nitrogen, ammonium, sediment-bound nitrogen, total phosphorus and sediment-bound phosphorus, were reduced by 90%, 54%, 70%, 68%, 81% and 75%, respectively. Concentrations of fecal coliform and fecal streptococci decreased by 51% and 77% when an

off-stream water source was available for grazing cattle. Lastly, an economic analysis of the data indicated that the cost of developing off-stream water sources was considerably less than that of implementing six fenced stream bank buffer zone scenarios on the two farms.

# Dedication

It is only appropriate that I dedicate this thesis to three conservationists, Tom Greene, Frank Shrader and T. "Tap" Weddle, who conceived the idea for this research. Each of these men are shining examples of the many federal, state and local government employees who work diligently every day to protect our nation's resources.

## Acknowledgments

Thanks must first be extended to the farm owners who agreed to have this research conducted on their farms; Dan and Liz Bender of Floyd, VA and Phillip and Charlotte Hanes of Winston-Salem, NC. Special thanks must also be given to Tim Caudill, manager of the River Ridge Cattle Corporation. Tim was not only an ideological ally in this project, but he also did his best to teach me about cattle production and driving across pastures in springtime. Thanks is also extended to the Virginia Department of Conservation and Recreation and the Winston-Salem Foundation for their financial support of this project.

I would like to thank the members of my committee, Saied Mostaghimi, David Vaughan, Vivien Allen and Eldridge Collins. Each could endure the many crises I had when I descended upon their office. I would especially like to thank Saied Mostaghimi for his financial support during my graduate studies and the numerous revisions of this thesis (I believe I owe him a new red pen). I would also like to thank the following graduate students whom I either tricked, coerced or begged into going out and playing with the cows with me; Clay Brumback, Mark Dougherty, Joe Frazee, Sheeram Indamar, Jamie Lowery, and Gangling Ren.

Lastly, I would like to thank my loving and patient wife, Juliana. She has been steadfast in her understanding of how stressed and distant I became often working on this thesis. Juliana

is also a decent surveyor, if someone needs an extra hand. I will warn you; you have to really watch to keep her from running off and trying to pet a calf.

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# I. Introduction

Agriculture has been cited as the largest contributor to our nation's nonpoint source pollution problem by the U.S. Environmental Protection Agency (U.S. EPA, 1976). In many regions of the United States, pastureland for cattle is one of the most dominant agricultural land uses. In the Appalachian foothills, many of these pasturelands are on steep slopes and have streams lying within them. Landowners have traditionally allowed cattle to use these streams as a direct source of water. In many situations, this traditional practice has had a detrimental impact on the quality of downstream water bodies.

The impact of cattle on streams has been the focus of attention for local citizens' groups and many federal and state agencies. Efforts have been made to evaluate the impact of cattle on riparian vegetation (Hary and Medin, 1990), terrestrial wildlife (Medin and Clary, 1989), downstream fisheries (Hubert et al., 1985) as well as stream stabilization (Buckhouse et al., 1981; Marlow et al., 1987). Most of these studies, however, were conducted on western public lands on which cultural and grazing practices, stocking rates, pasture size, and environmental conditions differ greatly from those existing in the mountainous regions of the eastern United States.

There are few economically and environmentally sustainable alternatives for landowners who water cattle in streams. Fencing cattle from streams has been suggested by Skovlin (1981), Platts and Wagstaff (1984), Davis (1981) and others when considering the downstream impact of beef and dairy production. Due to the great spans of floodplains and the patterns in which streams meander through the Appalachian countryside, fencing off these areas will severely decrease the current area available to cattle production and stream bank fences will be prone to damage or removal by seasonal rains on higher order streams. The loss of available grazing land and production, and the cost of fencing materials and repairs, may drive many existing landowners to shift their mode of production or to leave agricultural production entirely.

The availability of a water trough was shown by Miner et al. (1992) to decrease the time cattle spent in streams by 90 percent. Although not documented, Miner et al. (1992) hypothesized that the decreased time in stream should relate to a reduction in loadings of fecal bacteria. Due to surface runoff (Schepers and Francis, 1982) and the suspension of fecal bacteria in sediment (Sherer et al., 1992), this hypothesis may not be true. Also in the study by Miner et al. (1992), conducted in Oregon, interactions of heat, humidity, escape from flies and possible fescue toxicosis were not investigated in evaluating the effectiveness of the trough in decreasing time in stream or improving water quality.

The present study undertook a multidisciplinary approach to investigate the interactions of stream bank erosion, water quality, cattle behavior, and economics, on a farm scale, to test the effectiveness of providing cattle with an off-stream water source as a stream stabilization and water quality Best Management Practice (BMP). The impact of cattle on three headwater streams was investigated on two commercial cow-calf operations in southwest Virginia.

The impact of providing cattle with an off-stream water source was evaluated within the respective farm's normal method of operation. No efforts were made by the investigators to influence stocking density, grazing pressure or animal well being. However, the farm operators consulted with investigators when decisions potentially affecting the current research needed to be made. Headwater streams were chosen to be investigated over larger order streams in an attempt to decrease interactions of stream scouring and the use of the stream as a cooling or bathing mechanism by the grazing cattle.

This study hypothesizes that if the presence of off-stream water sources is successful in attracting cattle away from streams, then stream bank damage should be less than those systems that rely on stream access as the sole water source. Also, if water quality improves during the periods when the water trough is provided, this will indicate that the reduction in feces being directly deposited into the stream is related to the cattle preferring to drink from the trough and not from the stream. Thus, providing cattle with an off-stream water source will bring about an environmental benefit, as well as water for cattle. The stated hypothesis also suggests that water troughs, through spring developments or other methods, serve as a more cost-effective method of decreasing stream bank erosion and improving water quality than the implementation of fenced stream bank buffer zones. In a time when many eastern cattle producers are concerned that stream bank fencing may be presented as a mandated watershed management practice, the economic and environmental sustainability of alternative practices such as "Water troughs as BMPs" must be investigated.

## Goal and Objectives

The overall goal of this study was to evaluate the feasibility of using water troughs as a Best Management Practice (BMP) in reducing erosion, nutrients and bacteria from pasturelands. This goal was achieved through the accomplishment of the following objectives:

1. Compare the behavior of cattle using streams as a primary water source to those which have access to streams as well as too off-stream water sources.

2. Estimate and compare stream bank erosion in pasture systems using rotational stocking where streams are and are not utilized as the primary water source.

3. Estimate and compare stream nutrients, fecal bacteria and mineral concentrations from pasture systems where streams are and are not utilized as the primary water source.

4. Contrast the environmental impacts and economic costs and benefits of installing a spring and water trough system as an environmentally sustainable BMP to foster stream bank stabilization and improve water quality, as compared to traditional and proposed practices.

# II. Literature Review

## Overview

Cattle grazing is synonymous with the American culture. Colonists brought cattle from the Old World and started a long tradition of beef and dairy production in our country. Yet, today many cattle producers are threatened by legislation which may change their livelihood. Fencing streams has emerged as a miracle remedy to cure the ills which cattle production causes upon our water resources. As honest and credible stewards of our land and water, we must fully understand a certain agricultural practice before accepting such a conservation management strategy. Otherwise, the strategy will strike a larger impact upon our nation's heritage and economy, rather than improving environmental quality.

The impact of grazing cattle on water quality is of considerable importance to water quality management agencies (Miner et. all, 1992) across the country. The fact that grazing cattle do have an impact on streams is undisputed. However, the extent of their impact on vegetation, wildlife, stream bank integrity and water quality is highly disputed.

This chapter presents research that was conducted to quantify the impact of grazing cattle on stream bank stability and erosion, nutrient and bacteriological loading, especially total and fecal coliforms as well as fecal streptococci. Special emphasis is placed upon observations of cattle behavior. Efforts were made to describe behaviors which were observed in different systems, and the implications that these observations have upon improving riparian zone and water quality management. Effects of forage quantity and quality on cattle utilization of riparian vegetation were also described. Lastly, research focusing on excluding cattle from streams as well as other alternatives and the economics of mandated stream fencing are discussed.

## Grazing Management

Before investigating the effects of cattle on stream bank stability and water quality, it is appropriate to discuss many of the definitions and descriptions of various grazing management methods and strategies used in the studies discussed in this literature review. It is important to understand the systems in which various conclusions are presented in order to fully understand the impact of cattle on riparian resources. Emphasis will be placed on the comparison of continuous and rotational stocking methods, then the issues concerning stocking intensities will be discussed.

Grazing system refers to a defined, integrated combination of animal, plant, soil, and other environmental components and the grazing method(s) by which the system is managed to achieve specific results or goals (Allen, 1991). Allen (1991) stresses that the description of the grazing system should include certain information, including: number, kind, slope, erosion status, and soil classification of land units; number, kind, sex, size, and age of livestock; duration of use and non-use periods for each unit in the system; grazing method(s); type(s) of forage; geographic location and elevation; type of climate, mean annual and seasonal temperatures; and precipitation.

A grazing method is the manner in which the livestock are manipulated. Allen (1991) defines it as a procedure or technique of grazing management designed to achieve a specific objective(s). Vallentine (1990) describes grazing management as the manner in which grazing and nongrazing periods are arranged within the maximum feasible growing season, either within or between years. The major difference between a "grazing system" and a "grazing method" is that a grazing system is a site-specific description of grazing operation, while a grazing method is a tool which can be used, regardless of location (i.e. across systems) to perform a certain task.

Several grazing methods have been investigated for their potential to alleviate certain impacts caused by grazing including; continuous stocking; rotational stocking; rotational deferment; deferred-rotation; rotational rest; rest-rotation; high intensity, low frequency (HILF); short duration; and mob grazing. Definitions, descriptions and comparisons of these grazing method are given in the following paragraphs:

**Continuous Stocking** *is a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout "a defined grazing" period when grazing is allowed* (Allen, 1991). Continuous stocking is not synonymous with no management or livestock neglect. For many forages and environments the partitioning of the grazing management unit is not necessary in order to achieve certain goals within a defined use period.

**Rotational Stocking** *is a grazing method that utilizes recurring periods of grazing and rest among two or more paddocks in a grazing management unit throughout the period when grazing is allowed* (Allen, 1991). The lengths of grazing and of the rest periods should be defined for each paddock within the grazing management unit. Grazing methods such as rotational deferment, deferred-rotation, rotational rest, rest-rotation, high intensity, low frequency (HILF), short duration, and mob grazing are modifications of the general understanding of rotational stocking.

**Rotational Deferment** *is a multipasture unit method in which deferment is scheduled among the respective pasture units on a rotating basis* (Vallentine, 1990). Deferment is defined as the provision for nongrazing from the breaking of dormancy until after seedset or equivalent vegetative reproduction. This method is best utilized when applied to perennial forages where growth and grazing are both seasonal. Benefits from planned nongrazing through Rotational Deferment is dependant on when it is applied (Vallentine on Booysen and Tainton, 1978):

1. Early Spring - provide relief when plants are drawing on their stored reserves and developing full leaf systems.
2. Spring - accelerate regrowth when potential is maximum.
3. Summer - benefit flowering and producing seed.
4. Autumn - accelerate carbohydrate (TAC) buildup and storage.
5. Yearlong - enable seedlings to establish, preferred species to recover from very low vigor, or fine fuel to accumulate for prescribed burning.

Table 2-1 gives an example of a Rotational Deferment timetable for a single (6 month) growing season.

**Table 2-1. An example of Rotational Deferment.**

| | | Pasture Unit | | |
|---|---|---|---|---|
| **Year** | **Period** | **A** | **B** | **C** |
| 1 | May 1 - June 30 | ND | G | G |
| | July 1 - August 30 | ND | G | G |
| | September 1 - October 30 | G | G | G |
| 2 | May 1 - June 30 | G | ND | G |
| | July 1 - August 30 | G | ND | G |
| | September 1 - October 30 | G | G | G |
| 3 | May 1 - June 30 | G | G | ND |
| | July 1 - August 30 | G | G | ND |
| | September 1 - October 30 | G | G | G |

Pasture units are expressed in terms of two or three herd or one herd with access to multiple pasture units. G, grazing; ND, nongrazing constituting deferment (Adopted from Vallentine, (1990).

**Deferred-Rotation** *is a one-herd combination grazing method that implements rotational deferment* (Vallentine, 1990). In a deferred-rotation grazing system alternating periods of grazing and non-grazing are assured and continuous grazing in any pasture is ruled out. Using the same 6-month growing season application as the rotational deferment, deferred-rotation is described in Table 2-2.

**Table 2-2. An example of Deferred-Rotation.**

| | | **Pasture Unit** | | |
|---|---|---|---|---|
| **Year** | **Period** | **A** | **B** | **C** |
| 1 | May 1 - June 30 | ND | G | N |
| | July 1 - August 30 | ND | N | G |
| | September 1 - October 30 | G | N | N |
| 2 | May 1 - June 30 | N | ND | G |
| | July 1 - August 30 | G | ND | G |
| | September 1 - October 30 | N | G | N |
| 3 | May 1 - June 30 | G | G | ND |
| | July 1 - August 30 | N | G | ND |
| | September 1 - October 30 | N | N | G |

Pasture units are expressed as three pasture units with one herd. G, grazing; N, nongrazing; ND, non-grazing constituting deferment. Adopted from Vallentine (1990).

**Rotational Rest** *is a multipasture system in which 12 months of rest is scheduled among the respective pasture units on a rotating basis* (Vallentine, 1990). Rest in this context denotes a nongrazing treatment in which a pasture unit is left ungrazed for a full 12 months and one forage crop is foregone and not grazed even after maturity. Table 2-3 gives an example of a 4.5-month growing season.

**Table 2-3. An example of Rotational Rest.**

| | | Pasture Unit | | |
|---|---|---|---|---|
| **Year** | **Period** | **A** | **B** | **C** |
| 1 | June 1 - July 15 | NR | G | G |
| | July 15 - September 1 | NR | G | G |
| | September 1 - October 15 | NR | G | G |
| 2 | June 1 - July 15 | G | NR | G |
| | July 15 - September 1 | G | NR | G |
| | September 1 - October 15 | G | NR | G |
| 3 | June 1 - July 15 | G | G | NR |
| | July 15 - September 1 | G | G | NR |
| | September 1 - October 15 | G | G | NR |

Pasture units are expressed in terms of three pasture units and two herds. G, grazing; NR, nongrazing constituting 12-month rest. Adopted from Vallentine (1990).

**Rest-Rotation** *is a multipasture system in which 24 months of rest is scheduled every five years among the respective pasture units on a rotating basis, where 40% of the pasture units are rested each year* (Vallentine, 1990). Research on rest-rotation grazing frequently found that forced heavy stocking one year in the cycle may cause more harm to the forage plants than combinations of rest and deferment can undo. Success with rest-rotation grazing has largely been restricted to the mountain bunchgrass range of steep, heterogenous with minimal "suitable" range (Vallentine, 1990). A four-pasture unit, two-herd rest-rotation plan for the mountain ranges of the western United States is presented in Table 2-4.

**Table 2-4. An example of Rest-Rotation.**

| | | Pasture Unit | | | |
|---|---|---|---|---|---|
| **Year** | **Period** | **A** | **B** | **C** | **D** |
| 1 | June 15 - August 15 | G | G | ND | NR |
| | August 15 - October 15 | G | N | G | NR |
| 2 | June 15 - August 15 | NR | G | G | ND |
| | August 15 - October 15 | NR | G | ND | G |
| 3 | June 15 - August 15 | ND | NR | G | G |
| | August 15 - October 15 | G | NR | G | N |
| 4 | June 15 - August 15 | G | ND | NR | G |
| | August 15 - October 15 | N | G | NR | G |

G, grazing; N, nongrazing; ND, nongrazing constituting delayed grazing; NR, nongrazing constituting 12 month rest. Adopted from Vallentine (1990).

**High Intensity, Low Frequency (HILF)** *is a grazing method based on obtaining forced utilization of vegetation by using high stocking densities and short grazing periods, which makes relatively long nongrazing periods necessary for plant recovery* (Kothmann, 1984). Allen (1990) notes that HILF is a relative concept and is best described in terms of grazing management and grazing method. Semi-humid and semi-arid HILF systems have varied grazing days from over two weeks to 30 - 45 days.

**Short Duration** *is a rangeland grazing method which employs 5 to 12 pasture units in the system, where each grazing period is approximately 3 to 10 days but less than 14 days long* *and employs variable nongrazing periods, depending upon the time needed to make ample regrowth but not exceeding 60 days* (Kothmann, 1980). Although short-duration grazing utilizes high stocking densities, grazing pressures are reduced by shortening the grazing periods (Kothmann, 1984). The shorter grazing periods and moderate defoliation allow shorter rest periods and present animals with less mature forage, thereby potentially increasing diet quality.

**Mob Grazing** *is a method which employs grazing by a relatively large number of animals at a high stocking density for a short period of time* (Allen, 1991). This method is different from short duration grazing. Mob grazing is a grazing method which is based on some specific objectives of pasture management, while short duration grazing is based on some specific objectives of animal response.

Similar to the problems associated with the definitions of short-duration and mob grazing, the lack of standardized definitions for grazing intensity categories inhibits complete understanding of many research grazing systems. Trimble (1995) reviewed 18 studies giving definitions of grazing intensity, 12 of which used some form of cows per acre-time or animal unit months per ha (AUM $ha^{-1}$). Average values and ranges for light, moderate and heavy grazing are given in Table 2-5. The remaining six studies investigated by Trimble used various definitions including extremely heavy short duration term stocking rates which were not convertible to a AUM $ha^{-1}$ unit.

**Table 2-5. Categorization of grazing intensity in AUM $ha^{-1}$.**

| Grazing Intensity | Average | Low Value | High Value |
|---|---|---|---|
| Light | 0.65 | 0.17 | 1.5 |
| Moderate | 1.2 | 0.16 | 3.7 |
| Heavy | 2.5 | 0.22 | 7.4 |

## Hydrologic Response: Runoff and Infiltration

Very few studies have been conducted which relate livestock grazing or livestock grazing practices directly to runoff. Hydrologic research has primarily focused on the recharge of soil moisture for growing forage in the arid and semiarid western rangeland (Blackburn et al, 1980). Runoff volume has also not been heavily researched for two more additional reasons. First, grazing impact studies, almost exclusively, have been conducted on western rangelands. Secondly, runoff has been found to be spatially and seasonally variable on many rangeland sites (Achouri and Gifford, 1984; Menzel et al., 1978). Largely for these reasons direct runoff has been inferred by concentrating on infiltration as an indicator of range hydrology (Blackburn et al, 1980) and grazing impact.

The direct force of cattle hooves has the potential to reshape the land. That force is often conceptually underestimated because it is conceived as static, i.e. the mass of the cow (typically 400-500 kg) divided by a few square cm of the basal hoof area (Trimble, 1995). But once there is movement by the cow, the mass of the cow is transferred to one or more hooves, resulting in acceleration. A 530-kg cow can exert 250 kPa of vertical stress while walking on level ground. When the cow is climbing a steep hill slope or stream bank the impact is greatly enhanced. The mass is then concentrated on the down slope rear leg which propels the animal up slope. Due to the quick acceleration of this act, along with the mass of the cow, a considerable force is generated. Dividing the force by the basal area of one hoof, the unit force on the soil becomes high, indeed (Trimble, 1995). If the hoof acted normal to a level slope, this may simply compact the soil, but given the lateral vector on a steeper slope, the power to shear and move soil down slope, thus reshaping the surface, is greatly enhanced. Hoof compaction results in increased bulk density which leads to reduced infiltration and increased overland flow (runoff) which, in terms, leads to increased erosion.

One of the earliest studies which investigated the impact of livestock grazing and grazing method on infiltration was conducted by Rauzi and Hanson (1966) on the Cottonwood Range in South Dakota. Three grazing systems (light, moderate, and heavy) were compared in terms of soil bulk density, pore space and infiltration (Table 2-6). It is clearly illustrated by Table 2-6 that, livestock grazing, as well as the different grazing methods impact on hydrologic response. In the top 10 cm of the soil, bulk density increased and pore space decreased since the soil was compacted as the grazing intensity increased. Furthermore, the infiltration of the lightly grazed paddock was found to be 1.8 times that of the moderately grazed treatment. The lightly grazed treatment also showed an infiltration rate 2.5 times that of the heavily grazed treatment.

**Table 2-6. Bulk density, pore space and infiltration affects by various stocking rates.**

| Treatment | Stocking Rate | Bulk Density | Pore Space | Dry Infiltration | Wet Infiltration |
|---|---|---|---|---|---|
| | **AUM / ha** | **g / cm³** | **% volume** | **cm / hr** | **cm / hr** |
| Heavy | 1.88 | 1.29 | 7.7 | 2.82 | 1.29 |
| Moderate | 1.02 | 1.24 | 8.4 | 4.39 | 1.75 |
| Light | 0.76 | 1.17 | 10.6 | 6.93 | 3.20 |

Dry and wet infiltration rates are totals after 1 hour. Adopted from Rauzi and Hanson (1966).

Data from natural rainfall and sprinkler infiltrometer studies were statistically analyzed by Gifford and Hawkins (1979), during the development of a deterministic model for predicting infiltration rates under livestock grazing conditions. The authors concluded that there was a) a distinct influence on infiltration by grazing intensity, b) no significant difference exists between light and moderate grazing on infiltration, and c) a distinct impact from heavy grazing which is significantly different from that of light/moderate grazing on infiltration.

The Grazing Impact Model, developed by Gifford and Hawkins (1979), incorporated a recovery mechanism for infiltration due to rest or deferring of grazing. Response to grazing (decreased infiltration) occurs linearly over the entire grazing duration (even though there is no data to support this assumption). The model initially assumed a linear recovery over time as follows:

$$\mathbf{f = f_p + (f_t - f_p)t/T} \quad (1)$$

where,

$f$ = infiltration rate
$f_p$ = beginning (present infiltration)
$f_t$ = target (infiltration),
$t$ = active period duration (years)
$T$ = linear recovery time (years)

Gifford and Hawkins (1979) proposed that hydrologic recovery could be quantified as a non-linear function in the form of :

$$\mathbf{f = f_p + (f_t - f_p)(1 - exp\ (-t/\tau)} \quad (2)$$

where,

$\tau$ = recovery time constant

Intuitively, recovery should be a function of land type, range condition, intensity of use and climate. Climate could be expressed as a season or long term distributed function of interim precipitation (Gifford and Hawkins, 1979). However logical this idea may be, no data exists to support this theory.

McGinty et al. (1979) also found that the grazing method employed can cause significant differences in rangeland infiltration. The study compared the infiltration rates of a deferred-rotation (5.2 ha/AU/yr) and a continuously stocked system (4.6 - 5.4 ha/AU/yr) to a 27-year exclosure on the Edwards Plateau, Texas. Terminal infiltration was found to be similar between the four-paddock rotation system and the 27-year exclosure with rates of 10.40 cm/h and 10.24 cm/h, respectively. It was believed by McGinty et al. (1979) that grazing management affects water intake and sediment production by altering soil and vegetation variables. Rangeland, under heavy continuous grazing, had lower infiltration rates than rangeland under the 4-paddock deferred- rotation system or the livestock exclosure. Infiltration rate differences were generally found to be related to differences in plant biomass, bulk density, depression storage and soil depth.

Even though the stocking rates of the deferred-rotation and continuously stocked systems were similar (5.2 and 4.6-5.4 ha/AU/yr, respectively), the heavy, continuously stocked paddock was found to have an infiltration rate greater than half of that of the deferred-rotation system (4.41 cm/hr)(Figure 2-1). McGinty et al. (1979) concluded that the deferred-rotation system maintained and possibly improved range and hydrologic conditions.

Several studies have investigated the effect of grazing intensity on infiltration rate through changes in vegetative cover. Generally, infiltration rates are significantly greater within shrub canopies than range midgrass interspaces , and infiltration rates of midgrass interspaces are significantly greater than shortgrass interspaces (Wood and Blackburn, 1981). Wood and Blackburn (1981) investigated 30-minute infiltration rates of : heavy and moderate continuous stocking; rested and deferred-rotation; rested and grazed high intensity low frequency (HILF);

and two 20-year-old livestock exclosures grazing methods. Infiltration was measured within each of the three vegetative covers; shrub canopy; midgrass interspace; and shortgrass interspace. Infiltration rates of the deferred-rotation treatment were found to be similar to those areas where grazing was excluded for a long time (Figure 2-2). Figure 2-2 also illustrates that the infiltration rates of the HILF treatments were found to be similar to those of the heavily, continuously stocked treatment.

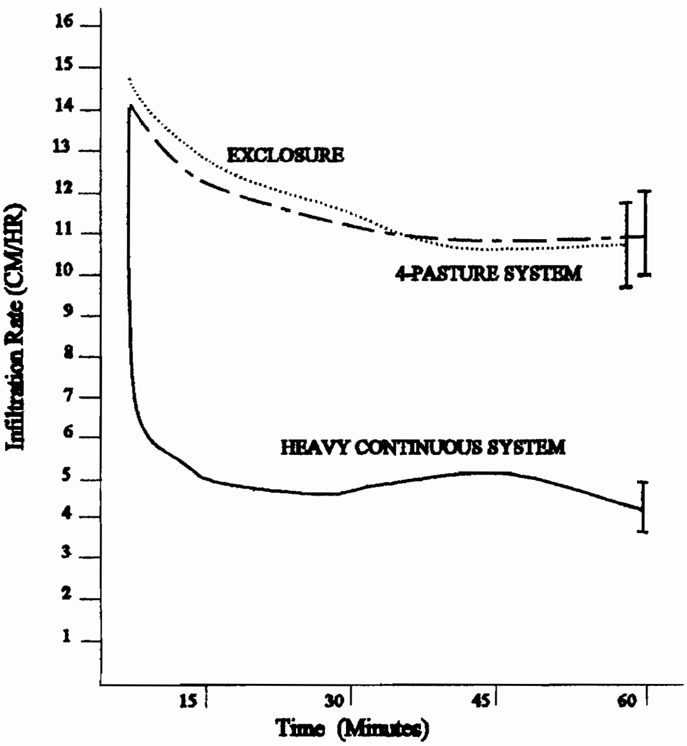


**Figure 2- 1. Infiltration rates for heavy, 4-pasture system and exclosure pastures.**
**(Vertical lines represent 95% confidence intervals (McGinty et al.,1978).)**

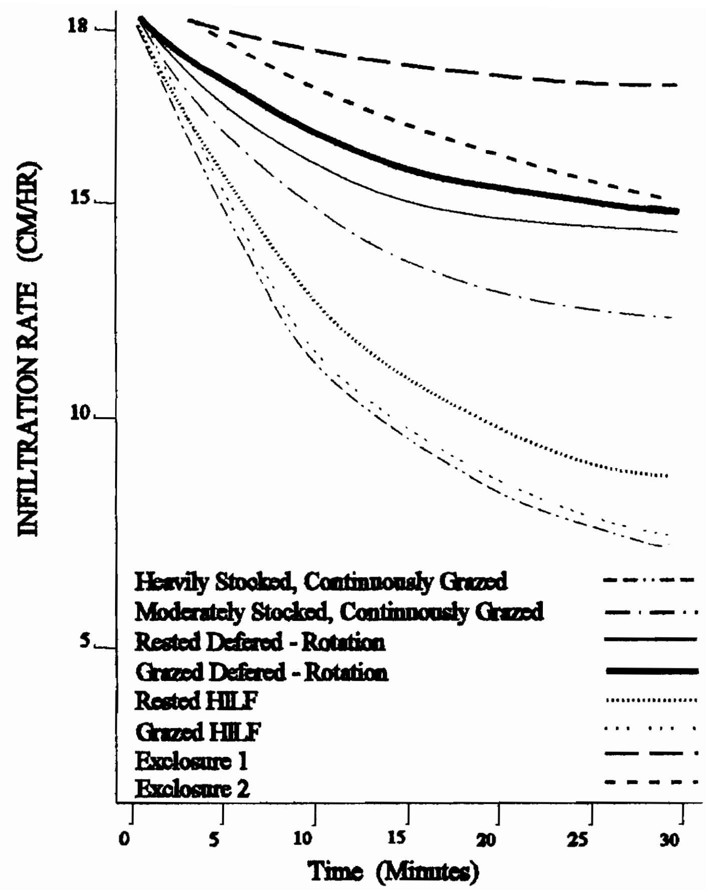


**Figure 2-2. Midgrass interspace infiltration curves for various grazing treatments.** Adopted from Wood and Blackburn (1981).

Wood and Blackburn (1981) also found definite relationships between the various grazing methods and infiltration rate. Several parameters were found to influence infiltration rate, including aggregate stability, % organic matter, mulch, standing crop, bulk density, initial surface (0-3 cm) moisture content, as well as ground, perennial grass and total grass cover.

Also on the Edwards Plateau, Thurow et al. (1988) found that infiltration rates decreased and interrill erosion increased in heavily short-duration stocked (SDG) (14 paddocks, 4 days gazed: 50 days rest (1 herd), 4.6 ha/AU) and heavy continuously stocked (HCG)(4.6 ha/AU) grazing systems. Reduction of infiltration rates in the heavily stocked pastures was typified by decreased grass cover, litter and midgrass cover during drought, and their ability to recover to pre-drought levels during periods of above normal precipitation. Conversely, infiltration rates in the moderately stocked SDG and moderately continuously stocked (MCG)(8.1 ha/AU) were able to recover from drought level values and maintain initial or improved infiltration rates during periods of above-normal precipitation.

Across grazing methods, Thurow et al. (1988) found that livestock induced changes in vegetative composition from bunch-like midgrasses to shortgrass, caused the greatest changes in infiltration rate. Similar to the findings of Sims et al.(1982), the high crowns of the bunchgrasses were observed to be more susceptible to damage from the heavy grazing pressure under the SDG and HCG systems. Shortgrass cover was also found to decline rapidly during dormant periods and quickly increase growth during warm, moist periods. In response to this cyclic growth pattern, infiltration rates were observed to seasonally fluctuate in SDG and HCG pastures dominated by shortgrass. However, pastures with a favorable midgrass and shortgrass species composition did not show major fluctuations in infiltration rate.

Similar to the recovery mechanism in the Grazing Impact Model (Gifford and Hawkins, 1979), it has been inferred that grazing methods such as deferred, grazed and rested rotation, as well as HILF, provide mechanisms for hydrologic recovery. These may involve soil recovery in terms of "improvements" in infiltration and a more beneficial sward.

Soil recovery, in terms of increased infiltration rate, occurs due to the decreased number of days in which a herd would be impacting a single pasture. This results from the movement of cattle between paddocks in order to achieve a certain agronomic, production or conservation goal(s). Secondly, the seasonal cycling of regrowth of vegetation (Sims et al. 1982, Thurow et al. 1988) in a rotationally grazed sward has been suggested to be a major factor demonstrating a more favorable hydrologic response than other grazing methods. Seasonal regrowth of vegetation will foster vegetative regrowth, resulting in increased soil cover and will break up the soil through root growth and tillering. The seasonal regrowth of the sward will result in the increased retention and production of mulch, as compared to continuous systems (Thurow et al., (1988). The synergetic effect of rotating grazing livestock in terms of rest and recovery, as well as the allowance for the regrowth of vegetation during the grazing, has been demonstrated to show higher infiltration rates than comparable continuously grazed systems (McGinty et al. (1978); Wood and Blackburn (1981); and Thurow et al. (1988)).

However, all rotational grazing systems may not demonstrate favorable hydrologic conditions. Thurow et al. (1988) concluded that heavy stocking rates and climate, rather than grazing method, were the major factors affecting hydrologic response. Heavily stocked SDG and HCG methods may increase forage utilization (Thurow et al., 1988 *on* Ralph, 1983), but were found not to be well suited for long term range soil and water conservation. The moderately stocked HILF and MCG methods appeared to be more appropriate for conservation of long-term hydrologic conditions (Thurow et al. (1988)).

## Stream Bank Stabilization and Erosion

The extent of cattle impact on stream bank integrity and erosion is a subject of debate among researchers. However, there is little debate over the destructive potential of grazing cattle. Cattle slough off stream banks when they go to drink water or cross streams. Riparian vegetation are grazed and thus decrease vegetative cover or become disturbed. Soil is either slid into the stream by passing cattle or is dislodged to the point where it could be carried downstream by runoff.

The effect of cattle within different grazing systems was investigated by Buckhouse et al. (1981) at the Starkey Experiment Station in northeast Oregon. Nineteen grazing treatments were performed over a period of three years, representing season-long, deferred-rotation, rest rotation and no grazing. Each system was stocked at a rate of 3.2 ha per animal unit month (AUM). Buckhouse et al. (1981) found no significant pattern of accelerated stream bank deterioration due to the moderate livestock stocking. In 1976 and 1977 grazing treatments showed a mean annual stream bank loss of 16 and 14 cm and the ungrazed (control) treatments showed 11 and 8 cm of loss, respectively. Even though the grazed treatments on both years showed higher mean annual erosion losses, they were not significantly different from the control (at $p<0.10$). Buckhouse et al. (1981) concluded that most bank cutting losses were associated with over-wintering periods when high water, ice flow and channel physiognomy were critical.

Hayes' (1978) conclusions from a study conducted in central Idaho endorses the findings of Buckhouse et al. (1981). Hayes found that rest rotational grazing did not significantly accelerate channel movement. The study also found that the degradation during spring discharge, along ungrazed stream banks, was significantly greater than the degradation occurring along grazed stream banks (Hayes, 1978). Both of the studies conducted by Buckhouse et al. (1981) and Hayes (1978) suggest that certain highly hydrologically significant events may mask the impact which cattle may, or may not, be inducing upon a stream. In the case of the study in Idaho, erosional losses were found to be greater in ungrazed treatments than in grazed treatments.

Kauffman et al. (1983) study on a 3-km section of Catherine Creek, also in northeastern Oregon, did not support the results presented by Buckhouse et al. (1981) and Hayes (1978). A late season livestock grazing system was stocked at a rate of 1.3-1.7 ha/AUM. Prior to the construction of exclosures, there were 5,473 m of stream bank on the study area and 3,492 m were considered to be accessible by livestock (i.e. there were no steep cliffs, old fences or dense vegetation). Stocking intensity before the exclosures were constructed was 48-50 m of accessible stream bank (MAS) per animal unit month. After the exclosures were constructed 1,804 m of accessible stream bank were accessible to the cattle which increased the stocking intensity to 25-30 MAS/AUM. Kauffman (1983) also suggested that such stocking intensities (MAS/AUM), calculated by the length of accessible stream bank, should be used rather than traditional stocking rates in describing the cattle-stream use potential for a pasture.

Kauffman et al. (1983) found that significantly greater stream bank erosion and disturbance occurred in grazed areas than in excluded (fenced) areas during the 1978 and 1979 grazing periods. The stocking rate of 1.3-1.7 ha/AUM was found by Kauffman (1982) to have little effect on riparian vegetation. However, grazing intensities of 23-30 MAS/AUM showed to have a significant impact on stream bank erosion. These findings illustrated a greater environmental hazard for Catherine Creek than Buckhouse et al. (1981) or Hayes (1978) found with similar light to moderate stocking rates (Kauffman, 1983). Kauffman (1983) concluded that it is likely that some streams are more susceptible to disturbance than others.

Trimble (1994) separated the erosion effects due to mechanical trampling damage and stream bank scour (described as the hydrologic scour on vertical bank sides). He found that grazed stream banks, mainly cattle gaining access to the stream at regular points (ramps) or at sporadic locations, appeared to erode about three to six times faster than ungrazed stream banks, over the 5.8 year observation period. The erosion rate of the grazed, as compared to the ungrazed stream banks is about 0.04 $m^3$/yr. Trimble (1994) noted that while some of this material will be deposited on downstream floodplains or aid in rebuilding downstream banks, much would add to downstream sediment yield.

Areas continually used by cattle for stream access were shown by Trimble (1994) to be susceptible to further erosion during high discharges. Exclusion of cattle from these areas would allow smaller channel-forming discharges to partially replace material previously lost. This recovery process would be especially aided by the establishment of herbaceous cover in the ramps. Although erosion from cattle access to creeks at ramps was shown to increase, erosion due to stream bank scour did not appear to be reduced when cattle were excluded. Along an ungrazed section of the stream, stream bank erosion was found to be significantly greater than grazed sections. It was hypothesized that the additional woody vegetation of the ungrazed section induced more turbulence near the bank, causing more erosion. Conversely, in smaller events, the vegetation may create a more quiescent local community, thereby protecting the banks (Trimble, 1994).

Trimble's method (Trimble, 1994) of differentiating between erosion types was not pointed out in any of the studies conducted by Buckhouse et al (1981), Kauffman et al (1983), or Hayes (1978). This difference in describing the type of erosion may correlate to the difference in conclusions presented by Buckhouse et al.(1981), Hayes (1978) and Kauffman (1983).

Marlow et al. (1985) found that cattle use alone did not explain the degree of change in channel profile. They examined why some streams were more susceptible to bank disturbance as Kauffman (1893) concluded. Marlow et al. (1985) found that as soil moisture decreased, channel alteration (erosion) also decreased. It was found earlier that the greatest amount of bank alteration occurs when the soil moisture content exceeds approximately 10% of total volume. Their studies suggested that increased stream bank erosion by high flows occurs when bank soil moisture is high. Also, the combination of high flow, moist stream banks, and cattle use leads to major stream alteration.

Because of the grazing susceptibility of moist stream banks, Marlow and Pogacnik (1987) stated that the reduction in cattle numbers will produce little riparian management. Fewer cattle will simply restrict bank damage to localized spots in the pasture. These damaged areas, although infrequent, will continue to contribute to further riparian [and water quality] degradation. They suggested that this can be avoided by deferring cattle use until after banks have dried sufficiently to limit trampling damage.

## Erosion and Nutrient Losses

Analysis of water quality parameters has been conducted in several studies to quantify the impact of range cattle on surface water bodies. Many of the parameters studied included total suspended solids (TSS), total dissolved solids (TSD), chemical oxygen demand (COD), total organic carbon (TOC), ammonia-nitrogen ($NH_4$-N), nitrate-nitrogen ($NO_3$-N), total Kjeldahl nitrogen (TKN), orthophosphates ($PO_4$), soluble phosphorus, total phosphorus (TP), and chlorine (Cl).

Johnson et al. (1978) studied the impact of 75 cow/calf pairs, managed at a stocking rate of 1.2 ha/AUM, on Trout Creek in central Colorado for 21 days. They observed no statistically significant difference in the physical or chemical properties of the stream water that could be attributed to the grazing cattle. Average concentrations of nitrate-nitrogen during the period of grazing were 0.30 and 0.36 mg/L in the ungrazed and grazed pastures, respectively. Afterward, during a period of no grazing, nitrate concentrations averaged 0.13 mg/L. The presence of cattle did not significantly increase nitrate levels (Johnson et al., 1978). The concentration of orthophosphates, total suspended solids and total dissolved solids also did not significantly increase in the presence of cattle over the 21-day study period.

Gray et al. (1983) found no statistically significant difference in TSS and nitrate-nitrogen due to the presence of grazing cattle, also on Trout Creek, Colorado. Concentrations of ammonia-nitrogen under the moderate-grazing conditions were found to be significant only once during the two year study.

Schepers and Francis (1982) found that runoff from a 32.5-ha area of a 40-ha pasture in south-central Nebraska had been significantly impacted by the 35-45 cow/calf pairs. The stocking rate and management practices were described as typical of a controlled rotational grazing system. Except for TKN [which decreased by 19%], concentrations of $NH_4$-N, $NO_3$-N, soluble P, total P, TOC, COD, Cl and total solids in runoff waters from pastureland were increased by grazing cattle at the time of runoff. Runoff from an ungrazed control area within the pasture contained the highest chemical concentrations that ranged from 1.94 to 10.8 times greater than those from an adjacent pasture under ungrazed conditions. The authors attributed these concentrations to wildlife activity and the leaching of nutrients from vegetative material.

## Fecal Bacteria

Fecal coliform and fecal streptococci are intestinal bacteria which are present in the feces of warm blooded animals. One cow produces an estimated 5.4 billion fecal coliforms and 31 billion fecal streptococci daily (USEPA, 1976). Based on these estimates, it is not surprising that the presence of cattle usually is associated with elevated numbers of bacteria in streams (Gary et al., 1983).

Potential, but relatively rare, waterborne bacterial diseases transmissible through cattle manure are salmonellosis, leptospirosis, anthrax, and brucellosis (Diesch, 1970) as well as cryptosporidiosis, tuberculosis, tularemia and toxoplasmosis (Walker, 1988). Fecal coliform and fecal streptococci are known as indicator bacteria, because they can easily be detected by laboratory methods. The presence of fecal coliforms or fecal streptococci does not confirm the presence of any of the above mentioned bacterial diseases, yet illustrates a higher probability that such diseases may be present.

The level of fecal contamination in a stream is related to the amount of feces deposited in or near a stream. Gary et al. (1983), showed that cattle along Trout Creek, in Colorado's Front Range spent 65% of the day within 100 m of the study stream and that 5% of the day was spent in or on stream banks. Considering the time spent in or near the stream channel and its small area in relation to the whole pasture, Gray et al.(1983) concluded that, the potential for cattle to contribute large amounts of manure and urine to the streams, and to detach large amounts of bank material or stream sediments, appeared great.

Manure was collected and weighed from within 3.04-m (10-ft) wide corridors along both sides of the study stream. The amount of expected manure production, based on figures from the Midwest Plan Service Livestock Waste Facilities Handbook MWPS-18, assumed that 3.13 kg of total solids would be produced by each 453.59 kg (1000 lb) of live weight beef feeder every day. Gray et al. (1983) concluded that only 4.1 - 5.8% of the potential manure produced was deposited within the 3.04-m (10-ft) wide corridors along both sides of the stream.

Gray et al. (1983) also found that the presence of cattle grazing along Trout Creek increased fecal coliforms and fecal streptococci counts by 1.6 to 12.5 and 1.5 to 3.8 times, respectively, over normal levels found in Trout Creek. However, significantly higher levels of fecal coliforms and fecal streptococci were observed only when 150 head of cattle were present in the 72.9 ha (180 ac) or 85 ha (210 ac) pastures. Similarly, Buckhouse et al. (1979) found that fecal coliform levels increased slightly during the grazing season, but in all cases the numbers were well below the suggested standards for primary contact and recreational use.

In an earlier study, Johnson et al. (1978) found that the presence of cattle [1.2 ha/AUM] significantly elevated the fecal coliform and fecal streptococci counts over those in an ungrazed pasture, during a 21-day study period. However, after removal of the cattle, both fecal coliform and fecal streptococci counts dropped to non-significant levels within nine days after the cattle were removed.

## Cattle Behavior

Cattle behavior has been studied by many researchers. Almost exclusively, these studies have been conducted on western public lands. The intent of these studies has been to describe the interaction of range cattle to water quality and riparian use. The emphasis of many studies has been to describe where range cattle spend most of their day, during different seasons. If cattle are spending large amounts of time in riparian zones, the research question then becomes why are they preferring these areas over others and for what reasons.

Marlow et al. (1986) concluded, from their study in southwestern Montana, that cattle use of foothills and riparian zones was affected most by forage and climatic conditions. The report stated that if there was sufficient precipitation prior to the grazing season, cattle grazing were concentrated in the uplands until early July and then gradually shifted to the riparian zone to where it became the primary grazing area during September. This pattern was attributed to the dwindling quality and quantity of upland forage. Thus, as upland forages became more mature and less palatable, cattle were reduced to concentrating their feeding along the riparian zones.

Marlow et al. (1986) also showed that cattle preferred to rest in the uplands during June and July. Resting in the riparian zone became significant during hot, August afternoons (a conclusion also supported by Byrnat (1982), Myers (1981) and Severson and Boldt (1978)) only when face flies were not a problem. During September, where there were low populations of face flies, cooler nights and low quality and quantity of upland forage, riparian zones became the primary location of grazing and resting. Similarly, Gary et al. (1983) showed that cattle on Colorado's Front Range spent 65% of the day with in 100 m of the study stream and that 5% of the day was spent in or on stream banks.

Smith et al. (1992) concurred, with Marlow et al. (1986) conclusion about the importance of forage quality and quantity in cattle habitat selection, but added the importance of available water. Smith et al. (1992) found that cattle, in both small pastures and large allotments in the Bighorn Basin of Wyoming, showed a greater preference to habitats near water. It was concluded that when adequate livestock water was present, grazing cattle would be more likely to select areas of higher quality and quantity of forages.

Due to the importance of the channel [riparian] areas in maintaining habitat diversity and trapping sediment, grazing management should emphasize maintenance of channel vegetation. It was not shown that a particular season of grazing seemed to result in more detrimental grazing utilization of channels when water was not limited. Smith et al. (1992) concluded that, vegetation in or near the channel can best be protected by developing water points in adjacent uplands.

## Fescue Toxicity

Tall fescue (*Festuca arundinacea* Schreb.) is one of the most important pasture grasses in the United States. Grown on over 14.2 million ha (35 million ac), this cool season perennial grass has the potential for high quality and should give good animal performance. However, tall fescue has the reputation for reduced average daily gain (ADG) of grazing cattle (Stuedemann & Hoveland, 1988), reproduction problems (Ball et al., 1991), low milk production (Siegel et al. 1985), gangrenous conditions in hooves and tails (Bush et al., 1979) as well as the retention of winter coats into summer months, combined with a generally less slick coat (Ball et al., 1991). These varied animal responses to grazing tall fescue can be associated to a fungal endophyte (*Acremonium coenophialum* Morgan-Jones and Gams) which spends its entire life cycle living within the plant (Bacon & Siegel, 1988).

Three separate syndromes can be associated with the problems caused by grazing endophyte infected tall fescue:

**1. Fescue foot** produces the most dramatic visible symptom on cattle grazing tall fescue. The clinical signs include a gangrenous condition of the hooves and tail as well as the loss of ear tips due to the nuecrosis of extremeties. The syndrome seems to be related to lower air temperatures and is much more a problem in the northern areas as compared to the southern areas of the tall fescue growing region.

**2. Bovine fat necrosis** is characterized by hard fat masses in adipose tissue surrounding intestines, thus causing problems with digestion and calving. This syndrome has been associated with the application of excess nitrogen (N) fertilizers either in the form of poultry litter (Williams et al., 1969) or commercial fertilizers (Stuedemann et al., 1975).

**3. Fescue toxicosis or"Summer Slump"** is the most far reaching symptom of problems associated with endophyte infected tall fescue in terms of economic impact on livestock producers. Summer slump is associated with low ADG, reduced conception rates, intolerance of heat, failure to shed the winter coat, elevated body temperature, increased respiration rate and nervousness. Summer gains of steers has been measured to be as low as 0.45 kg/day (1 lb/day) (Stuedmann & Hoveland, 1988). Growing steers and heifers have been observed to be highly sensitive to fescue toxicity, with ADG being reduced about 0.045 kg/day (0.1 lb/day) per 10 percent increase of endophyte infection within a pasture (Ball et al., 1991). It has also been highlighted by Stuedemann & Hoveland (1988) that steers grazing highly infected tall fescue spend more time in the shade, less time grazing, and preform poorer compared to steers grazing on relatively endophyte-free tall fescue.

Of the three sydromes, fescue toxicosis or summer slump can be attributed to changes in cattle behavior which result in the degradation of stream and water quality. It has long been observed that cattle grazing toxic tall fescue will have a tendency to wallow in mud (Boman et al., 1973) or stand in ponds or creeks during hot portions of the day. Allen (1994) also observed steers grazing on highly infected tall fescue, which did not have access to surface water, concentrate their urine in a corner of a pasture. This concentration of urine formed a wallow after days of standing and walking in the area. Due to the effects of fescue toxicosis forcing cattle to spend more time within the stream areas, it can be construed that the level of impact (erosion, decreased water quality) upon these areas will increase.

The presence of tall fescue in a pasture does not directly relate to poorly preforming livestock or eroded and polluted streams. Many management strategies exist to eleviate the symptoms of grazing endophyte infected tall fescue. Pastures can be managed to maintain a diversity of grass or legume species. Kentucky bluegrass (*Poa pratensis*), orchardgrass (*Dactylis glomerata*) or common bermudagrass (*Cynodon dactylon*) in a sward can be effective in diluting the toxic fescue. Tall fescue can also be closely grazed in the spring. Close grazing will reduce production of flowers and seeds thus reducing the spread and concentration of the endophyte, as well as decreasing shading of other forages. Summer nitrogen applications of pastures will favor warm-season grasses such as bermudagrass providing a dilution effect of the toxic fescue. Feeding of hay other than toxic fescue, either from endophyte-free fescue, orchardgrass, red clover (*Trifolium pratense*), bermudagrass or other grasses and legumes may reduce winter toxicity problems including fescue foot. Grain supplementation may also be effective in reducing winter tall fescue toxicity symptoms. Re-establishment of highly infected tall fescue pasture with endophyte-free tall fescue or other species can be extremely expensive. In severe cases, however, the cost of re-establishment of endophyte-free fescue or other species will be recovered through improved animal production.

## Stream Bank Fencing

The concept of stream bank fencing, as a method of decreasing the impact of cattle on western lands, received support from Jon Skovlin's report to the National Academy of Sciences (1984). In the report Skovlin took a mulitdisciplinary approach to review the impact of grazing on riparian zones, discussing wildlife, fisheries, riparian vegetation as well as water quality issues. Skovlin concluded his study with ten recommendations for riparian zone management:

1. Do nothing.
2. Improve distribution by obtaining greater upland use within the existing system; i.e., reduce use in riparian zone (possibly changing the age class of cattle).
3. Change season of use.

4. Implement specialized grazing seasons or systems to restore riparian zones and improve distribution in the uplands.
5. Rest entire grazing unit for 5 years or until target levels of recovery in riparian zones have been achieved.
6. Fence meadow flood plain to control use of entire riparian zone (and, consequently, the uplands).
7. Fence streamside corridors for preservation of complete habitat (provide access to water where needed).
8. Combine two or more of the above solutions.
9. Revegetate with woody cover and apply 5, 6, or 7.
10. Eliminate grazing.

Support for Skovlin's recommendations for streamside fencing can be found from studies of the relatively long term benefits which can be associated with cattle exclosures. Stuber (1985) studied the affect of protecting a 40-ha section along 2.5 km of Sheep Creek, Colorado which was fenced during the mid to late 1950's. Stocking rates for the Sheep Creek Allotment have been reduced from 1900 AUMs in 1939 to 600 AUMs in 1990 and has been grazed season-long from mid-June to mid-October (Shultz and Leininger, 1990)

Fish habitat within the fenced area of Sheep Creek was found to be deeper, narrower, had less stream bank alteration and better stream bank vegetation than comparable unfenced sections. Estimated trout crop was twice as great and preproportional stocking densities (PSD) were higher than unfenced sections. In 1983 and 1984, there were 196% and 228% more (95 vs. 186 and 58 vs. 132 kg/ha) fish, respectively, than in the unfenced sections. Higher numbers of non-game fish were also present in the fenced sections along Sheep Creek. Van Nelson (1979) found that the fish population changed from 88% non-game to 98% trout after a 4.8 km section of Otter Creek, Nebraska was fenced from grazing cattle.

Stuber (1985) concluded that it appeared that heavier streamside recreation use and cattle grazing has resulted in adverse impacts to the stream/riparian habitat in the unfenced sections of the stream. This is supported by the results of comparative habitat sampling (i.e., wider, shallower, more stream bank alteration, etc.).

Long term benefits of streamside fencing to the woody vegetation along Sheep Creek was reported by Shultz and Leininger (1990). During two years of study, when the carrying capacity of the allotment was estimated to be 621 AUM's and was stocked at 600 AUMs, shrub canopy within exclosures was found to be 5.5 times that of grazed areas. Canopy cover of willows (*Salix* sp.) was found to be 8.5 times greater within the fenced areas as compared to areas grazed by cattle.

Even though many researchers have shown that stream bank fencing produces some environmental benefits, fencing of every stream from cattle is not an economically viable solution. This is not to say that some areas may best be protected by eliminating cattle access and fencing the stream. The livestock industry opposes extreme measures such as stream bank fencing, and concedes the use only in "rare and unusual cases" (Swan, 1979) and not as a general management strategy. The National Cattleman's Association passed a resolution at their 1982 annual meeting opposing proposals by federal land management agencies for fencing riparian areas along streams unless it was voluntarily entered into by both the agency and the livestock operator (Platts and Wagstaff, 1984).

Fencing of riparian areas, even if it is done voluntarily by public and private sectors, will create economic costs which will limit its practicality. Fencing of all riparian habitats is supported by many land managers and researchers who stress the importance of protecting the entire habitat and not just the stream banks.

Platts and Wagstaff (1984) stated that the fencing of all riparian habitat, rather than just along the banks, would become very expensive in terms of labor, material and lost grazing area, and in many situations, could prove to be economically unsound. They reported that a 4 wire fence in the West would cost approximently $1863/km ($3000/mi) and $30 - $90 per year for maintenance. It would cost twice this amount if both sides of the stream need to be fenced. If fencing was required on the 24150 km (15,000 mi) of fishable streams managed by the

BLM it would cost $90 million to construct and $18 - $57 million for maintenance during the next twenty years. To protect the 15,000 and 71,210 miles of BLM and USFS fisheries, respectively, in the continental U.S. would cost taxpayers $517 million dollars to construct and $104 - $320 million for 20 years of maintenance. If a cost of $4.27/m or $4265/km ($1.30/ft, $6870/mile) for a 4-strand barbed wire were used, as suggested by the Natural Resources Conservation Service (1994), the total cost would equal $1.2 billion for construction alone.

It can be construed that the cost of fencing and maintenance along these fisheries will be repayed by recreational fisherman. Platts and Wagstaff (1984) tested the practicality of such a hypothesis as part of a cost-benefit analysis by quantifying fisheries values and stream bank fencing costs. They assumed three days of fishing each at a value of $15.75 by a resident would equal one day of fishing by one recreational visitor day (RVD) as prescribed by the U.S. Department of Agriculture (1980). Therefore, fishery use would have to increase 76 RVD's per kilometer (47 RVD's/mi) of stream per year to match the cost of fencing. Even if fishery production increases as Stuber (1985) suggests in response to stream bank fencing, it is probably unrealistic that use will increase by such a high degree.

In addition to the cost of fencing, land and grazing managers must add the cost of lost grazing area. Platts and Wagstaff (1984) suggest that this could equal one animal unit month (AUM) per acre in highly productive riparian zones. A 30.5-m (100-ft) corridor would contain about

3.04 ha per stream kilometer (12 ac/stream mi) or the equivalent of 12 AUM's. If a producer is leasing a grazing unit or owns the unit and is required to construct fencing due to suggested governmental regulations, these exclosed areas would increase the cost of available grazing area and provide no benefit to the cattle. In southwest Virginia, a 30.5-m (100-ft) corridor along one stream mile would cost a producer $180 in lost grazing area (Hunnings, 1994).

## Alternatives

The environmental benefits of cattle being excluded from stream or riparian zones has clearly been shown. Kauffman et al. (1983) showed that erosion and stream bank disturbance was significantly greater in moderately grazed areas as compared to excluded areas. Stuber (1985) found that trout habitats which were fenced off for over thirty years were more productive than habitats along the same stream where cattle had access.

Even though the benefits of stream bank fencing has been shown, such riparian zone management strategies, like those which Skovlin (1984) and others suggest, may come at a high price. The estimated cost of $0.2 billion to $ 1.2 billion dollars (Platts and Wagstaff (1984); NRCS (1994), respectively), is a large amount of money to spend to protect just the identified fisheries of the BLM and USFS. The cost of protecting other public lands as well as privately grazed lands throughout the country would be prohibitive. Fencing along many streams would become damaged particularly by large storm events thus needing constant repair. Extensive buffer zones to protect riparian areas or to decrease the likelihood of storm damage would decrease the available land for grazing.

The appropriate size of such fenced buffers is also disputed in the literature. The size of the stream bank buffer depends on a range of criteria. Castelle (1994) identified four criteria for determine the adequate buffer size for aquatic resources: (1) resource functional value, (2) intensity of adjacent land use, (3) buffer characteristics, and (4) specific buffer functions required (i.e. water temperature moderation, sediment removal, nutrient removal or the protection of species diversity). Generally, smaller buffers are adequate when the buffer is in good condition (i.e., dense native vegetation, undisturbed soils), the wetland or stream is of relatively low functional value (i.e. high disturbance regime, dominated by nonnative plants), and the adjacent land use has low impact potential (i.e. park land, low density residences) (Castelle, 1994). Larger buffers would be required for high value wetlands and streams that are bounded from intense adjacent land uses by existing buffer zones which are in poor condition.

Given that agencies typically do not consider all of the four criteria, and that buffer widths are most often based on functional value of political acceptability alone, there are some general guidelines for sizing stream bank buffer zones. There are two types of buffer zone categories: fixed-width and variable-width. Each of these two types of buffers have specific advantages and disadvantages. Fixed-width buffers are most often based on a single parameter, such as functional value. Fixed-width buffers are more easily enforced, dot not require regulatory personnel with specialized knowledge of ecological principals, allow for greater regulatory predictability, and require smaller expenditures of both time and money to administer (Castelle, 1994). Fixed-width buffers often do not consider site-specific conditions and, therefore, may not adequately protect aquatic resources. Variable-width buffers are generally based on a combination of buffer sizing criteria, such as functional value, and adjacent land use intensity. Variable-width buffers requirement also consider site-specific conditions and may be adjusted accordingly to adequately protect aquatic resources. Variable-width buffers also require a greater commitment of resources and a higher level of training for project staff, while offering less predictability for land use planning (Castelle, 1994).

From a review of literature, Castelle (1994) concluded that buffers less than 5 to 10 m in width provide little protection for aquatic resources in most conditions. Buffers of a minimum of 15 to 30 m in width were found to protect wetland and streams under most circumstances. Castelle (1994) added that the minimum buffer widths toward the lower end of this range may provide for maintenance of the natural physical and chemical characteristics of the aquatic resources. Buffer widths toward the upper end of this range were found to be the minimum necessary for the maintenance of the biological components of many wetland and stream systems.

If the stream in a grazing area is fenced, regardless of private or public initiation, water must still be provided for livestock or else the area cannot be grazed. Marlow and Pogacnik (1986) showed that cattle prefer to graze in upland areas if there is sufficient forage available. Smith, et al. (1992) concurred and stated that when livestock water was available, cattle preferred to graze in upland areas, regardless of allotment size. Smith et al. (1992) continued to state that riparian vegetation [and habitat] can best be protected by developing water points in adjacent uplands.

Upland water development, suggested by Smith et al.(1992) and Marlow and Pogacnik (1986), is a water quality management practice which has been noted by some farmers and conservationalists to be quite effective. Water development has been viewed in the past as solely a farm improvement, in terms of cost-share support. However, NRCS district conservationalist, Tom Greene (1994), has observed that when water troughs were installed, large stream bank vegetation, like alders and willows (*Salix* sp.), were able to be established along stream banks in southwest Virginia because cattle would spend less time in the stream.

Miner et al. (1992) observed hay-fed cattle in Oregon when they had access to both a stream and a water trough. They found that, over an eight-day observation period in December, cattle would prefer to drink from a trough rather than from a stream. The cattle's preference resulted in a 90% reduction of time they spent in the stream area if a stream was their sole source of drinking water. Miner et al. (1992) hypothesized that this 90% reduction of time in stream would correlate to a decrease in fecal and nutrient loading to the stream. Clawson (1993) observed that the installation of a water trough had a significant impact on cattle use in riparian areas. Use of a pasture stream dropped from 4.7 to 0.9 minutes per cow per day, and use of a wide streamside area dropped from 8.3 to 3.9 minutes per cow per day after the trough was installed. This related to an 81% reduction of time cattle spent drinking from the stream and a 53% reduction in the time cattle spent in an adjacent stream side area. It was concluded by Clawson (1993) that the water trough offered a convenient and preferred water source, over the traditional sources, 75.3% of the time.

Upland water can be developed in many different ways. Hydraulic rams can take water from a flowing stream and pump it up to a height of 37 m (120 ft) with some models, depending on the slope of the stream. Wells can be drilled and water can be pumped with electrical, solar, wind or even animal powered pumps. Springs, if available, can be captured and can provide a relatively inexpensive source of water for cattle. A spring development and water trough system can be installed in southwest Virginia for $1,200 - $1,500 (NRCS, 1994) for the initial spring development and the first trough. Subsequent troughs can be installed downhill for $600 plus piping costs ($1/ft - installed). The cost of this spring development is comparable to excluding less than 0.2-km (1/8-mi) with a 4 strand barbed wire fence.

## Summary

In this chapter many contrasting research findings of the impact which cattle grazing has on water quality, stream bank erosion and riparian habitats were presented. Observations of cattle behavior were used to describe and explain why some of these interactions have taken place. The proposal of mandatory stream bank fencing by Jon Skovlin (1984) and others was reviewed and its environmental benefits, as well as economic costs were discussed. Lastly, the use of an upland water source as an alternative to stream bank fencing was presented.

As suggested in this chapter, the multidisciplinary approach taken by this study is necessary in order to evaluate the effect of an off-stream water source as a stream stabilization and water quality BMP. Methods of estimating stream bank erosion and water quality must be matched with observations of cattle behavior in order to fully understand and evaluate the role and effectiveness of a water trough within a rotational grazing system. Lastly, the economic costs and benifits of these systems needs to be understood prior to accepting water troughs as a BMP.

# III. Methodology

## Experimental Design

The study took place on two farms in southwest Virginia that utilized rotational stocking. Three pastures as part of larger cow/calf grazing/production systems were investigated. A spring-fed stream originated in each pasture. Two stream/pasture systems were observed at the Bender Farm in Floyd, VA and another was observed at the River Ridge Farm located near Independence, VA.

A pre- and post-BMP comparison of the same study areas was used to evaluate the impact of providing grazing cattle with an off-stream water source on streambank stabilization (erosion), bacteria, nutrient concentrations and animal behavior. During the pre-BMP phase of the study, cattle had access to only one stream in each of the observed pastures as their source of water. After eight months, water troughs were available in the pastures and cattle had continued access to streams. At no time during the study were the cattle excluded from streams.

To provide water for the troughs, springs were developed according to design specifications of the Soil Conservation Service (1992). Water from the springs filled concrete troughs to allow the cattle to drink. Gravel pads were constructed around the troughs on each site. Since a spring development system already existed on the River Ridge Farm, overflow pipes were first removed in order to prohibit the troughs from filling with water (pre-BMP period). The overflow pipes were then reinstalled for the second phase of the study (post-BMP period). This method proved to be inappropriate as the trough would fill with approximently 1 cm of water. Cattle were also observed to get water by sucking on the inlet pipe of the trough. To resolve this problem, the overflow pipes were replaced and wooden covers were placed over the troughs in order to prohibit cattle to drink from the trough during the pre-BMP treatment period.

The number of cattle and the dates of rotation on the observed pastures were recorded. The stocking densities for each pasture, as well as the overall system stocking rate were calculated for the two farms.

Prior to the initiation of the study, monitoring equipment was installed and surveys were conducted in preparation of the project. On the River Ridge Farm, a standard rain gauge and a weighing rain guage were installed. The raingauges were read and serviced on a daily basis and maintained weekly by the farm operator. A hygrothermograph was also installed on each farm and serviced on a bi-weekly basis by the farm operator. Stream flow data were obtained by measuring the time to collect a known volume of water (3.785 L or 18.925 L.) at the pond outlet. On the Bender Farm, staff gauges were installed near the outlet of each stream to record water levels in the streams. Two cross-sectional surveys, one upstream and one downstream of the installed staff gauge, were conducted. Stream flow rating curves for each stream were developed from the cross-sectional surveys using the Manning's Equation. The staff gauge height, as well as the corresponding stream flow, were read and recorded on a biweekly basis, coinciding with water quality sampling times. Surveys of stream length and bed slope, as well as length of accessible streambank were conducted on both farms.

The three pastures were evaluated for the condition of their existing vegetation. Each pasture was surveyed on the basis of botanical composition. Approximations for total biomass (kg/ha) as well as the percentage of ground cover, including grasses, legumes and weeds were made for each community. The tall fescue (*Festucea arundinacea* Schreb.) in each vegetative community was diagnosed for the percentage of endophyte infection by the fungus *Acremonium coenophialum* (Morgan, Jones and Gams) using the procedures described by Bacon et al. (1977). Thirty tall fescue tillers were collected in the spring of 1995 following the procedures suggested by Bacon et al. (1977) on each of the three pastures. The samples were analyzed using a plant tissue staining test recommended by the Auburn University Fescue Toxicity Diagnostic Center (Alabama Agricultural Experiment Station, 1995). The botanical composition of the riparian zone was determined prior to and throughout the study.

## Site Descriptions

## Bender Farm at Floyd, Virginia

The Bender Farm is located in north-central Floyd county, Virginia, along Virginia Route #617 and lies within the East Fork of the Little River Watershed. The farm encompasses approximately 275 acres (110 ha), ranging in elevation from 1300 to 1600 ft (396 to 488 m). Eight pastures and 3 crop fields (corn, mixed grains) were found on the farm, each varying in elevation, slope and source of available water for livestock use.

The two pastures involved in this study, identified as North and South Bender, are located east of Middle Creek and between Virginia Route #679 and Virginia Route #608 (Figure 3-1). The North and South Bender pastures are part of a 114 acre (46 ha), eight paddock rotational grazing system.

In the spring of 1995, the North and South Bender pastures were divided into 2 and 3 paddocks, respectively. The area, water source provided and shade availability within each of the paddocks are shown in Table 3-1.

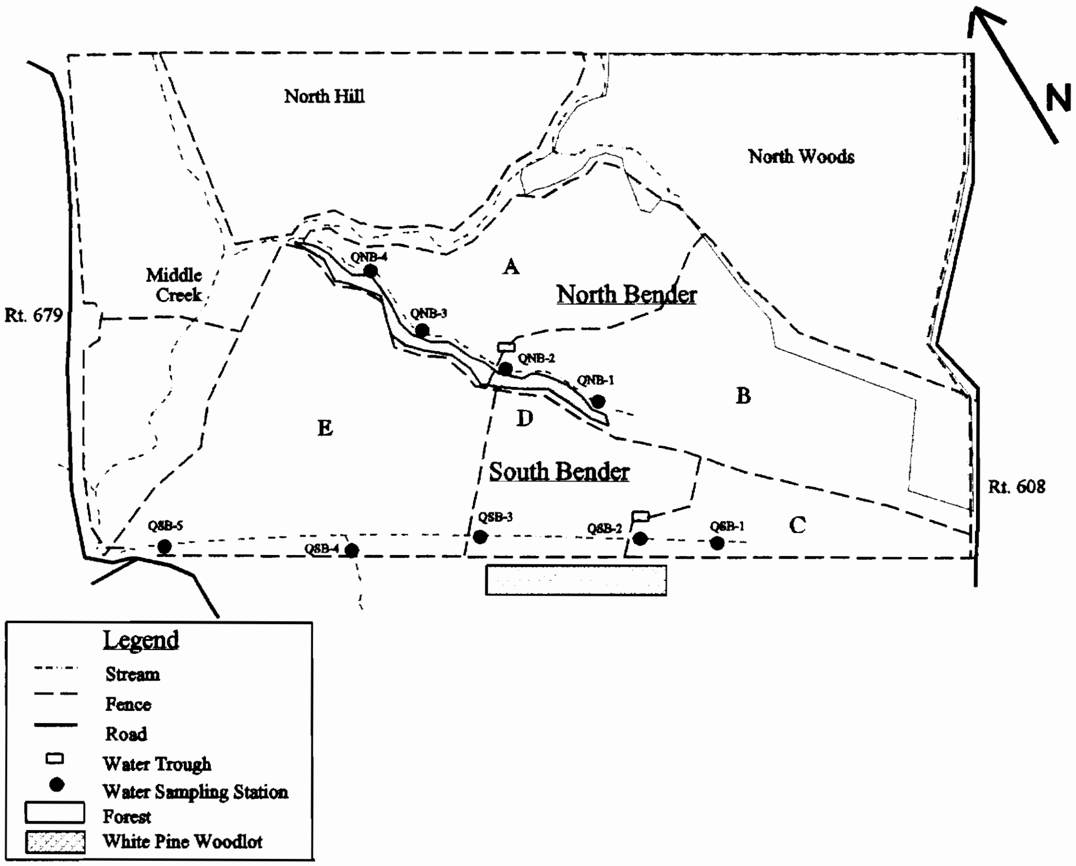


**Figure 3-1. Location of Bender Farm, Floyd, Virginia.**

**Table 3-1. Pasture and paddock descriptions: Bender Farm, Floyd, VA.**

| Pasture | Paddock | Area ac (ha) | Water Source | Shade Availability |
|---|---|---|---|---|
| North Bender | | 41(16.6) | | |
| | A | 14 (5.7) | stream and trough | along stream & abundantly w/in paddock |
| | B | 27 (10.9) | stream and trough | along stream & abundantly w/in paddock |
| South Bender | | 55 (22.3) | | |
| | C | 23 (9.3) | stream and trough | none |
| | D | 8 (3.2) | stream and trough | limited along stream & w/in paddock |
| | E | 24 (9.7) | stream | none |

**Watershed Description**

A spring-fed stream originates within both of the study pastures. The North Bender stream basin consists of pasture and forestland located north of the fence along a ridge which separates the North and South pastures and drainage basins. The North Bender stream is well defined from its source with a bedslope of 4.32% and a distance of 1400 feet (427 m). The South Bender stream basin consists primarily of pastureland but also includes row crop fields, in the east and southeast of the spring head, and a White Pine woodlot to the south (Figure 3-2). The South Bender stream is fed by a conglomerate of springs, rather than from a single spring such as the one which forms the North Bender stream. Subsequently, the channel is poorly defined for the first 350-feet (106.7-m) of the stream's 1600-ft (488- m) length (4.3% slope). This undefined stream area is characterized as possessing wide, poorly defined stream banks, a poorly drained subsoil, and supporting a range of aquatic vegetation including: Chufa (*Cyperus esculenta*), Bulrush (*Scirpus* sp.), Burdock (*Articum minus*), Cattail (*Typha latifolia*), Spotted Jewelweed (*Impatiens capensis*), and Arrow-Leaved Teartthumb (*Polygonum sagittatum*). Two areas of Speckled Alder (*Alnus rugosa*) also lie along the stream.

**Soils**

The study pastures are underlain by two deep, moderately and moderately well drained, crystalline rock and alluvium-derived soils on the 4 to 25% slopes. The majority of the pasture is underlain by Chester Loam (hydrologic soil group C) and the stream channels are composed of Delanco-Check Loam Complex (hydlogic soil group D) (VPI&SU, 1994). The surface horizon of the Chester loam is described as a moderately fine granular, friable, slightly sticky, slightly plastic, very dark grayish brown loam extending to a depth of only 4 inches (10 cm). The subsoil is characterized as a mottled, slightly plastic, friable and strongly acidic, strong brown loam, sandy, clay loam or sandy loam extending to a depth of 50 inches (127 cm). The Delanco-Check Loam Complex surface horizon is described as a friable, sticky strongly acidic, dark grayish brown fine sandy loam with common fine roots extending to a depth of 8 inches (20 cm). The subsoil is characterized as a mottled, blocky to massive structured, sticky, friable, plastic, light yellowish brown to light gray clay loam or very cobbly sandy clay loam with common fine mica flakes extending to a depth of 72 inches (183 cm). To improve pasture on both soils several suggestions were made including increasing the carrying capacity by establishing and maintaining a mixture of grasses and legumes, proper stocking rates, controlling weeds, and rotating or deferring grazing (VPI&SU, 1994). It was alos recommended that economic yields could be enhanced by applying lime and fertilizer based on soil test results (VPI&SU, 1994).

**Vegetation**

A sward of primarily cool season grasses and legumes had produced a good turf on the two study pastures. Tall fescue (*Festuca arundinacea*), orchardgrass (*Dactylis glomerata*) and Kentucky bluegrass (*Poa pratensis*) are the dominant grasses, while red clover (*Trifolium pratense*) and white clover (*Trifolium repens*) dominate the legumes. Occasional species within the pasture include timothy (*Phleum pratense*) during late spring especially within the eastern portions of both pastures, Johnson grass (*Sorghum halepense*) during the months of July and August, and broomsedge (*Andropogon virginicus*) on the steep slopes during the late summer months and continuing into winter. Common weeds included ragweed (*Ambrosia artemisiifolia*), common thistle (*Cirsium* sp.), Queen Anne's lace (*Daucus carota*), horse nettle (*Solanum carolinense*), mayweed (*Anthemis cotula*), and chicory (*Cichorium intybus*).

Shade is abundant within the North Bender pasture and streambank but is less available within the South Bender pasture. Many large White oaks (*Quercus alba*), Red oaks (*Quercus rubra*) and Black Locust are found within the North Bender pasture while Speckled alder (*Alnus rugosa*), Black Locust (*Robinia pseuda-acacia*) and Apple (*Pyrus malus*) are found along the streambanks and hill adjacent to the South Bender pasture. Shade is only available within Paddock-B of the South Bender pasture along the adjacent Eastern White pine woodlot in the morning hours and under a large apple and Red maple (*Acer rubrum*) tree during afternoon hours.

## Grazing Management

The Bender Farm is a family-owned and operated farm and produces Angus-Hereford calves for both Virginia and mid-western markets. Two gravity-fed 400-gallon (1514-L) water trough systems were installed in April, 1995. Paddock fencing for the rotational grazing system was completed during June, 1995.

A mixture of seasonal continuous (November, 1994 to April, 1995) and rotational stocking (April, 1995 to October, 1995) were used as the primary grazing methods. Cows and calves were continuously stocked on stockpiled tall fescue and were supplemented with fescue-orchardgrass-timothy hay and corn silage for the winter months. Due to an early spring drought, cattle only grazed the North Bender pasture before they were removed from the study area. Pastures were cut for hay prior to the return of cattle to the study pasture for summer grazing. Yearling heifers and steers proceeded a herd of pregnant and lactating cows with calves as a First-Last grazing system for one rotation cycle before the yearlings were removed from the study area. A complete description of stocking on the study pastures and paddocks is provided in Appendix A.

## River Ridge Farm, Independence, Virginia

River Ridge Farm is located southwest of Independence, Virginia and northeast of Mouth of Wilson, Virginia, on Virginia Route #711 along the New River in Grayson County. The farm encompasses 480 acres (194 ha), ranging in elevation from 2400 ft (732 m) along the New River to 3000 ft (915 m) on the highest ridges. Fourteen pastures exist on the farm varying in elevation, slope, and source of available water for livestock use. The study pasture involved in this study is located in the northeastern area of the farm, north of Virginia Route 711 (Figure 3-2).

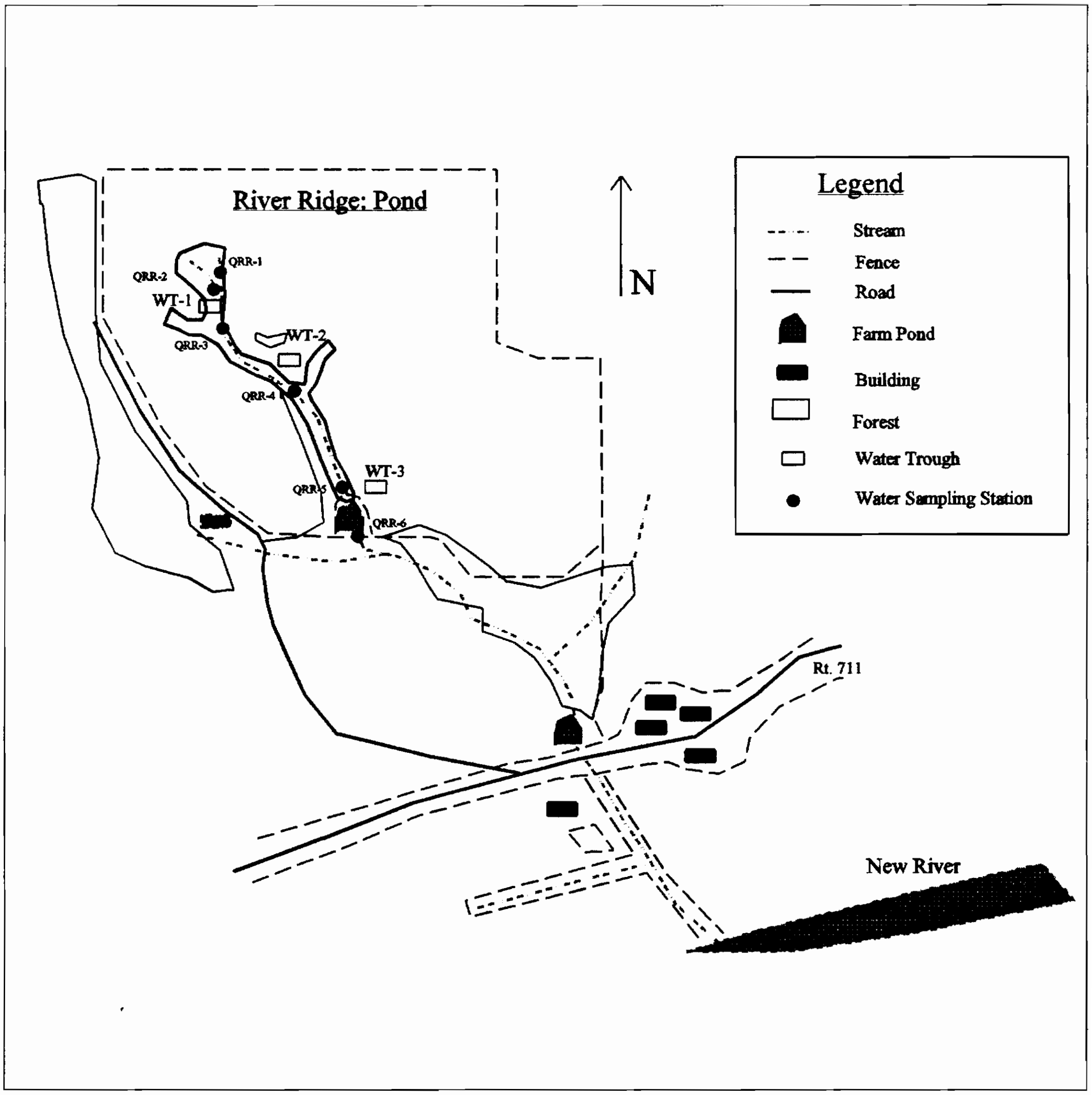


**Figure 3-2.** **Location of River Ridge Farm, Independence, Virginia.**

**Watershed Description**

The 35 acre (14.2 ha) pasture depicted in Figure 3-2 is a concave watershed with 5 to 30 percent slopes. The pasture covers approximently 98% of the watershed area and only a small portion (2%) of watershed area lies outside the pasture boundary to the west. A spring-fed stream originates and bisects the pasture. The stream originates from one source spring, however, two other springs (one west of the source spring and another east of the stream between water trough #2 and water trough #3) provide a significant amount of flow during periods of frequent rainfall. The stream is bounded by trees and shrubs including Red maple, White oak, Sassafras (*Sassafras albidum*), Speckled alder, European holly (*Ilex aquifolium*), and Eastern White pine.

The stream flows into a small farm pond, which received major repairs and reshaping during June, 1994, prior to the start of this project. Also prior to the study, fences were constructed to exclude the farm pond and the two springs which serve as the source of water for a series of three water troughs used during the post-BMP phase of the study.

**Soils**

The study pasture is underlain by well drained granite and schist derived soils (Devereux and Patteson, 1934). The area is primarily underlain by Porters Loam supporting an aggressive sward and turf. The mellow, friable, easily tilled surface horizon extends to a 6-10 inch (15-25 cm) depth and possesses a brown to grayish-brown color. The subsoil ranges from dark yellowish-brown to redish-brown clay or clay loam, extending to a depth of 24 to 30 inches (61 to 76 cm). The subsoil is described as being friable and crumbly while being readily able to be crushed down to friable mass (Devereux and Patteson, 1934). The area west of the stream can be classified as Rabun Loam. This dark-red to maroon smooth friable clay is derived from dark-colored hornblende schist or diorite rocks. The areas underlain by the Rabun soils are bare in many areas even after extensive grading, fertilization and reseeding attempts.

## Vegetation

A vigorous sward of primarily cool season grasses and legumes have produced a good turf on the majority of the pasture. Tall fescue, orchardgrass and Kentucky bluegrass are the dominant grasses, while red clover and white clover dominate the legumes. Occasional species in the pasture include timothy during late spring, and johnson grass during the months of July and August. Common weeds include the common thistle, Queen Anne's lace, horse nettle, myweed, jimsonweed and chicory. As mentioned in the previous section, the area west of the stream is underlain by Rabun soils and was much less productive than all other parts of the study pasture. The ground in this area is bare in many areas despite extensive grading, liming, fertilization and reseeding attempts in previous years.

Vegetation along the streambank is dominated by various tree and shrub species including Red maple, White oak, Sassafras, Common alder, European holly, and Eastern White pine. Other vegetation within the stream area include Henbit (*Lamium amplexicaule*), Chufa, Bulrush, Cattail, Poison Ivy (*Rhus typhina*), Raspberry (*Rubus idaeus*), and Blackberry (*Rubus allegheniensis*).

Shade within the pasture is predominantly available only along the stream. Large trees and shrubs provide extensive shade around the source spring and water trough #1 (Figure 3-2). Shade is also extensive along the ephemeral channel from the downstream spring. The shade away from the stream corridor is found in three places: 1) in a stand of White pines 50 ft. (15.2 m) north of water trough #2; 2) in a stand of locust and White oaks on the ridge west of water trough #2, and; 3) a wooded area east of the farm pond. The wooded area east of the farm pond provides the most extensive area for shade other than along the stream channel.

### Grazing Management

The River Ridge Farm is managed by the River Ridge Cattle Company and produces Brangus-Brahma calves for both Virginia and mid-western markets. A system of three gravity-fed 250 gallon (946 L) concrete water troughs was installed in the study pasture in 1985.

Mob grazing, during the months of March and October, is the primary grazing method used on the study pasture. Mob grazing can be described as allowing rotational stocking of a relatively large number of animals at a high stocking density for a short period of time (i.e. 100-200 cows and calves for 4 to 7 days) (Allen, 1991). Additionally, the study pasture along with the other areas was used during March and April, 1995, to hold cows and newborn calves until the majority of calving was complete before the start of the rotational stocking season. A complete description of stocking on the study pasture is provided in Appendix A.

## Field Research Procedures

The following section describes the field, laboratory and statistical methods which were used in the study. They are presented in the following order according to research objectives: cattle behavior, stream bank erosion, water quality analysis and economic analysis.

### Cattle Behavior

Cattle observations were randomly made three times during both treatment phases (pre- and post-BMP). Cattle observation periods were conducted continuously from sunrise to sunset on a five-minute interval. Observations were made from the cab and rear of a pick-up truck parked either off pasture, if available, or within the observed pasture at a distance which would not disturb the cattle. The number of cattle drinking from the stream or trough, within the stream or trough areas, and the percentage of herd grazing were recorded during each time interval.

The stream and trough area was defined in this study to be the distance of two adult cow lengths (3.7 - 4.6 m) from the center of the stream or the edge of the water trough. The number of animals (cows, calves, and bulls) on the observed pasture was obtained from the farm managers prior to the day of observation. Each animal was treated as individual unit, with the exception of the observation period conducted on August 22, 1995 on the South Bender Pasture where only the adult cows were counted due to the unknown number of newly born calves present.

Observations were also made between the 5-minute intervals to describe the behavior of the herd or individual animals. Notes were made pertaining to the area along stream used, size of groups watering together, distance traveled to water in relation to grazing area and closest stream or trough location and the behavior of age/sex groups within the herd.

The number of 5-minute intervals was multiplied by the number of animals observed to calculate the total cow-observations possible during the observation period. The number of animals observed, within each interval, at the stream and trough drinking and within the stream and trough areas, was summed up and divided by the number of possible cow-observations to calculate the percentage of the observation period that cattle were found to conduct the respective activity. The number of animals observed during each interval for all activities was divided by the number of animals observed, and then averaged to calculate the percentage of herd participation in each activity for the observation period. The cumulative time and the cumulative time per animal observed for each activity were calculated for the observation period by assuming each animal preformed a certain activity (i.e. drinking from the trough or stream) until the next time interval.

Since the number of cattle within the stream area included the number of animals drinking from the respective source, the percentage of the day spent in the stream area associated with activities other than drinking (i.e. grazing, walking, loafing, nursing, etc) was calculated by the following equation:

$$OA = (1 - \frac{\Sigma sd}{\Sigma sa}) \times 100 \qquad \textbf{(3)}$$

where, OA = percentage of time spent by cattle in the stream area associated with activities other than drinking from the stream.
sd = cow observations within the stream drinking.
sa = cow observations within the stream area.

Similarly, the percentage of time spent within the trough area associated with other activities was also calculated.

Comparisons between the pre- and post-BMP treatment observation periods were made by averaging the observation periods during each treatment period. The observation period with the largest number of 5-minute intervals (i.e. observations) was used as the reference observation period in order to have a common time scale for subsequent comparisons. The time intervals of the remaining observation periods were weighted in order to create a common time scale. The cumulative time per animal and the percentage of herd participation in each activity and observation period were averaged amongst the pre- and post-BMP treatment observation phases. Lastly, the percentage of difference in cumulative time per animal and the percentage of herd participation was calculated by comparing the mean and standard deviations for each activity during the pre- and post-BMP treatment periods.

## Stream Bank Erosion

Estimates of stream bank erosion and impact were made before and throughout the study. These estimates were made by installing pairs of 30-cm (1-foot) long, 13-mm (1/2-inch) diameter steel pipes along each side of the stream. The number of cross sections within each of the pastures is given in Table 3-2.

**Table 3-2. Number of cross section pairs used to measure stream bank erosion.**

| Pasture Name | # Cross Section Pairs (Sept. 1, 1994) | # Cross Section Pairs (April 15, 1995) | Length of Stream ft (m) |
|---|---|---|---|
| River Ridge Farm | 19 | 18 | 1060 (323) |
| Bender Farm - North | 11 | 10 | 1408 (429) |
| Bender Farm - South | 20 | 17 | 2310 (704) |

Pipes were placed randomly on both sides of straight, meandering, and previously crossed and non-crossed portions of the stream channel at an average spacing of 15 ft (4.6 m) along the stream. The side of the stream which was closest to the primary grazing area was denoted as the inside side of the stream. The free end of a 100 ft (32.8 m) tape measure was placed on the pipe on the outside bank of the stream, referred to as the reference stake, and was stretched across the stream to the back of the stake found on the inside bank of the stream. The tape was then stretched to a predetermined known distance before measurements along the cross section were made.

The distance from the reference stake to the outside edge of the stream bank was measured to the outside edge of the stream, inside edge of the stream and the inside edge of the stream bank using a plumb bob (Figure 3-3). All measurements of the cross section were made on the upstream side of the stretched tape. Estimates of vertical streambank erosion were not

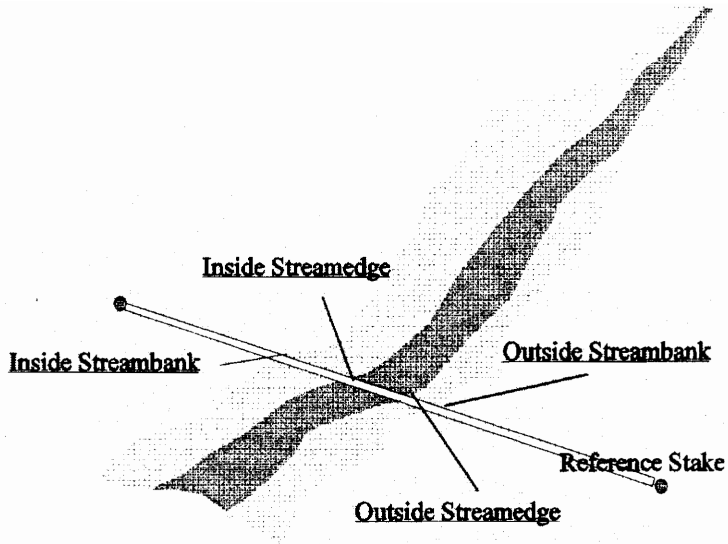


**Figure 3-3. Schematic of the methodology used for measuring a stream cross section to estimate stream bank erosion.**

made during the cross sectional survey. The type of pasture management and observations of cross-sectional areas were noted at the time of measurement.

Differences in the distance from each reference cross section stake to the stream bank and to the stream edge were calculated from the most recent measurement to the previous measurement. Changes in distances were also calculated using the current measurment to the beginning of the treatment period, and to the beginning of the study period, for post-BMP measurements. The location of the edge of the streambank was allowed only to increase through time. If the most recent measurement was found to be closer to the stream than the previous measurement the previous value was substituted for the most recent value. No adjustments were made to the edge of stream measurements. The average and standard deviations were calculated for losses during each of the periods between measurements and the total losses during the pre- and post-BMP treatment periods.

A regression analysis was preformed for each farm in order to describe which factors induced the most influence on streambank erosion during each treatment period. The seven variables used in the analysis were:

1. Measurement period,
2. Unit days during period,
3. Grazing intensity during period,
4. Percentage of period grazed,
5. Presence of stream meander,

6. Presence of shade, and
7. Presence of ramp.

Unit days was calculated by summing the number of cows and calves and multiplying the results by the number of days which the cattle grazed during the measurement period. The value for calves was weighted by a factor of 0.5 of that for cows. Grazing intensity was described as the number of unit days divided by the number of grazing days. The percentage of period grazed was described as the number of grazing days divided by the number of days between the dates of cross section measurement.

A Wilcoxon signed-rank test was performed on the total loss of stream bank, total movement in stream edge and the width of stream for each edge of bank, stream and cross section, respectively. An alpha value of 0.05 was used to detect whether a difference was found to be statistically significant.

## Water Quality

Variations in water quality parameters were evaluated prior to and after the BMPs were installed in each field. A total of eleven water quality sampling stations were used in this study. Seven stations were located at the River Ridge Farm (Figure 3-2), and four sampling stations were established along the North-Bender Farm (Figure 3-1). A total of 297 water quality samples were taken from the two farms. The following water quality parameters were evaluated from semi-monthly 500-ml water quality grab samples taken at each station:

1. total suspended solids
2. nitrate-nitrogen
3. ammonium
4. total Kjeldahl nitrogen
5. filtered total Kjeldahl nitrogen
6. orthophosphorus
7. total phosphorus
8. filtered total phosphorus
9. runoff quantity (stream flow)

In addition, monthly 100-ml samples were evaluated for the following water quality parameters:

1. fecal coliform
2. fecal streptococci
3. total coliform

In addition to the above listed parameters, samples from the River Ridge Farm were also valuated for the following minerals:

1. potassium
2. calcium
3. magnesium
4. sodium
5. sulphur

Water quality samples were collected, labeled, packed in ice and delivered to the Biological Systems Engineering Department Water Quality Laboratory at VPI&SU. All water quality samples were analyzed by the Biological Systems Engineering Department Water Quality

Laboratory at VPI&SU with the exception of the mineral samples which were analyzed by the ICP Laboratory supported by the Crop, Soil and Environmental Sciences Department at VPI&SU. The data quality standards for the nutrients analyzed are provided in Table 3-3.

The semi-monthly water quality parameters were statistically evaluated similarly to the methods described by Spooner et al. (1985). The concentrations of all parameters expressed in ppm (mg/L) were evaluated at each sampling station (Appendix B). The concentrations of the three fecal bacteria were also evaluated in terms of colonies per 100 mL of water. Due to the skewness of the data, the non-parametric Wilcoxon signed rank sum test was used to evaluate each parameter rather than the Student t-test or regression comparison methods suggested by Spooner et al. (1985).

The nutrient and mineral samples from the outlet of each stream (QRR-5 and QNB-4) were also evaluted in terms of their loading and flow-weighted concentration. Pollutant loading (kg) at each of the stream outlets was calculated by multiplying the concentration by the flow observed at the time of sampling and the number of days since the last sampling date. In order to evaluate pollutant loading in terms of the volume of observed rainfall, the mass of pollutant was then divided by the amount of rainfall (cm) recorded since the last sampling date. If no rain had occured since the last sampling date, the mass was carried over to the next sampling time where rainfall was recorded. The pollutant loadings for each outlet and treatment period were then evaluted using the non-parametric Wilcoxon signed rank sum test. Flow-weighted concentrations (mg/L) for each treatment period were calculated by summing the mass of each pollutant (kg) and dividing it by the total flow volume observed during the

## Table 3-3. Data quality standards for laboratory sample analysis.

| Parameter | Detection Limit (mg/l) | Percent Recovery | Precision (mg/l) | QC Protocol* | Method |
|---|---|---|---|---|---|
| Ammonia ($NH_3$ - N) | 0.01 | 98 - 102% recovery | ± 0.06 | 1 dup. per 20 samples<br>1 EPA QA-QC standards per 40 samples<br>1 spike per 40 samples<br>1 blank run daily | EPA 350.1 |
| Nitrate ($NO_3$ - N | 0.05 | 96 - 100% | ± 0.026 | 1 dup. per 20 samples<br>1 EPA QA-QC standards per 40 samples<br>1 spike per 40 samples<br>1 blank run daily | EPA 353.2 |
| Orthophosphate ($PO_4$ - P) | 0.01 | 89 - 94% | ± 0.013 | 1 EPA QA-QC standards per 40 samples<br>1 spike per 40 samples<br>1 blank run daily | EPA 365.1 |
| TKN | 0.1 | 97 - 101% | ± 0.126 | 1 dup. per 17.5 samples<br>2 EPA QA-QC standards per 35 samples<br>1 blank per 35 samples<br>1 spike per 35 samples | EPA 351.2 |
| Total-P | 0.05 | 91 - 94% | ± 0.056 | 1 dup. per 17.5 samples<br>2 EPA QA-QC standards per 35 samples<br>1 blank per 35 samples<br>1 spike per 35 samples | EPA 365.1 |
| Total Suspended Solids | 0.02 | ± 5% relative error | ± 0.74 | 1 dup. per 40 samples<br>1 blank per 40 samples<br>1 EPA standard per 200 samples | EPA 160.2 |
| Fecal/Total Coliform (Membrane filtration) | | 95% confidence limit | | 1 dup. for each sample | APHA 9221 |
| Fecal Strep (Membrane filtration) | | 95% confidence limit | | 1 dup. for each sample | APHA 9230 |
| Minerals | | ± 10% relative error | | 1 dup. per 20 samples<br>1 standard per 5 samples | ICP |

* The QA protocol was designed as a minimum allowed QC procedures to follow based on the data quality objectives for this project. Detection limits are lab values based on the height of recorder noise at maximum sensitivity. (Gas Chromatograph, Dr. H. McNair, 1985 ACS Shortcourse publication).

study period ($m^3$). The percent of change, in loading and flow weighted concentration, which occured during the post-BMP treatment period was then calculated for each pollutant.

Statistical comparisons were also performed to determine if a statistical difference existed between the water found in a spring-fed trough and in an adjacent stream. Such a difference in water quality may account for an observed preference of cattle to drink water from the trough rather than from the adjacent stream. Such a difference may also suggest a benefit to cattle which utilize an off-stream water source as their primary water source even when they have equal access to an adjacent stream. The analysis was preformed by comparing the average concentrations from WT3 and QRR-6 on the River Ridge Farm (Figure 3-2) during the post-BMP period.

The effectiveness of the River Ridge farm pond in reducing water pollutants was also evaluated. The test was preformed by comparing the pre- and post-BMP average and flow weighted concentrations and loadings from the pond inlet (QRR-5) and the pond outlet (QRR-6).

## Economic Analysis

The economic cost of water development on the two study farms in southwest Virginia was compared to the cost of implementing proposed practices for reducing herd impact on stream stabilization and water quality. The impact of various proposed management practices, i.e. stream bank fencing, was evaluated on the Bender and River Ridge farms. The cost of materials, installation, maintenance and the loss of land from production was compared, at various buffer zone distances from the stream, to the cost of installing the proposed BMP.

Farm and pasture boundaries, acreage, and stream length were located and estimated from aerial photographs provided by the Floyd and Grayson county Agricultural Stabilization and Conservation Service (ASCS) offices, or United States Geoligical Survey (USGS) quadrangle maps. Four fixed-width buffer lengths [10-ft (3-m), 50-ft (15-m), 100-ft (30-m), 200-ft (60-m)] were used. Two variable-width combinations utilizing the four buffer lengths in terms of the order of the stream in which they are protecting were also compared. For the first buffer zone combination, referred to as Fencing BMP-1, all streams of first and second order were assumed to have buffer lengths of 50-ft. Third order streams were given buffer lengths of 100-ft and streams larger than third order were assumed to be protected by fenced buffers of 200-ft. The second buffer combination, Fencing BMP-2, was the same as Fencing BMP-1, except that all the streams equal to or greater than third order were protected with 100-ft fenced buffers.

The area of the four buffers and the perimeter of fencing required were calculated by assuming a buffer distance from an average stream edge and the fencing perimeter located at a distance equal to the buffer length away from the stream origin. Buffers for pastures along the New River on the River Ridge Farm were calculated by assuming only a one sided fenced perimeter along the river.

The cost of fencing, fence maintenance, and land rental fees was determined by using data provided by the NRCS and Virginia Cooperative Extension Service (Hunnings, 1994). A four-strand barbed wire fence at a cost of $1.30 per foot of fencing was used for all calculations. The $1.30 cost includes all materials and labor. The cost of fence maintenance for a twenty year design life was assumed to be ten percent of the initial cost or $0.13 per foot. The cost of lost grazing area, within the fenced buffer, was assumed to be $15.00 per acre per year (Hunnings, 1994). The rental cost over the design life of the fence would equal $300.00 per acre of lost grazing area. No cost of perimeter fencing, maintenance or cost of lost area was accrued when 69% or greater of the grazing area was lost when estimating the cost for Fencing BMP 1 and 2.

The cost of water development was estimated for the two farms. The cost of water development for each pasture in grazing production at the time of the study was calculated by estimating the cost to install the water system already in place, estimating the cost of a planned water development, or estimating the cost of an unplanned water development. Two types of water development systems for grazing cattle were used in this study: spring development and low-flow solar pumps. The itemized cost of the two types of systems was determined by using the estimates provided by the NRCS and is presented in Table 3-4.

The actual cost of water development for the two types of systems could vary between sites. This is especially true for the spring development sites which would require a specific amount of vertical fall from the captured spring to a suitable water trough location. In some sites a trough location could be found 75 ft (23 m) away from the captured spring, while on another site a piping distance of 500 ft (152 m) may be required to achieve the required vertical fall. Therefore, a 300 ft (91 m) piping distance was assumed for both types of systems on all sites. The cost of installing stream bank fencing according to the six buffer scenarios and the cost of water development on the two farms was compared in terms of total cost of implementing the practices. Comparisons were also made in terms of cost per acre, per foot of stream, and per water trough to be installed.

**Table 3-4. Itemized cost of spring development and low-flow solar pump water development systems for grazing cattle.**

| System Type | Componet | Material | Unit | Cost |
|---|---|---|---|---|
| Spring Development | Development | Backhoe | 15 hours | $675.00 |
| | | Concrete | 2 yards | $103.34 |
| | | 4" PVC Sch. 40 Pipe | 10 feet | $13.10 |
| | | 4" Corrugated Drain Tile | 40 feet | $16.00 |
| | | Gravel | 10 tons | $80.00 |
| | | Collection Bowl | | $50.00 |
| | | Labor | 20 hours | $100.00 |
| | Trough | Trough (400 gallon) | | $438.00 |
| | | Concrete | 3 yards | $155.00 |
| | | 12" Corrugate Plastic Pipe | 3 feet | $17.00 |
| | | Gravel | 4 tons | $32.00 |
| | Pipeline | Ditching, Pipe Installation & Covering | foot | $1.07 |
| | | 1" 160 PSI Plastic Pipe | foot | $0.40 |
| | Spring-Head Fencing | 4-Strand Barbed Wire | foot | $1.30 |
| | Re-Seeding | Seed, Fertilizer, Lime & Mulch | | $175.00 |

**Table 3-4 (continued). Itemized cost of spring development and low-flow solar pump water development systems for grazing cattle.**

| System Type | Componet | Material | Unit | Cost |
|---|---|---|---|---|
| Low-Flow Solar Pump | Solar System | Low-Flow Pump (24 VDC): 1-4 GPM, 60 Watt Solar Panels (24 VDC), Wiring, Voltage Booster & Solar Panel Ground Mount | | $1,700.00 |
| | | Solar Tracker | | $475.00 |
| | Water Collection | Backhoe | 7.5 hours | $338.00 |
| | | Concrete | 2 yards | $103.34 |
| | | 4" PVC Sch. 40 Pipe | 10 feet | $13.10 |
| | | 4" Corrugated Drain Tile | 40 feet | $16.00 |
| | | Gravel | 10 tons | $80.00 |
| | | Collection Bowl | | $50.00 |
| | | Labor | 10 hours | $50.00 |
| | Trough | Pre-Cast Concrete Reservoir (1,500 gallon) | | $890.00 |
| | | Backhoe | 2 hours | $90.00 |
| | Pipeline | Ditching, Pipe Installation & Covering | foot | $1.07 |
| | | 1" 160 PSI Plastic Pipe | foot | $0.40 |

# IV. Results and Discussion

In this chapter results obtained on fescue toxicity, cattle behavior, stream bank erosion, water quality and the economic analysis are presented. The effect of the BMP in reducing cattle's impact on stream bank erosion and water quality is also discussed.

### Fescue Toxicity

The results of the tissue stain test of tall fescue samples, for the endophyte *Acremonium coenophialum*, for the Bender and River Ridge farms are presented in Table 4-1. The table also provides the daily gain loss which would be expected as compared to cattle which were fed endophyte-free fescue.

**Table 4-1. Percent of endophyte infection and loss of gain for the Bender and River Ridge farms.**

| Farm | Pasture | % Fescue in pasture | Endophyte Infection (%) | Gain lost as compared to cattle grazing endophyte-free fescue (lbs/day) |
|---|---|---|---|---|
| Bender | North | 40 | 72 | 1.44 |
| Bender | South | 45 | 78 | 1.56 |
| River Ridge | Pond | 40 | 77 | 1.54 |

The percent of infection of the endophyte *Acremonium coenophialum* within the three pastures involved in this study was found to be "probably damaging" by the Fescue Diagnostic Center at Auburn University. Due to the high percentage of endophyte infection on the three study pastures considerations of the possible effects of fescue toxicosis on cattle behavior, stream bank erosion and water quality should be made before assessing the effect of the BMP.

## Cattle Behavior

In this section the results of the three day long observations during the pre- and post-BMP treatment phases are presented. Observations of cattle behavior were made on 5-minute time intervals throughout the day. The percentage of cattle grazing, the number of cattle within the stream and trough areas and the number of cattle drinking from the stream or trough was recorded during each 5-minute interval (Appendix C). The stream and trough areas were defined as the length of two adult cows or approximately 3.7 - 4.6 m.

The percentage of the cow-day (5:30 am to 8:30 pm) where one or more cows was observed in the stream area is presented in Table 4-2. Cattle were found to be present in the stream area an average of 56% of the day during the pre-BMP period and 43% of the day during the post-BMP treatment period. Information on the presence of cattle in the stream area, regardless of the observed activity, during the pre- and post-BMP periods is illustrated in Figure 4-1.

The results presented in Figure 4-1 show the reduction in cattle use of the stream area during the post-BMP period, due to the presence of an off-stream water source. The greatest percentage of cattle use of the stream area during the pre- and post-BMP periods were found to be 17% and 4%, respectively. Peak percentage of herd use of the stream area during the post-BMP treatment period was 76.5% less than the pre-BMP period. The stream area during the post-BMP period was found to be used by only 4% of the herd.

**Table 4-2. Percentage of time spent in the stream area by one or more cow during the pre- and post-BMP period.**

| Date | Farm | Percentage of day where one or more cow was observed in the stream area |
|---|---|---|
| Pre-BMP | | |
| 11-22-94 | SB | 65 |
| 12-03-94 | RR | 51 |
| 1-10-95 | NB | 51 |
| Average | | **56** |
| Post-BMP | | |
| 6-29-95 | RR | 46 |
| 8-22-95 | SB | 55 |
| 9-26-95 | RR | 28 |
| Average | | **43** |

NB: North Bender; SB: South Bender; RR: River Ridge

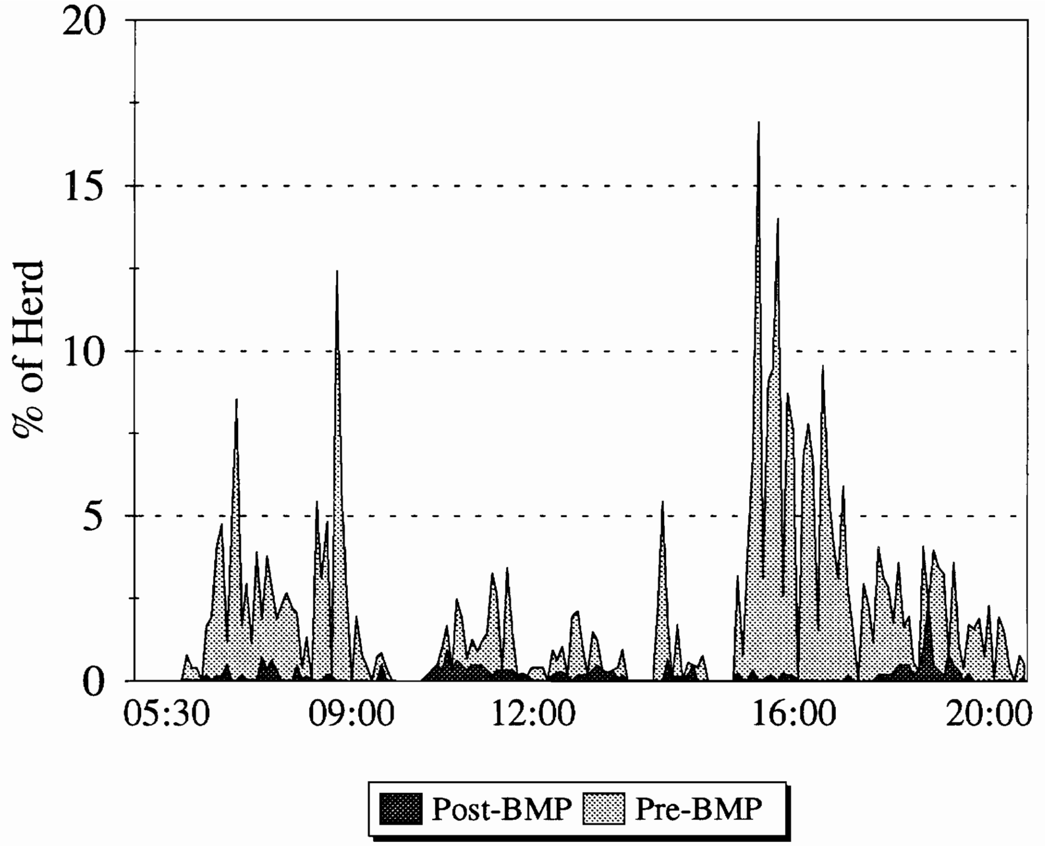


**Figure 4-1. Cattle use of the stream area during pre- and post-BMP periods.**

Table 4-3 shows the average percent of animals observed drinking from the stream or trough or found within the stream or trough areas between 5:30 am to 8:30 pm. The table includes values from all cow-day observations for both the pre- and post-BMP periods. The average daily herd use drinking from the stream during the pre-BMP and post-BMP periods were 1.06% and 0.03% of the observed cow-day, respectively. A 97.5% reduction in average daily herd use of the stream as a source of drinking water resulted due to the presence of an off stream water source. Average daily herd use of the stream area for all uses, including drinking water, during the pre- and post-BMP periods were 1.95% and 0.16% of the observed cow-day, respectively,. The average daily herd use of the stream area was reduced by 91.9% as a result of BMP installation.

The average percent of the herd drinking from the trough or spending time in the trough area was 0.30% and 0.64%, respectively, of the observed cow-day. The results show a definite reduction in the time which cattle spent in the stream area and in the use of the stream as a drinking water source during the post-BMP period. These values represent the average percentage of herd which involved in the respective activities during the observation period. The figures do not account for the length of time spent by the animals during each activity or the number of cattle which was involved with a certain activity at a specific time or during the cow-day.

Table 4-3. **Average percent of herd use of the stream and trough areas and percent of herd observed to be drinking from the stream or trough.**

| Date | Farm | Percent of herd drinking from stream | Percent of herd in stream area | Percent of herd drinking from trough | Percent of herd in trough area |
|---|---|---|---|---|---|
| Pre-BMP | | | | | |
| 11-22-94 | SB | 0.912 | 1.981 | NA | NA |
| 12-03-94 | RR | 1.106 | 1.808 | NA | NA |
| 1-10-95 | NB | 0.901 | 1.872 | NA | NA |
| Average | | **1.062** | **1.945** | NA | NA |
| Post-BMP | | | | | |
| 6-29-95 | RR | 0.069 | 0.399 | 0.777 | 1.688 |
| 8-22-95 | SB | 0.002 | 0.015 | 0.014 | 0.022 |
| 9-26-95 | RR | 0.003 | 0.004 | 0.004 | 0.008 |
| Average | | **0.027** | **0.158** | **0.299** | **0.641** |
| Percent Reduction | | **97.5** | **91.9** | NA | NA |

NB: North Bender; SB: South Bender; RR: River Ridge, NA: Not Applicable

The average cumulative time per cow spent within the stream drinking and stream area are depicted in Figures 4-2 and 4-3, respectively. The average time spent per cow within each of the observation periods is presented in Table 4-4. The average length of time spent by each cow drinking from the stream was 6.72 minutes and 0.72 minutes for the pre- and post-BMP periods, respectively. This corresponds to an 89.4% reduction in length of time each cow was drinking from the stream. These reductions are similar to those reported by Clawson (1993) who observed a drop from 4.7 to 0.9 minutes per cow when cattle were drinking only from a stream and when an off stream water source was available, respectively.

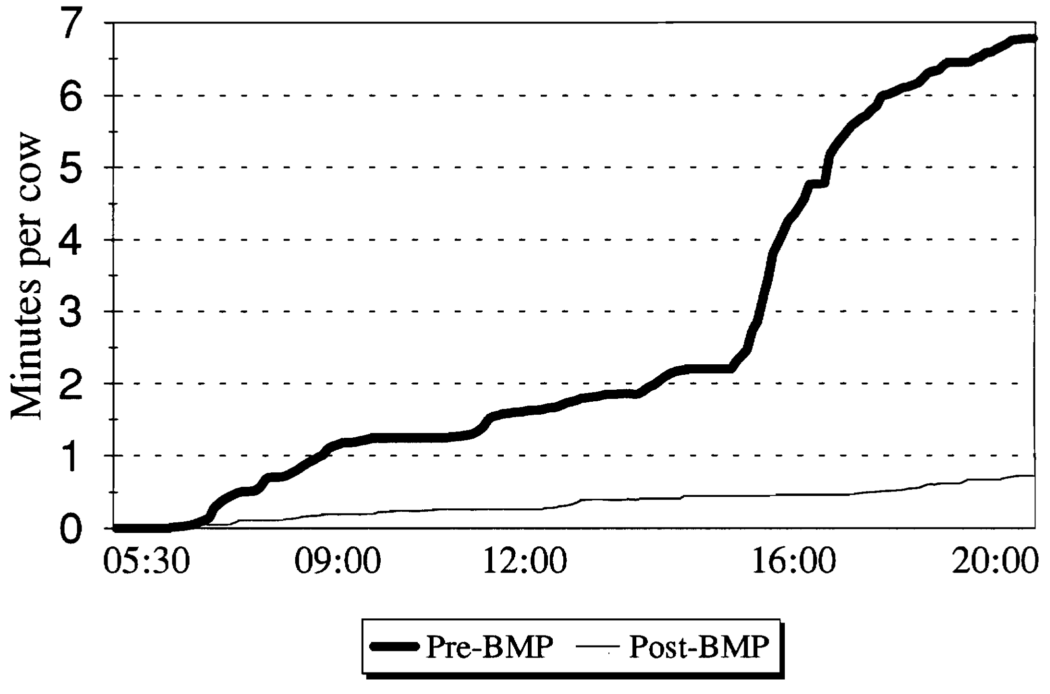


**Figure 4-2. Cumulative time per cow spent in the stream drinking for an average cow-day.**

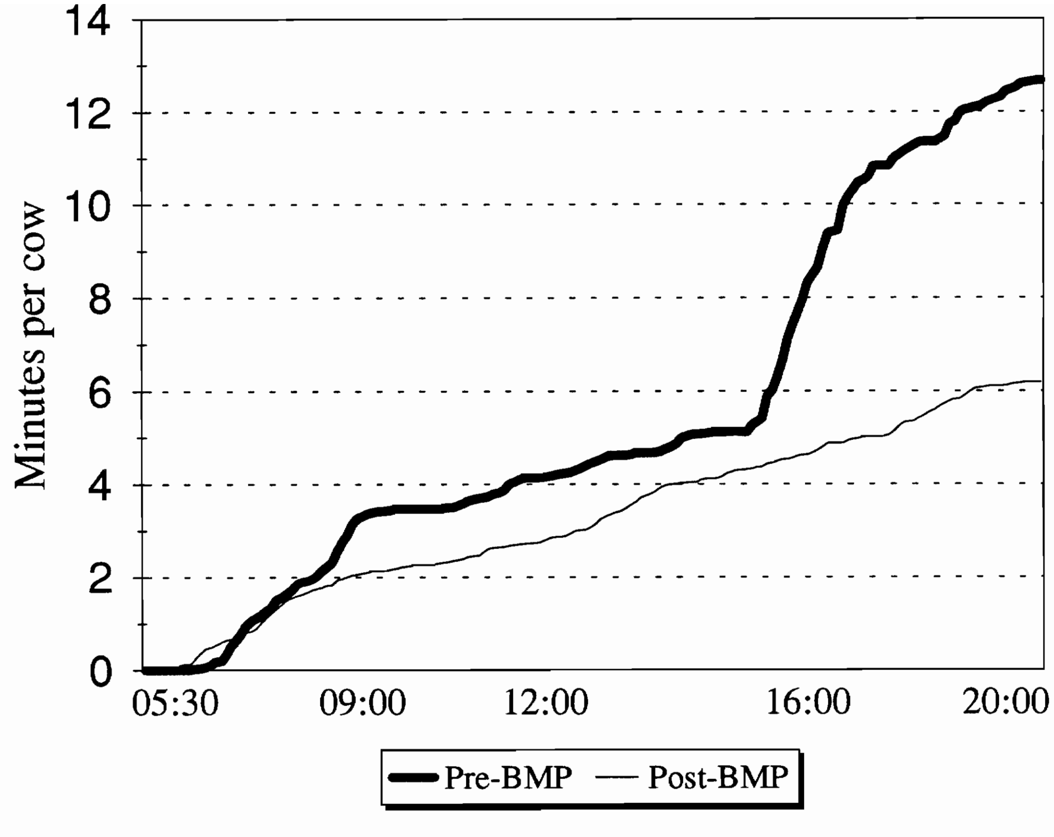


**Figure 4-3. Cumulative time per cow spent in the stream area for an average cow-day.**

**Table 4-4. Comparison of length of time spent by each cow drinking from the stream and being in the stream area.**

| Date | Farm | Cumulative time per cow drinking from the stream | Cumulative time per cow being in the stream area |
|---|---|---|---|
| Pre-BMP† | | | |
| 11-22-94 | SB | 6.20 | 13.33 |
| 12-03-94 | RR | 6.62 | 12.71 |
| 1-10-95 | NB | 7.35 | 12.02 |
| Mean | | **6.72** | **12.69** |
| Post-BMP‡ | | | |
| 6-29-95 | RR | 0.62 | 3.55 |
| 8-22-95 | SB | 1.31 | 12.33 |
| 9-26-95 | RR | 0.24 | 2.80 |
| Mean | | **0.72** | **6.19** |
| % Reduction in Mean | | **89.4** | **51.2** |

All values expressed in minutes. NB: North Bender; SB: South Bender; RR: River Ridge
†: without water trough. ‡: with water trough.

The average length of time spent by each cow within the stream area was found to drop from 12.69 minutes to 6.19 minutes during the pre- and post-BMP treatment periods, respectively. This corresponds to a reduction of 51.2% in the average cumulative time spent by each cow within the stream area due to the availibility of an off-stream water source for grazing cattle.

The pre-BMP values for cumulative time spent by each cow drinking from the stream and being in the stream area were less variable than those observed for the post-BMP period. This variation can be largely explained by the pasture conditions in the South Bender Pasture at the time of the post-BMP (8/22/95) observation. As previously discussed, the majority of the pasture was cut and baled for hay prior to cattle entering the pasture. It can be construed that the decreased amount of forage available within the main grazing area forced the cattle to seek vegetation within the stream corridor. Thus, the large value obtained for cumulative time per cow spent in the stream area mainly reflects the effect of the farm forage management practices rather than the BMP. The moderately increased values in cumulative time per cow spent drinking from the stream on the South Bender Farm reflects increased use of the stream as a drinking water source when the adjacent stream area is used for forage, as compared to the other post-BMP observations. It is believed that with better cattle/forage management, the average cumulative time per cow spent in the stream area or drinking from the stream would be reduced. This should result in a larger reduction in cumulative time spent within the stream area and use of the stream for drinking.

The average length of time drinking at the water trough and time spent in the trough area during the post-BMP treatment period are given in Table 4-5. The average length of time spent per cow drinking from a water trough and within the trough area was found to be 7.24 and 12.98 minutes, respectively. The high value (11.77 min.) recorded for cows drinking from the trough at the South Bender Farm may be due to the increased demand for water experienced by the pregnant and newly lactating cows. The lower cumulative time (6.00 min.) observed per cow in the trough area at the River Ridge Farm is believed to be due to cattle meeting their water needs from rain-coated forage during grazing rather than depending on the available trough or stream for water.

**Table 4-5. Comparison of time spent drinking from the trough and being in the trough area during the post-BMP treatment period.**

| Date | Farm | Cumulative time per cow at the trough drinking (min.) | Cumulative time per cow in the trough area (min.) |
|---|---|---|---|
| 6-29-95 | RR | 6.9 | 15.02 |
| 8-22-95 | SB | 11.77 | 17.92 |
| 9-26-95 | RR | 3.01 | 6.00 |
| Average | | **7.24** | **12.98** |

NB: North Bender; SB: South Bender; RR: River Ridge

The preference of the cattle to drink from an alternative water source over a stream is illustrated in Figure 4-4. The figure represents an average of the three post-BMP observation periods. The increased use of streams during the post-BMP period between the hours of 18:00 and 19:00 is due to insufficient capacity of the troughs during periods of high demand. Several times at the River Ridge Farm, especially on 6/29/95, water troughs were observed to be drank dry. The 760-L (200-gal) troughs would then have to be refilled by the cascading gravity flow of water from one trough to another. At one point the third trough was dry and cattle either waited for the trough to slightly fill with water or walked 100 m upstream to the

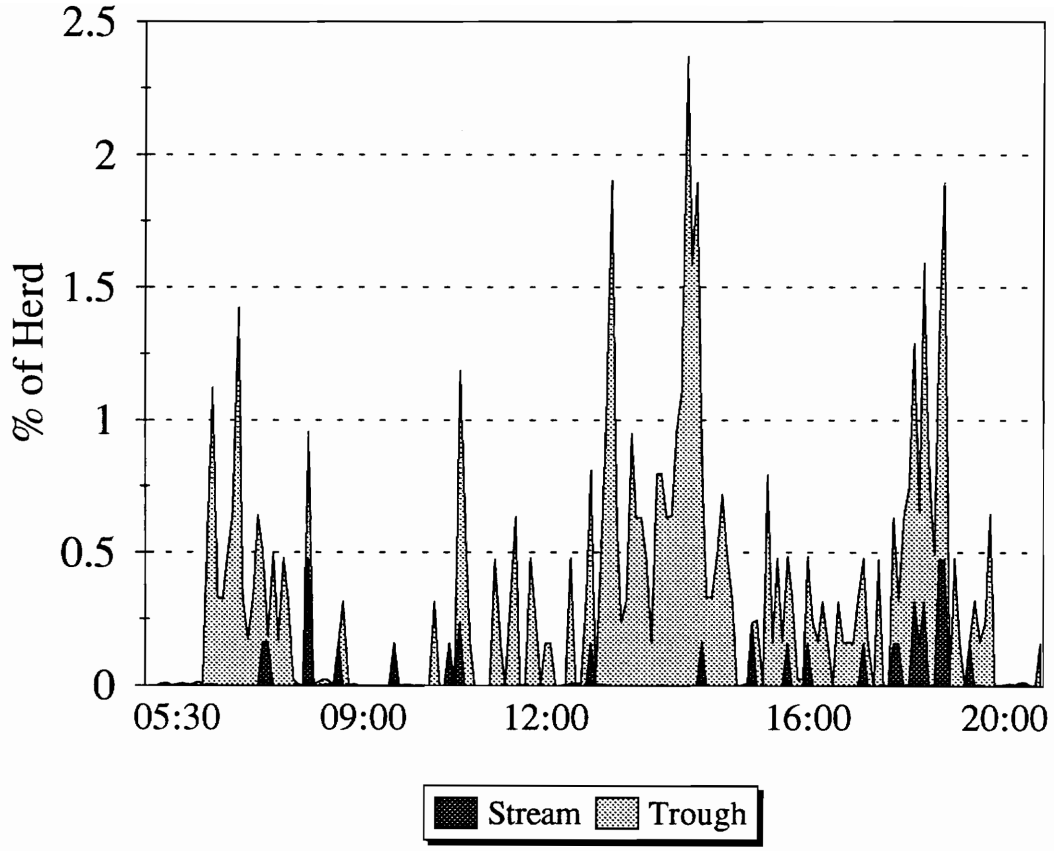


**Figure 4-4. Cattle water source preference during the post-BMP treatment period.**

next closest trough. Only five cows (3% of the herd) were observed during that time to select the stream (35 m away) as their source of water rather than continuing to the mid-pasture trough. The lack of sufficient storage for the watering systems can be identified as the reason for the increase in drinking from the stream during the later hours of the observation periods. The 1520- L (400-gal) water troughs installed on the Bender Farm were found to have sufficient capacity.

Table 4-6 further describes the observed cattle preference for the off-stream alternative water source during the post-BMP periods. The presence of an off stream water source for grazing cattle reduced the time spent by the cattle in the stream watering by an average of 91.7%, assuming the time which cattle spend drinking remains constant regardless of the source. This assumption seems to be reasonable since the average cumulative time per cow spent drinking from the stream, without a trough provided, and drinking from a water trough are comparable with mean values of 6.78 minutes and 7.24 minutes, respectively (Table 4-4 & 4-5). Godwin (1994) also found no significant difference between the cumulative time cattle or horses spent drinking from a stream, when an off stream water source was not provided, and the time spent drinking from an off-stream water source when it was made availible. It can be concluded that the presence of an off stream water source reduced the time which cattle spend drinking from the stream by 91.7%.

**Table 4-6. Off-stream water source preference during the post-BMP treatment period.**

| Date | Farm | Reduction in % of time spent drinking in stream due to trough installation |
|---|---|---|
| 6-29-95 | RR | 92 |
| 8-22-95 | SB | 90 |
| 9-26-95 | NB | 93 |
| Average | | **91.7** |

NB: North Bender; SB: South Bender; RR: River Ridge

The use of the stream and trough areas for activities other than drinking was highly significant especially after the installation of an off stream water source (Table 4-7). The percentage of time in the stream area spent on activities other than drinking during the pre-BMP period was 38% while the value for the post-BMP period was 88%. The reason for the increase is two fold. First, the time spent watering in the stream was previously reported to decrease by 89.4% in the presence of an alternative water source. Second, the stream area on the River Ridge Farm was used heavily for shade during the hot portions of the day. Also, as previously mentioned, the stream area within the South Bender Farm was utilized for its forage resources and as a traveling zone between the main grazing area and the morning time shade area located south of the stream and adjacent to the white pine woodlot on the neighboring property. These results are supported by the findings of Clawson (1993) who found that loafing accounted for 91.2% of the time spent in the stream corridor while grazing accounted for only 2.1%.

**Table 4-7. Percent of cow-day in the stream and trough areas spent on activities other than drinking.**

| Date | Farm | Treatment | % of cow-day in stream area spent on activities other than drinking | % of cow-day in trough area spent on activities other than drinking |
|---|---|---|---|---|
| 11-22-94 | SB | Pre-BMP | 53 | NA |
| 12-03-94 | RR | Pre-BMP | 32 | NA |
| 1-10-95 | NB | Pre-BMP | 27 | NA |
| Average | | | **38** | NA |
| 6-29-95 | RR | Post-BMP | 83 | 53 |
| 8-22-95 | SB | Post-BMP | 89 | 34 |
| 9-26-95 | RR | Post-BMP | 91 | 48 |
| Average | | | **88** | **45** |

NB: North Bender; SB: South Bender; RR: River Ridge, NA: Not Applicable

Even though the results of this study and those of Clawson (1993) may be different, both studies illustrate that while an off stream water source is extremely effective in reducing the time spent in the stream drinking, the dependency of cattle on the stream area still exists. This dependency is mainly due to an increase in the percent of time spent in the stream area on activities other than drinking, even though the total use of the stream area was reduced.

## Stream Bank Erosion

The results of measurements taken from randomly placed cross sections along two streams on the Bender Farm and one stream on the River Ridge Farm are presented in this section. Measurements were taken three times during each treatment period in order to estimate the amount of stream bank erosion, stream channel movement and stream width variation which took place due to the influence of grazing cattle and the presence of an off-stream water source (Appendix D).

The average values for stream bank erosion for the three streams is presented in Table 4-8.

**Table 4-8. Results of stream bank cross-sectional surveys.**

| | River Ridge | | | North Bender | | | South Bender | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-BMP | Post-BMP | D[1] | Pre-BMP | Post-BMP | D[1] | Pre-BMP | Post-BMP | D[1] |
| P -value | | | 0.006* | | | 0.020* | | | 0.014* |
| mean | 2.04 | 0.48 | 1.68 | 0.79 | 0.31 | 0.54 | 1.35 | 0.85 | 0.53 |
| st. dev. | 3.21 | 0.56 | 3.25 | 0.95 | 0.39 | 1.03 | 1.82 | 1.56 | 2.50 |
| % Reduction | | **76.5** | | | **60.8** | | | **36.9** | |

Means and standard deviations area expressed in terms of feet of stream bank erosion. (*) significant at 0.05 level.
D[1] = Difference between pre- and post BMP values.

The average stream bank loss during the pre-BMP treatment period was found to be 2.04 ft (0.62 m), 0.79 ft (0.24 m) and 1.35 ft (0.41 m) for the River Ridge, North Bender and South

Bender streams respectively. The average post-BMP losses were 0.48 ft (0.15 m), 0.31 ft (0.10 m), and 0.85 ft (0.26 m), respectively. This resulted in reductions of 76.5%, 60.8% and 36.9% during the post-BMP treatment period. The losses which occurred during the post-BMP period on the three farms were significantly ($\alpha = 0.05$) less than those which occurred during the pre-BMP treatment period.

The availability of shade, the degree of stream crossing, and the abundance of forage within the stream area can largely explain the differences in percent reductions of stream bank erosion on the three streams. The South Bender stream was crossed more than the other streams observed. Firstly, the stream was crossed frequently in order for cattle to move from the primary grazing area (on the north side of the stream) to shade during the morning and early afternoon hours. The River Ridge and North Bender pastures both possess shade away from the stream area. Secondly, there are no stream crossings present along the South Bender stream, as there was on the River Ridge Farm. Finally, the area south of the South Bender stream, although significantly smaller than the primary grazing area provided a significant amount of forage. As stated earlier, the reduction in area, was due to the primary grazing area north of the stream being cut for hay prior to grazing. This harvesting produced a gradient which forced the cattle to utilize the largely lower quality, but more abundant forage and browse along the stream corridor. The repeated daily crossings resulted in erosion of the stream banks which are the product of factors independent of those provided for by the BMP.

Two other tests were conducted in order to describe the impact of cattle on the stream area during the two BMP treatment phases. The degree of stream channel movement during each treatment period is depicted in Table 4-9. The table illustrates the average distance (ft) which the edges of stream moved during the two treatment periods. The average stream channel movement within the pre-BMP treatment period was 1.36 ft (0.42 m), 0.79 ft (0.24 m) and 0.53 ft (0.16 m) on the River Ridge, North Bender and South Bender streams, respectively. The corresponding post-BMP averages were 0.87 ft (0.265 m), 0.31 ft (0.095 m), and 0.57 ft (0.174 m) for the three streams, respectively, which resulted in a 36.2%, 60.8% and 7.5% percent reductions in average stream channel movement during the post BMP treatment period. However, differences were statistically significant only on the North Bender stream. This reduction in average stream channel movement shows that the water troughs installed as BMPs were effective on only one stream in stabilizing the movement of the stream channel due to influence of cattle.

**Table 4-9. Results of stream channel movement.**

| | River Ridge | | | North Bender | | | South Bender | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-BMP | Post-BMP | $D^1$ | Pre-BMP | Post-BMP | $D^1$ | Pre-BMP | Post-BMP | $D^1$ |
| P -value | | | 0.811 | | | 0.053* | | | 0.260 |
| mean | 1.36 | 0.87 | 0.49 | 0.79 | 0.31 | 0.48 | 0.53 | 0.57 | -0.04 |
| st. dev. | 1.90 | 0.71 | 2.20 | 0.91 | 0.30 | 0.95 | 0.68 | 0.62 | 0.57 |
| % Reduction | | **36.2** | | | **60.8** | | | **-7.5** | |

Means and standard deviations area expressed in terms of feet of stream bank erosion. (*) significant at 0.05 level. $D^1$ = Difference between pre- and post-BMP values.

The average values for the variation of stream widths on the three streams during the pre- and post-BMP treatment periods are presented in Table 4-10. The average stream width variation during the pre-BMP period was 1.84 ft (0.56 m), 1.58 ft (0.48 m), and 1.69 ft (0.52 m) for the River Ridge, North Bender and South Bender streams, respectively. The corresponding post-BMP averages were 1.81 ft (0.55 m), 1.40 ft (0.43 m), and 1.51 ft (0.46 m), respectively. This resulted in a 1.6%, 11.4% and 11.2% decrease in the variation in the stream channel width during the post-BMP treatment period. However, no significant differences in average stream width between the two treatments were found at the $\alpha = 0.05$ level. The results suggest that the widths of the stream on each farm were not affected by the presence of cattle, regardless of the presence or absence of an alternative water source. In addition , since the variation in stream width of the North Bender Farm was not significant, results suggest that the width of the channel was not significantly changed while the channel laterally changed its position between the pre- and post-BMP treatment periods.

The results of the regression analysis on the three farms during the pre-BMP period showed that the regression variables only slightly explained the level of erosion observed. The coefficient of determination ($R^2$) and the adjusted coefficient of determination (Adjusted $R^2$) values ranged from 0.01 to 0.15 for all possible combinations of the seven parameters tested. Even though the parameters did not fully explain the variability in the amount of stream bank loss observed during the pre-BMP period, an interesting trend was observed. The statistical models which included the parameters of unit days, the presence of a stream meander, shade and ramp mostly explained the variability observed in the pre-BMP period. However, due to the lack of strong correlation between model parameters and the pre-BMP data, a complete regression analysis on the data from the post-BMP period was not preformed.

**Table 4-10. Comparison of stream widths.**

| | River Ridge | | | North Bender | | | South Bender | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-BMP | Post-BMP | D[1] | Pre-BMP | Post-BMP | D[1] | Pre-BMP | Post-BMP | D[1] |
| P -value | | | 0.747 | | | 0.625 | | | 0.129 |
| mean | 1.84 | 1.81 | 0.03 | 1.58 | 1.4 | 0.17 | 1.69 | 1.50 | 0.187 |
| st. dev. | 0.51 | 0.80 | 0.87 | 0.84 | 0.38 | 0.95 | 0.62 | 0.64 | 0.50 |
| % Reduction | | **1.6** | | | **11.4** | | | **11.2** | |

Means and standard deviations area expressed in terms of feet of stream bank erosion. (*) significant at 0.05 level.
D[1] = Difference between pre- and post BMP values.

## Water Quality

The following section discusses the impact of the installed BMP on nutrient and mineral water quality as well as fecal bacteria from two streams on two different farms. Rainfall and stream flow records are presented first. Differences in water quality parameters between the pre- and post-BMP treatment periods are then discussed in terms of average concentration, nutrient loading and flow-weighted concentration for each treatment period.

Rainfall during both treatment periods was normal according to estimates provided by the National Oceanic and Atmospheric Administration (NOAA, 1995). The monthly rainfall values observed on the River Ridge Farm are presented in Table 4-11. The cumulative rainfall for the months of August, 1994 through October, 1995, which corresponded with the treatment periods are presented in Table 4-11.

Flow data from the two streams are presented in Table 4-12. Flow was calculated from a known volume sample on the River Ridge stream and from a rating curve developed for the North Bender stream. The total stream flow volumes from the River Ridge stream, during the pre- and post-BMP treatment periods, were relatively similar and estimated to be 85,300 $m^3$ and 84,200 $m^3$, respectively. However, the total flow volume from the North Bender stream was greater during the post-BMP treatment period (63,630 $m^3$) than the pre-BMP period (84,180 $m^{3)}$.

Water quality samples were taken every two weeks from the River Ridge and North Bender streams. Additional samples were also taken before, after and during some of the cattle rotations on the River Ridge Farm in order to coordinate water quality sampling with cattle movement. A total of 193 samples were taken from the six water quality stations (Fig. 3-1) on the River Ridge Farm, of which 83 were taken during the pre-BMP treatment period (8/17/94 - 3/17/95) and 110 were taken during the post-BMP (3/18/95 - 10/15/95) phase. A total of 104 samples were taken from the four water quality stations (Fig. 3-2) on the North

Bender Farm, of which 54 were taken during the pre-BMP treatment period (10/2/95 - 4/14/95) and 50 were taken during the post-BMP (4/15/95 - 10/15/95) treatment period.

**Table 4-11. Monthly rainfall observed on the River Ridge Farm, Independence, VA and normal monthly rainfall observed at Galax, VA.**

| Date | Cumulative Monthly Rainfall (cm) | Normal Monthly Rainfall (cm) |
|---|---|---|
| August, 1994 | 2.03 | 7.92 |
| September, 1994 | 3.33 | 9.14 |
| October, 1994 | 10.08 | 10.31 |
| November, 1994 | 6.32 | 8.76 |
| December, 1994 | 6.20 | 7.69 |
| January, 1995 | 18.72 | 17.88 |
| February, 1995 | 12.75 | 8.33 |
| March, 1995 | 10.26 | 5.99 |
| April, 1995 | 1.75 | 8.66 |
| May, 1995 | 12.95 | 9.35 |
| June, 1995 | 24.46 | 9.90 |
| July, 1996 | 15.37 | 10.74 |
| August, 1995 | 11.30 | ** |
| September, 1995 | 18.90 | ** |
| October, 1995 | 22.53 | ** |

** = Data not availible at time of study.

**Table 4-12. Stream flow rates for the River Ridge and North Bender farms.**

| Date | Flow Rate (0.001 $m^3$/sec) | |
|---|---|---|
| | River Ridge Stream | North Bender Stream |
| 18 Aug, 1994 | 2.3 | ** |
| 5 Sept, 1994 | 7.1 | ** |
| 12 Sept, 1994 | 3.1 | ** |
| 2 Oct, 1994 | 3.10 | 3.1 |
| 9 Oct, 1994 | 3.4 | 3.1 |
| 27 Oct, 1994 | 3.4 | ** |
| 30 Oct, 1994 | 3.4 | 3.4 |
| 14 Nov, 1994 | 3.7 | 3.5 |
| 28 Nov, 1994 | 11.9 | 3.7 |
| 11 Dec, 1994 | 9.3 | 5.4 |
| 18 Dec, 1994 | 3.7 | 4.3 |
| 8 Jan, 1995 | 4.2 | 4.1 |
| 21 Jan, 1995 | 3.7 | 4.1 |
| 12 Feb, 1995 | 3.7 | 4.3 |
| 5 Mar, 1995 | 4.2 | 4.7 |
| 18 Mar, 1995 | 4.2 | 4.6 |
| 2 Apr, 1995 | 4.0 | 4.1 |
| 15 Apr, 1995 | 4.0 | 4.1 |
| 30 Apr, 1995 | 3.4 | 3.5 |
| 14 May, 1995 | 3.7 | 4.1 |
| 29 May, 1995 | 3.7 | 3.7 |
| 11 June, 1995 | 3.1 | 3.8 |
| 27 June, 1995 | 3.4 | 4.6 |
| 29 June, 1995 | 3.7 | ** |
| 9 July, 1995 | 3.4 | 4.3 |
| 23 July, 1995 | 3.7 | 4.3 |
| 20 Aug, 1995 | 2.0 | 4.5 |
| 5 Sept, 1995 | 2.3 | 4.6 |
| 17 Sept, 1995 | 17.0 | 7.9 |
| 2 Oct, 1995 | 3.1 | 5.7 |
| 15 Oct, 1995 | 6.5 | 5.4 |

**: Flow was not calculated on this date.

The average concentrations of water quality parameters from all stations on both farms reflected the significant reductions in stream bank erosion discussed in the previous section. Significant reductions were detectedin the concentration of total suspended solids (TSS) in the River Ridge stream after BMP installation (Figure 4-5). The reduction in TSS concentrations reflects the reduction in stream bank erosion due to providing the off-stream water source. The installation of the water trough reduced the time which cattle drank from the stream during the post-BMP treatment period, and thus reduced the TSS concentration in the stream.

An 89% reduction in the flow-weighted concentration ofTSS was resultedat the pond inlet on the River Ridge Farm due to the installation of the off-stream water source (Table 4-13). At the same station, the loading of TSS per cm of rainfall during the post-BMP treatment period was significantly reduced (96%), as compared to the pre-BMP period. Both of these results further support the above-stated findings that, when cattle have access to an off-stream water source the total amount of suspended solids in a stream could be substantially reduced.

Even though the reductions in average stream bank erosion were similar, the TSS concentrations measured from the River Ridge Farm and the North Bender Farm did not follow the same trends. The TSS concentrations data for all stations on the North Bender Farm are presented in Figure 4-6. No significant reductions in TSS concentrations were found on any of the North Bender monitoring stations. However, at the stream outlet (QNB-

4) a 527% increase in the concentration of TSS was observed. An increase of 596% in the flow-weighted concentration and a 49% increase in loading (kg/cm rainfall) of TSS was also observed at the stream outlet.

**Table 4-13. Flow-weighted concentration and loading of total suspended solids for the outlets of the River Ridge and North Bender farms.**

| Farm | Flow Weighted Concentration (mg/L) | | | Loading (kg/cm rain) | | |
|---|---|---|---|---|---|---|
| | Pre-BMP | Post-BMP | % Change | Pre-BMP | Post-BMP | % Change |
| River Ridge | 132.35 | 14.28 | -89.21 | 292.84 | 11.06 | -96.22‡* |
| North Bender | 6.76 | 47.07 | 596.44 | 39.11 | 58.31 | 49.09 |

‡ = Significant difference between means at the alpha = 0.05 level. * = A negative value (-) indicates a reduction due to the installation of the BMP.

These contradictory results could be due to improper site restoration following the spring development and trough installation on the North Bender Farm. Insufficient cover and reseeding on the areas disturbed during BMP construction were observed on this farm. Four unauthorized retention-type structures were also constructed over the area disturbed during the spring development upstream of QNB-1 (Fig. 3-2). The structures were intended to impound water until it could slowly percolate over the water collection pipes, thus improving the water capturing efficiency of the spring development. Following periods of severely high temperatures and heavy rainfalls, these impoundments became wallows for the grazing cattle.

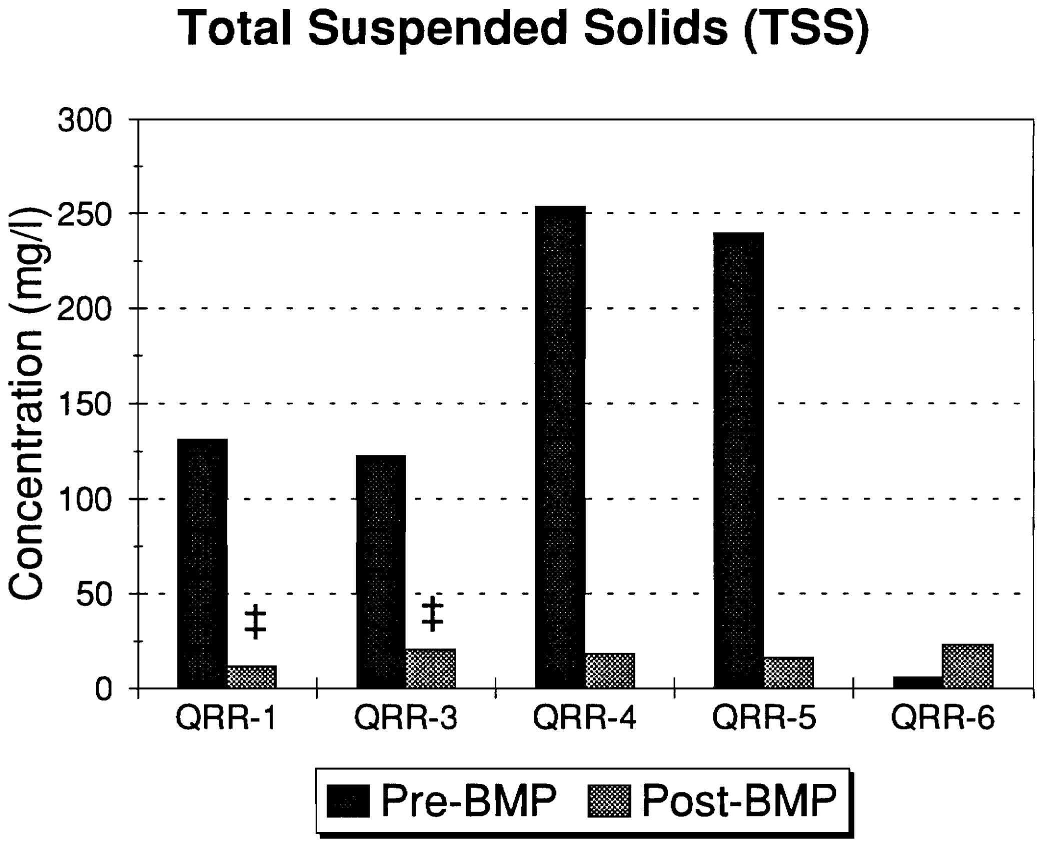


**Figure 4-5. Average concentration of total suspended solids for all stations on the River Ridge Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

Because the structures were not approved in the NRCS development design, NRCS and farm personnel agreed to remove the center portions of the impoundments, thus allowing the structures to drain.

The increases in average concentration, flow-weighted concentration and loading of total suspended solids on the North Bender Farm after BMP installation reflect improper site restoration following BMP construction and not the effect of the BMP. It is believed that the soil used for the construction of the retention structures and the spring development is the source of the increases in TSS concentrations and loadings and not from soil which would have been dislodged from the stream bank due to cattle trampling. This conclusion is supported by the 61% reduction in average stream bank erosion measured along the North Bender stream after the installation of the off-stream water source.

Concentrations of total nitrogen (TN), ammonium (NH4) and sediment bound nitrogen on the River Ridge Farm were generally reduced due to the installation of the BMP (Figure 4-7). Concentrations of TN and sediment-bound nitrogen increased during the post-BMP period at station QRR-1. Nitrate concentrations also increased significantly after BMP installation at QRR-1. It is not surprising to find increased $NO_3$ levels at this station. Due to the source area up-slope of QRR-1 and the increased mean air temperatures, concentrations of the soluble nutrient ($NO_3$) would be expected to increase at the headwater station during the primarily summertime post-BMP period, as compared to the wintertime pre-BMP period.

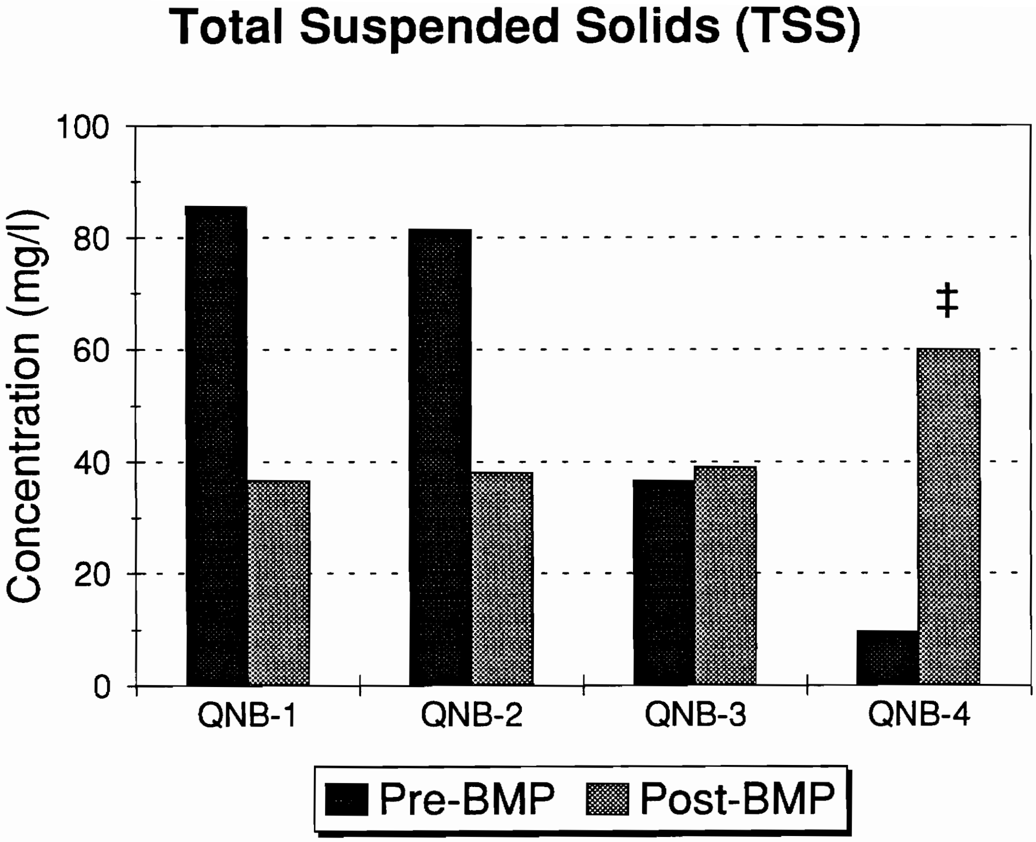


**Figure 4-6. Average concentration of total suspended solids for all stations on the North Bender Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

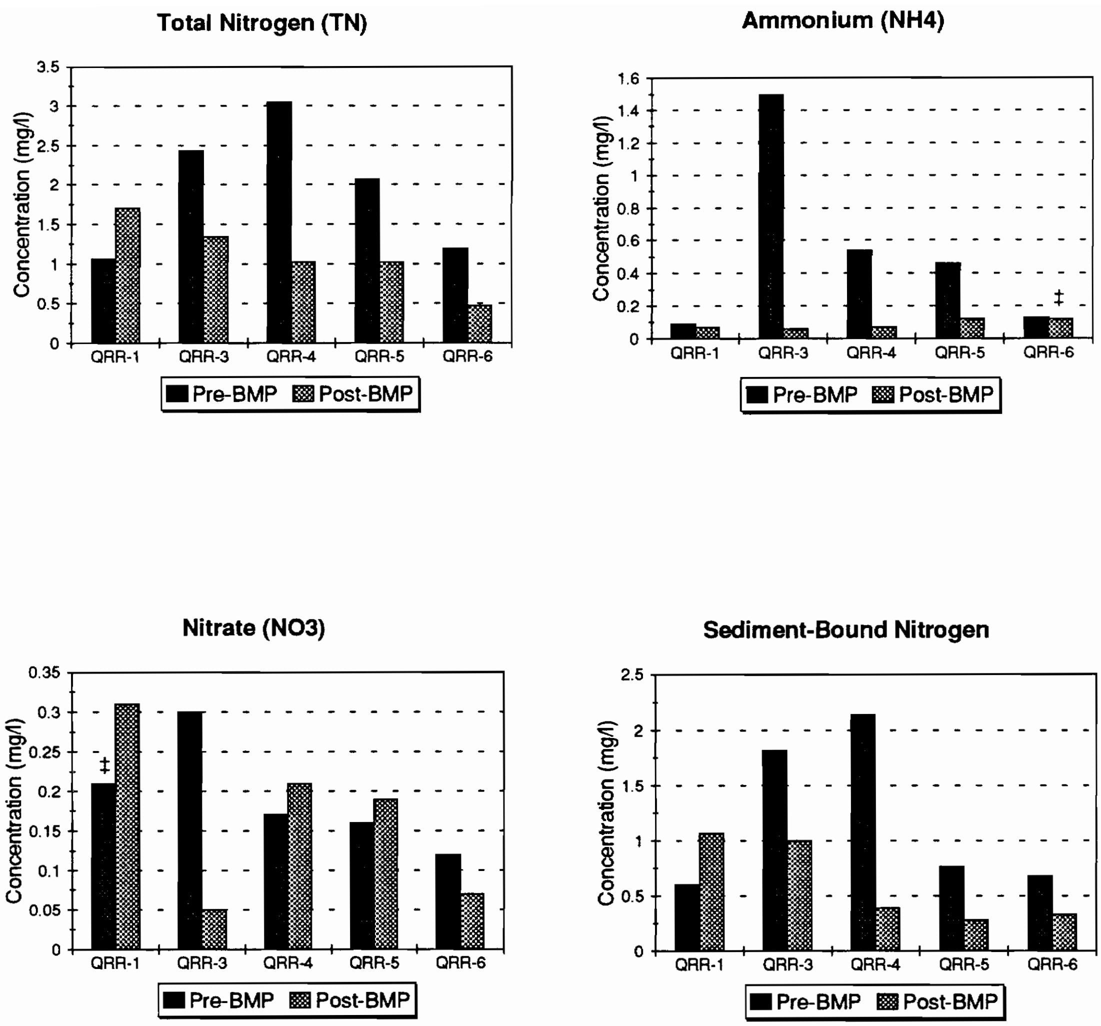


**Figure 4-7. Average concentration of total nitrogen, ammonium, nitrate and sediment bound nitrogen for all stations on the River Ridge Farm. ‡ =** Significant difference between means at $\alpha$= 0.05 level.

Table 4-14 presents the flow-weighted concentrations and loadings of total nitrogen, ammonium, nitrate and sediment-bound nitrogen for both farms and treatment periods. The percent of change which occurred during the post-BMP treatment period, as compared to the pre-BMP period, are alos reported in Table 4-14.

**Table 4-14. Flow-weighted concentrations and loadings of total nitrogen, ammonium, nitrate and sediment bound nitrogen for the outlets of the River Ridge and North Bender farms.**

| Parameter | Farm | Flow Weighted Concentration (mg/L) | | | Loading (kg/cm rain) | | |
|---|---|---|---|---|---|---|---|
| | | Pre-BMP | Post-BMP | % Change | Pre-BMP | Post-BMP | % Change |
| Total Nitrogen (TN) | River Ridge | 1.340 | 1.237 | -7.72 | 3.02 | 1.34 | -55.63‡* |
| | North Bender | 0.980 | 1.250 | 28.23 | 1.27 | 1.52 | 19.69 |
| Ammonium ($NH_4$) | River Ridge | 0.321 | 0.090 | -72.06 | 0.52 | 0.12 | -76.92‡ |
| | North Bender | 0.080 | 0.030 | -65.46 | 0.13 | 0.02 | -84.62 |
| Nitrate ($NO_3$) | River Ridge | 0.167 | 0.229 | 37.05 | 0.31 | 0.35 | 12.90 |
| | North Bender | 0.19 | 0.27 | 41.27 | 0.50 | 0.40 | -20.00 |
| Sediment Bound Nitrogen | River Ridge | 0.472 | 0.468 | -0.66 | 1.05 | 0.55 | -47.62 |
| | North Bender | 0.64 | 0.53 | -17.20 | 0.59 | 0.54 | -8.47 |

‡ = Significant difference between means at $\alpha = 0.05$ level. * = A negative value (-) indicates a reduction due to the installation of the BMP.

The flow-weighted concentrations of TN, $NH_4$ and sediment-bound nitrogen on the River Ridge reduced during the post-BMP treatment period. The reduction in the sediment-bound nutrient concentrations corresponds with the 89% reduction in flow weighted concentration of total suspended solids and 77% reduction in average stream bank erosion measured on the River Ridge Farm. Total nitrogen and ammonium loadings were significantly reduced by 56% and 77%, respectively, due to the presence of an off stream water source for grazing cattle. The water trough BMP was not effective in reducing $NO_3$; a soluble form of nitrogen. The flow-weighted concentrations of nitrate and nitrate loadings increased by 37% and 13%, respectively, (not significant $\alpha = 0.05$ level) during the post-BMP treatment period. As discussed earlier in this chapter, the increases in flow- weighted concentration and loading of $NO_3$ are not surprising. However, the water troughs appear to be more effective in reducing sediment and sediment-bound nutrient contributions than dissolved nutrient contributions.

As suggested by the results of total suspended solids, the degree of reduction in sediment-bound nutrients was less on the North Bender stream than those observed from the River Ridge stream. BMP responses to average concentrations of TN, $NH_4$, $NO_3$ and sediment-bound nitrogen (Figure 4-8) were mixed as compared to those found on the River Ridge stream. No significant differences in TN, $NH_4$, and $NO_3$ concentrations were observed as a result of BMP installation on the North Bender farm. Sediment-bound concentrations of nitrogen were reduced during the post-BMP period.

With the exception of total nitrogen, the reductions in flow-weighted concentrations and loadings from the North Bender Farm generaly followed the same trends as those observed for the River Ridge Farm (Table 4-14). The flow-weighted concentrations of $NH_4$ and sediment-bound nitrogen were reduced by 65% and 17%, respectively, due to BMP installation on the North Bender stream. Loadings of $NH_4$ and sediment-bound nitrogen were also reduced by 85% and 8%, respectively, during the post-BMP treatment period. As previously discussed, the 41% increase in the flow-weighted concentration of $NO_3$ is not surprising. Loadings of nitrate remained largely unchanged between the two BMP treatment periods. A 28% increase in the flow-weighted concentration of TN was observed at the outlet of the North Bender Farm. A 20% increase in TN loading was also observed during the post-BMP treatment period. It is believed that the significant increases in TSS at QNB-4 and the increased volume in stream flow during the post-BMP treatment period could partially explain the increased flow-weighed concentrations and loadings of sediment bound forms of nitrogen.

The concentration of sediment-bound phosphorus reduced due to the installation of the off-stream water sources on the River Ridge Farm (Figure 4-9). Significant reductions in the concentration of total phosphorus were obtained at QRR-1, QRR-3, QRR-4, and QRR-5 during the post-BMP treatment period. These reductions are also correspond with the significant reductions reported for TSS concentrations. The reductions in total phosphorus at QRR-2 were not statistically significant because of an insufficient number of samples

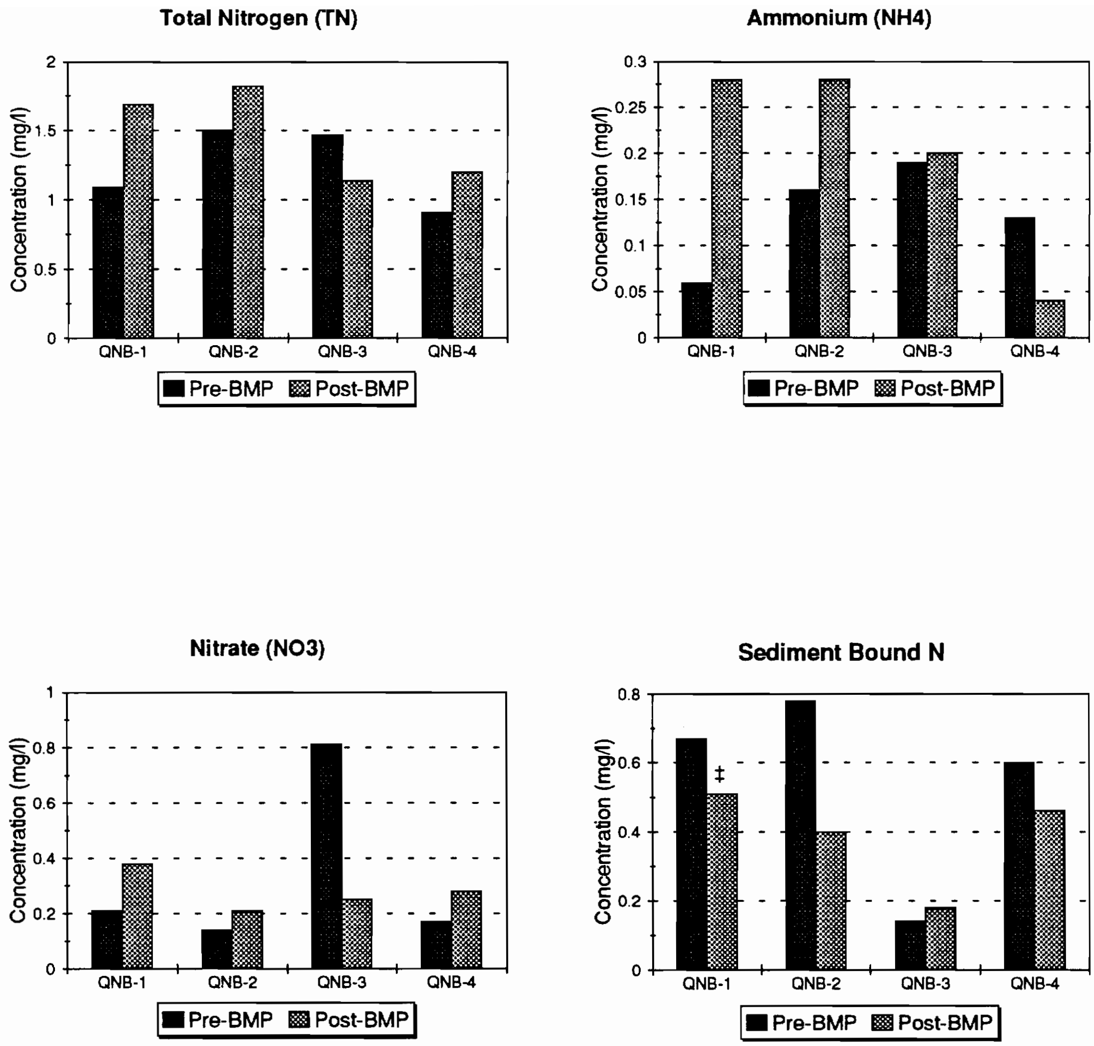


**Figure 4-8. Average concentration of total nitrogen, ammonium, nitrate and sediment bound nitrogen for all stations on the North Bender Farm. ‡** = Significant difference between means at $\alpha = 0.05$ level.

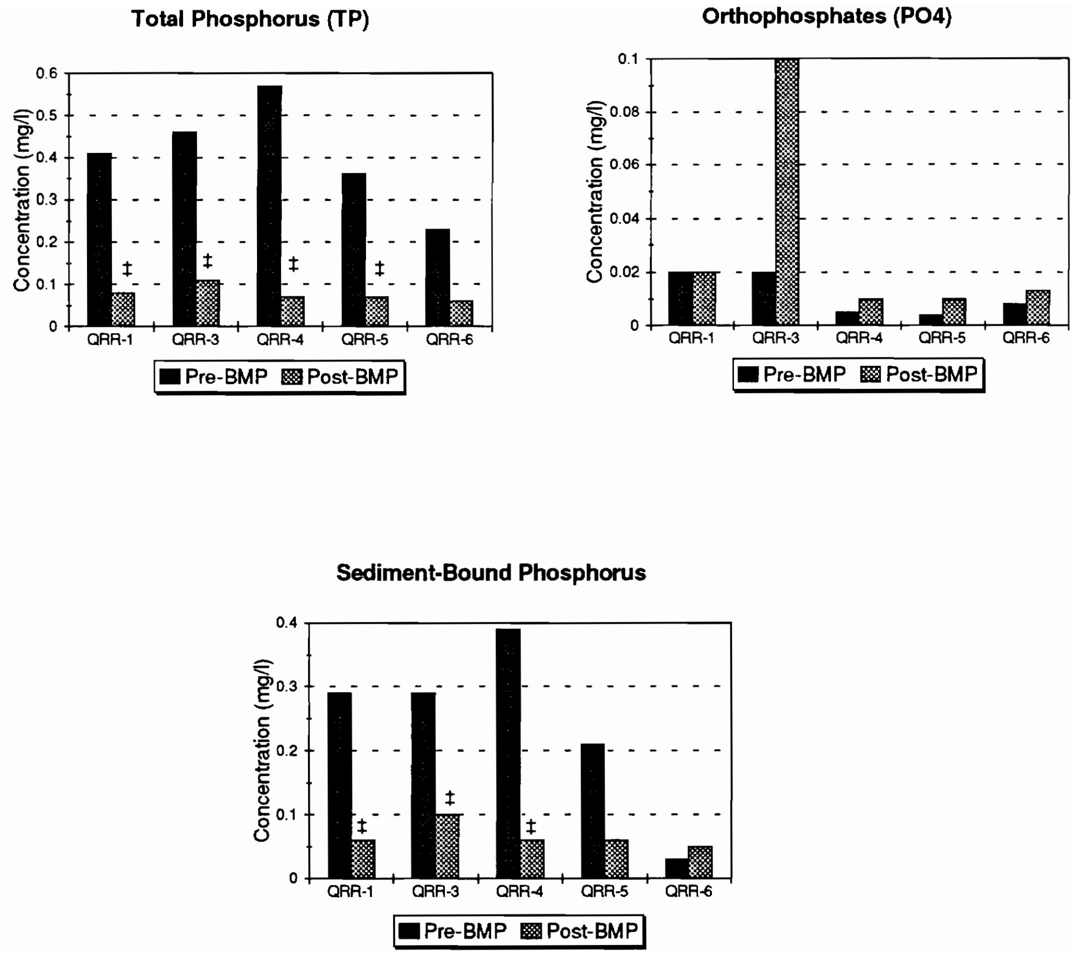


**Figure 4-9. Average concentration of total phosphorus, orthophosphates and sediment bound phosphorus for all stations on the River Ridge Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

during the post-BMP period due to the lack of sufficient flow at the station (Figure 3-2). Significant reductions in the concentration of sediment-bound phosphorus were found at QRR-1, QRR-3, and QRR-4. A 71% reduction in the average concentration of sediment-bound phosphorus found at QRR-5, was not statistically significant at $\alpha = 0.05$ (P-value of 0.0601).

**Table 4-15. Flow-weighted concentrations and loadings of total phosphorus, orthophosphates and sediment-bound phosphorus for the outlets of the River Ridge and North Bender Farms.**

| Parameter | Farm | Flow Weighted Concentration (mg/L) | | | Loading (kg/cm rain) | | |
|---|---|---|---|---|---|---|---|
| | | Pre-BMP | Post-BMP | % Change | Pre-BMP | Post-BMP | % Change |
| Total Phosphorus (TP) | River Ridge | 0.203 | 0.072 | -64.56 | 3.25 | 0.08 | -97.54‡* |
| | North Bender | 0.04 | 0.14 | 276.36 | 0.20 | 0.14 | -30.00 |
| Orthphosphates (PO4) | River Ridge | 0.004 | 0.007 | 98.47 | 0.04 | 0.01 | -75.00 |
| | North Bender | 0.001 | 0.012 | 1861.63 | 0.10 | 0.01 | -90.00 |
| Sediment Bound Phosphorus | River Ridge | 0.120 | 0.068 | -42.87 | 0.93 | 0.07 | -92.47‡ |
| | North Bender | 0.03 | 0.12 | 277.41 | 0.11 | 0.13 | 18.18 |

‡ = Significant difference between means at the alpha = 0.05 level. * = A negative value (-) indicates a reduction due to the installation of the BMP.

The flow-weighted concentrations of total phosphorus and sediment-bound phosphorus on the North Bender Farm increased by 276% and 277%, respectively (Table 4-15). These results are due to the significant increase in total suspended solids at QNB-4, as discussed previously. Since both values were calculated using the sample concentrations and flow volumes observed at QNB-4, the significant increases in TSS were reflected in these two values. The loading of total phosphorus at the North Bender Farm reduced by 30%. Soluble phosphorus, in the form of orthophosphates, increased or remain relatively unchanged due to the installation of the off-stream water source. However, no statistically significant differences in $PO_4$ concentrations were detected for the samples collected from the River Ridge stream. The concentrations of $PO_4$ followed the same trend as those reported for $NO_3$.

Unlike the average concentrations of nitrogen, the average concentrations of phosphorus on the North Bender Farm followed the same trends observed for the River Ridge Farm (Figure 4-10). The concentration of total phosphorus and sediment-bound phosphorus reduced at all stations except for QNB-4. This result was mainly due to the 526% increase in the concentration of total suspended solids reported for that station during the post-BMP treatment period. Average concentrations of orthophoshates were also greater at all stations during the post-BMP treatment period on the North Bender Farm as compared to pre-BMP concentrations.

The installation of the off-stream water source reduced the flow weighted concentration and loading of TP and sediment-bound phosphorus on the River Ridge Farm (Table 4-14). Reductions of 65% and 43% were resulted in the flow-weighted concentration of total phosphorus and sediment bound phosphorus, respectively, due to the installation of the water troughs. The loading of total phosphorus and sediment bound phosphorus were also significantly reduced by 98% and 92%, respectively, during the post-BMP treatment period. The flow-weighted concentration of orthophosphates increased by 98% while its respective loading decreased by 75% during the post-BMP treatment period. However, the loading of sediment-bound phosphorus increased by 18% (from 0.11 kg/cm-rain to 0.13 kg/cm-rain) during the post-BMP treatment period. The flow-weighted concentration of orthophosphates increased by 1862% while its respective loading decreased by 90% during the post-BMP treatment period on the North Bender stream.

The average concentrations of calcium, magnesium, potassium, sodium and sulphur, for the pre- and post-BMP treatment periods on the River Ridge stream are presented in Figure 4-11. With the exception of potassium at QRR-2, no statistically significant changes in any of the five minerals were found for the stream water quality stations on the River Ridge Farm. Significant increases in the average concentration of magnesium and sodium were detected at the pond outlet (QRR-6) during the post-BMP treatment period. These, and other, changes at the pond outlet will be discussed in more detail later in this chapter.

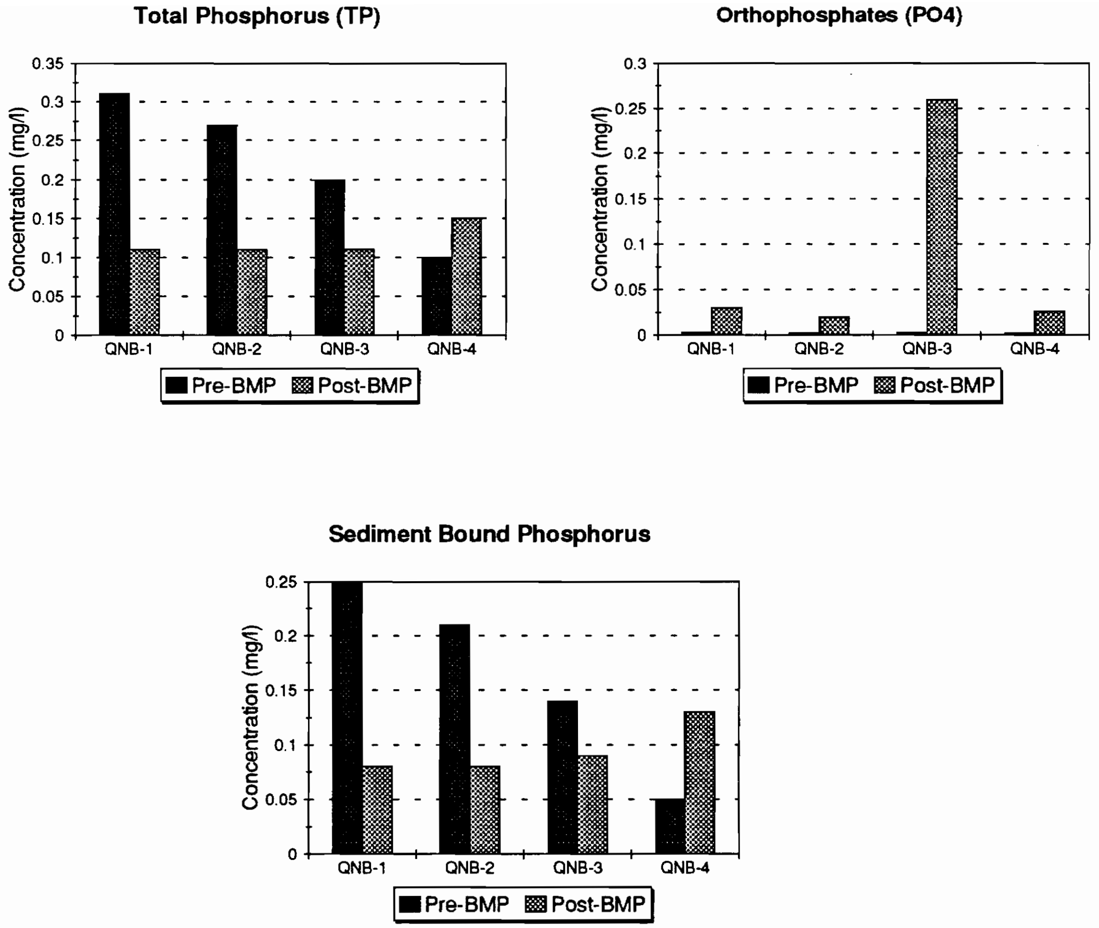


**Figure 4-10. Average concentration of total phosphorus, orthophosphates and sediment bound phosphorus for all stations on the North Bender Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

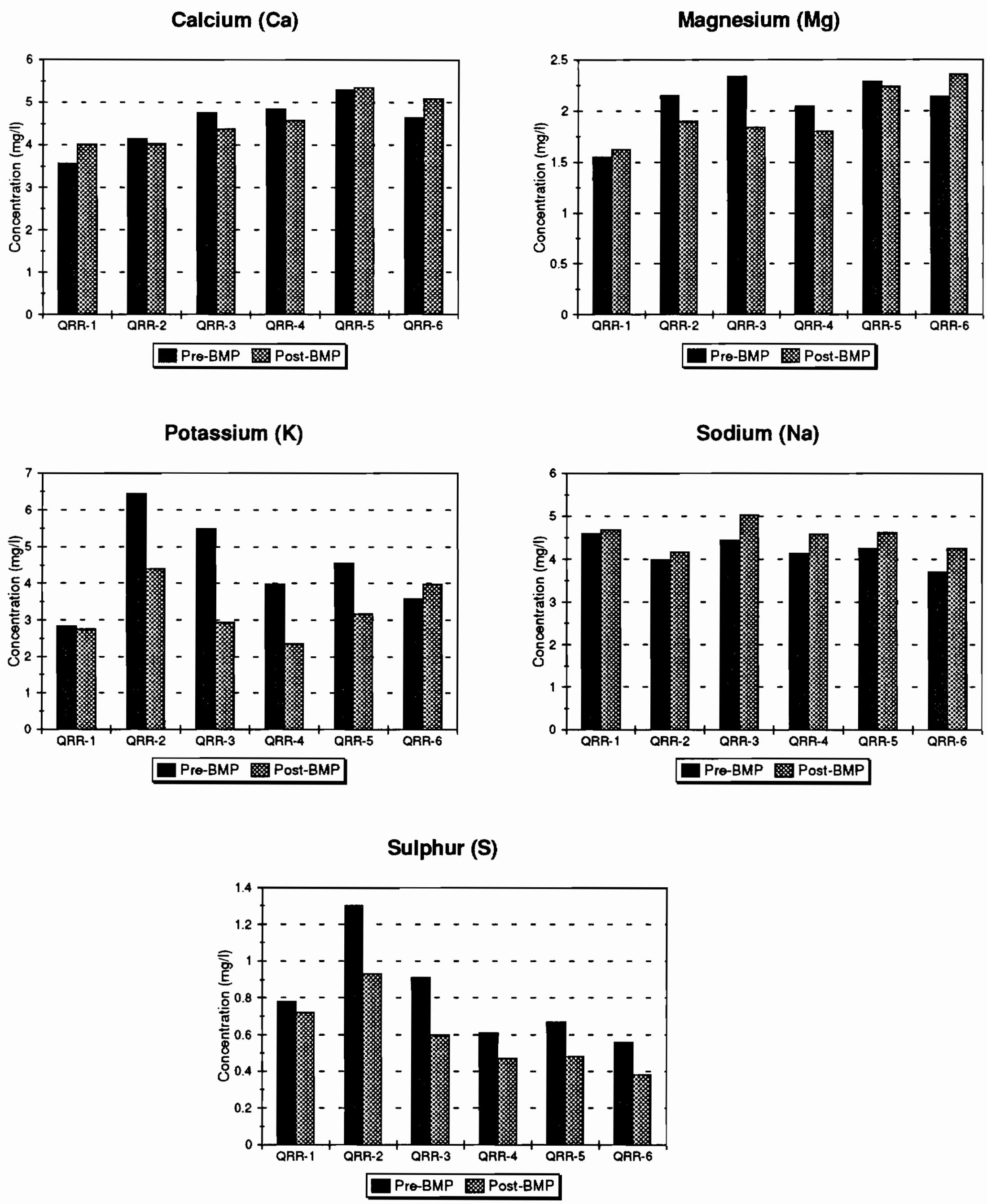


**Figure 4-11. Average concentration of calcium, magnesium, potassium, sodium and sulphur for all stations on the River Ridge stream.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

The flow-weighted concentration and loadings of the five minerals, for both the pre- and post-BMP treatment periods, are presented in Table 4-16. The table also presents the percent of change which took place during the post-BMP period as compared to the flow-weighted concentration and loading observed during the pre-BMP treatment period.

**Table 4-16. Flow-weighted concentrations and loadings of calcium, magnesium, potassium, sodium and sulphur for the outlet of the River Ridge Farm.**

| Parameter | Flow Weighted Concentration (mg/L) | | | Loading (kg/cm rain) | | |
|---|---|---|---|---|---|---|
| | Pre-BMP | Post-BMP | % Change | Pre-BMP | Post-BMP | % Change |
| Calcium (Ca) | 1.371 | 1.549 | 13.03 | 23.40 | 10.58 | -55.46‡* |
| Magnesium (Mg) | 0.433 | 0.423 | -2.22 | 9.72 | 4.03 | -58.54‡ |
| Potassium (K) | 3.823 | 3.453 | -9.67 | 10.76 | 7.68 | -28.62‡ |
| Sodium (Na) | 1.801 | 1.929 | 7.08 | 2.09 | 9.82 | 369.86 |
| Sulphur (S) | 0.150 | 0.149 | -1.60 | 3.76 | 0.76 | -79.76‡ |

‡ = Significant difference between means at the alpha = 0.05 level. * = A negative value (-) indicates a reduction due to the installation of the BMP.

The flow-weighted concentrations of the five minerals remained relatively unchanged due to the installation of the off-stream water source. The flow weighted concentrations of magnesium, potassium and sulphur were slightly less during the post-BMP treatment period as compared to the concentrations observed during the pre-BMP period. However, the flow-weighted concentration of calcium, and sodium increased during the post-BMP treatment period.

The loading of five minerals were significantly impacted by the installation of the BMP. Loadings of calcium, magnesium, potassium, and sulphur were significantly reduced by 55%, 59%, 29% and 80%, respectively due to cattle use of the off stream water source. Although not statistically significant, sodium loadings were found to increase by 370% during the post-BMP treatment period.

Figure 4-12 presents the concentration of total coliform(TC), fecal coliform (FC), and fecal streptococci (FS) for all stations on the River Ridge Farm. The total coliform, fecal coliform and fecal streptococci bacteria are used as indicators of nonpoint source pollution especially those directly deposited by grazing cattle. However, since the total coliform group consists of species of bacteria from soil, vegetative matter, and animals, a direct relationship between its occurrence and the presence of cattle cannot be justified (Stephenson, et. al, 1978.). Since the fecal coliform and fecal streptococci groups are directly related to the feces of warm-blooded animals, they are considered a more reliable indicator of pollution generated from grazing cattle.

Significant reductions in total coliform, fecal coliform and fecal streptococci were observed on the River Ridge stream due to the installation of the off-stream water sources. Significant

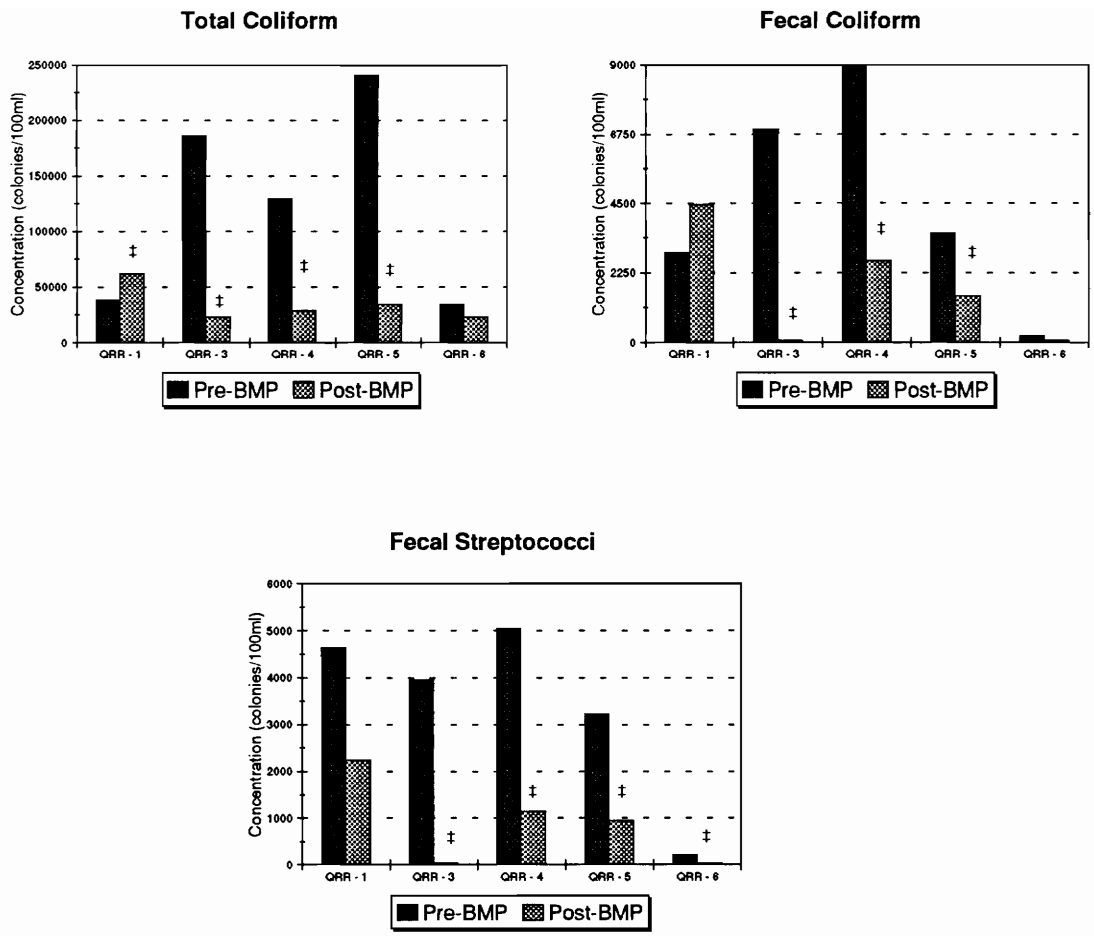


**Figure 4-12. Average concentration of total coliform, fecal coliform and fecal streptococci on the River Ridge Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

reductions of 88%, 78% an 86% in total coliform were found at sampling stations QRR-3, QRR-4 and QRR-5, respectively. A significant increase (61%) in total coliform was also observed at QRR-1. However, the increase in total coliforms can be attributed to the significant increase in total suspended solids also found at the headwaters of this station, as discussed previously. Significant reductions of 99%, 87% and 57% in fecal coliforms were also found at stations QRR-3, QRR-4 and QRR-5, respectively. A 53% increase in total coliform was found not to be statistically significant at the headwater station, QRR-1. Significant reductions in fecal streptococci were resulted at all stations on the River Ridge stream due to the installation of the off-stream water sources. Statistically significant reductions in fecal streptococci of 99%, 77%, 70% and 84% were found at the water monitoring stations of QRR-3, QRR-4, QRR-5 and QRR-6, respectively.

Data on total coliform, fecal coliform and fecal streptococci on the North Bender Farm greatly contradicted the results obtained for the River Ridge Farm (Figure 4-13). Statistically significant increases in total coliform, fecal coliform and fecal streptococci were found on the North Bender stream. Specific management practices on the North Bender Farm may have significantly impacted the observed concentrations of TC, FC and FS. The unauthorized construction of the retention-type structures, discussed earlier in this chapter, is believed to have impacted the concentrations of fecal bacteria reported in this study. The combined effect of the standing water and manure within the structures, as well as the suspension of fecal bacteria in bottom sediments (Sherer, 1992), is the basis for the increased fecal bacteria

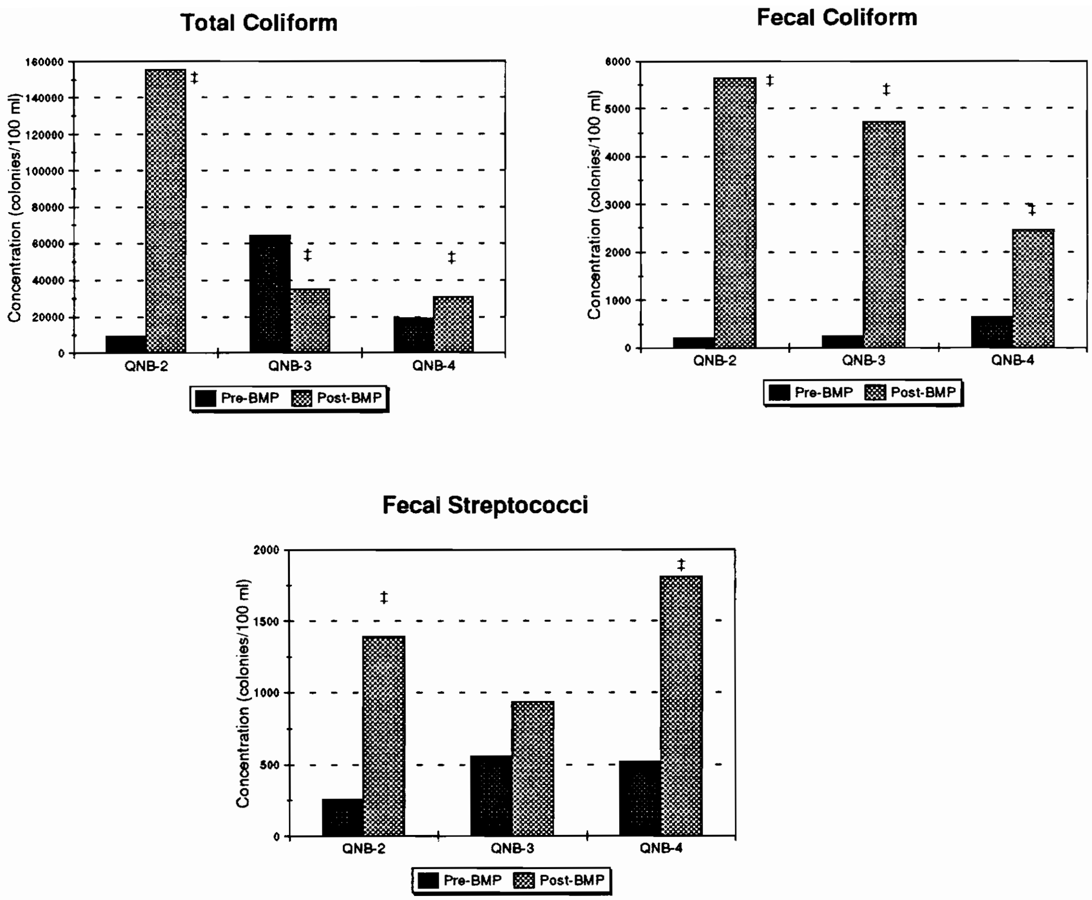


**Figure 4-13. Average concentration of total coliform, fecal coliform and fecal streptococci on the North Bender Farm.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

concentrations found on the North Bender stream and does not accurately reflect the effect of the installed BMP.

The reductions in total coliform, fecal coliform, and fecal streptococci concentrations are directly related to the dramatic changes in cattle behavior due to the presence of the off-stream water source. It can be construed that with the 51% reduction in cumulative time per cow spent in the stream, the amount of fecal matter deposited by each cow was also reduced. Thus, as the water trough drew cattle away from the stream (91.7% of the time) manure which would have been deposited in the stream was deposited near the off-stream water source. This study has shown that the BMP is effective in reducing the concentration of bacteria while cattle access to streams remained unchanged. However, results from the North Bender Farm have shown that farm management may mask the benefits of off-stream water sources for grazing cattle, as shown for the River Ridge Farm.

Two additional analyses were also performed in order to describe the effect of additional management practices within a rotational grazing systems which utilizes off-stream water sources. An analysis was conducted in order to describe the quality of water within a spring-fed water trough and a stream. Another analysis was also preformed in order to identify the effectiveness of a farm pond in reducing the concentration and loadings of bacteria, mineral and other water quality parameters. An analysis of the difference in the quality of water within a water trough and a nearby stream was preformed to evaluate the quality of the water

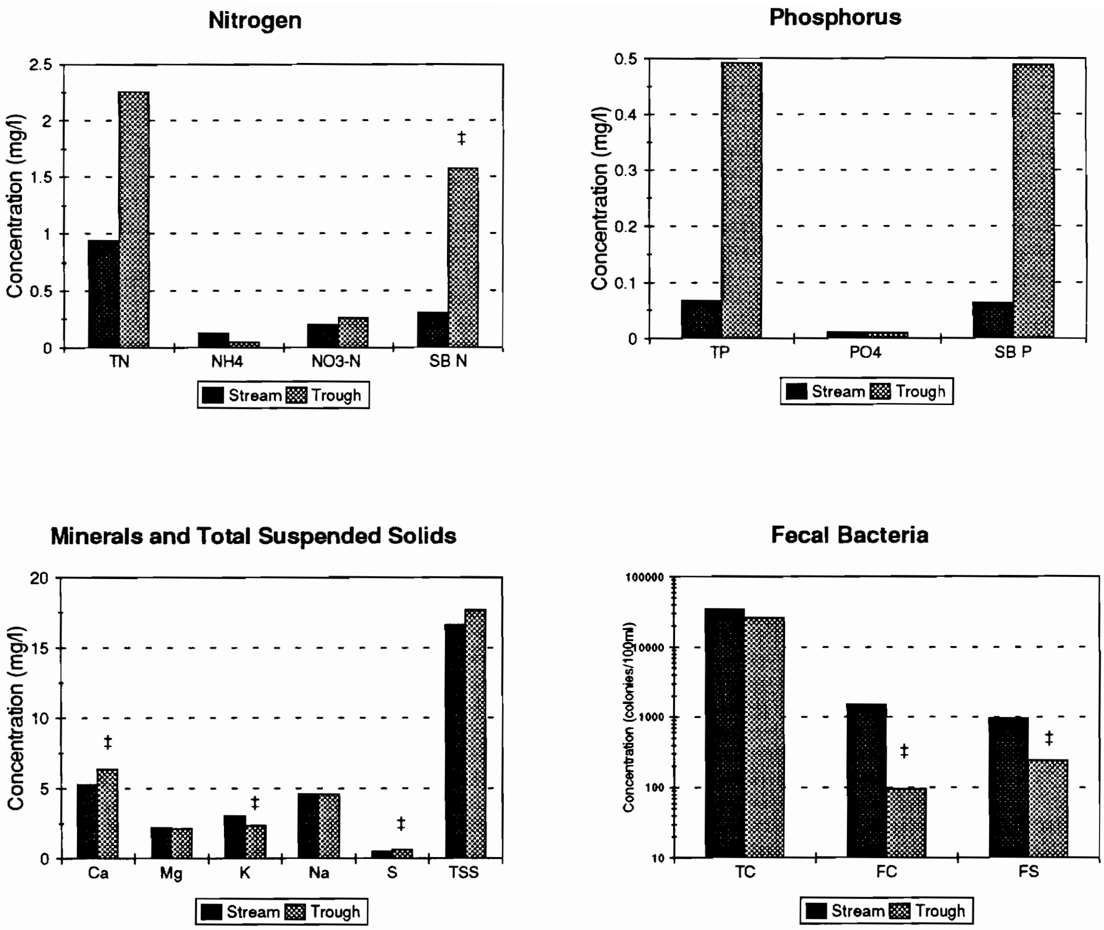


**Figure 4-14. Average concentration of bacterial, mineral and water quality parameters from the River Ridge stream and spring-fed water trough.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

in the trough and in the nearby stream. Figure 4-14 shows the changes in the average concentration of bacteria, mineral and other water quality parameters between samples taken from a stream (QRR-5) and a water trough (QRR-WT3). In the analysis a total of seventeen pairs of samples were taken during the post-BMP treatment period on the River Ridge Farm.

Water from a spring-fed trough had significantly lower concentrations of fecal coliforms and fecal streptococci than the water from an adjacent stream. Fecal coliform and fecal streptococci concentrations in the trough water were 97% and 75% less, respectively, than water sampled from an adjacent stream. These reductions would cause reduced risk of the transmittal of water borne infectious diseases by grazing cattle which utilize the off-stream water source as compared to utilizing a stream as the primary source of drinking water.

The reductions in mean total coliform values, although statistically not significant, between trough and stream waters are believed to be caused by the lack of trough draining and cleaning during the post-BMP treatment period. Algae was found to grow aggressively within the trough. The combination of algal growth and bacteria from bovine saliva may account for the differences between the total coliform concentration found in the trough and in the nearby stream. Frequent draining and cleaning of the troughs should result in less bacteria in the troughs.

Concentrations of mineral and water quality parameters were greater within the spring-fed water trough as compared to samples taken from a nearby stream. Significantly higher concentrations in sediment-bound nitrogen, calcium, and sulphur were found in the trough water. Although not statistically significant, higher concentrations of total nitrogen, nitrate, total and sediment bound phosphorus and total suspended solids were also observed in the trough water, as compared with the nearby stream water. Ammonium and magnesium concentrations were not affected, while the concentration of potassium were significantly less within the trough water as compared to the nearby stream.

An analysis was also performed to identify the effectiveness of a farm pond in reducing the concentration and loadings of bacteria, mineral and water quality parameters within a rotational grazing system which utilizes off-stream water sources. Samples were collected from the pond inlet (QRR-5) and the outlet (QRR-6) during the pre- and post-BMP treatment periods on the River Ridge Farm.

Significant reductions in nitrate, total suspended solids, fecal coliform and fecal streptococci were found due to the existence of the pond at the River Ridge Farm. A reduction of 92% in total suspended solids was found during the pre-BMP treatment period (Figure 4-15). The 61% and 71% reduction in nitrate during the pre- and post-BMP treatment periods, respectively, are illustrated in Figure 4-16. Significant reductions in fecal coliform (95%) were also found during the post-BMP treatment period while reductions of 97%in fecal

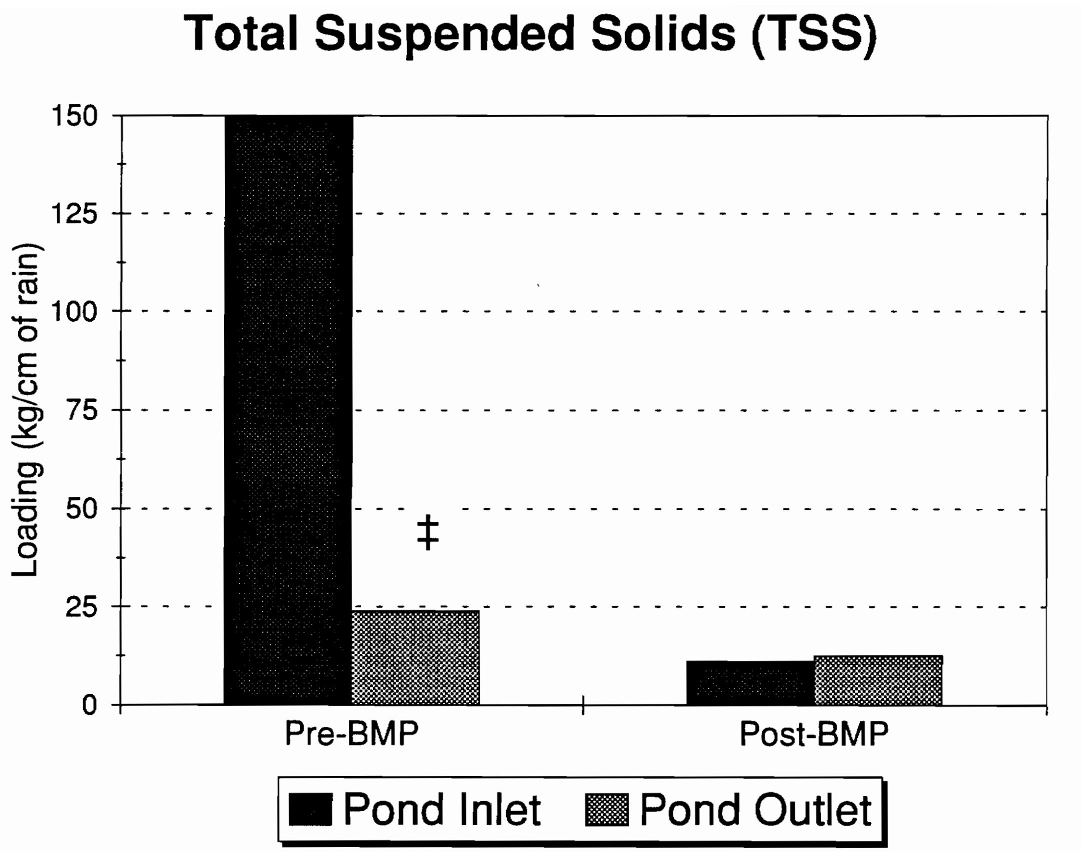


**Figure 4-15. Total suspended solids loading at the River Ridge pond inlet and outlet during the pre- and post-BMP treatment periods.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

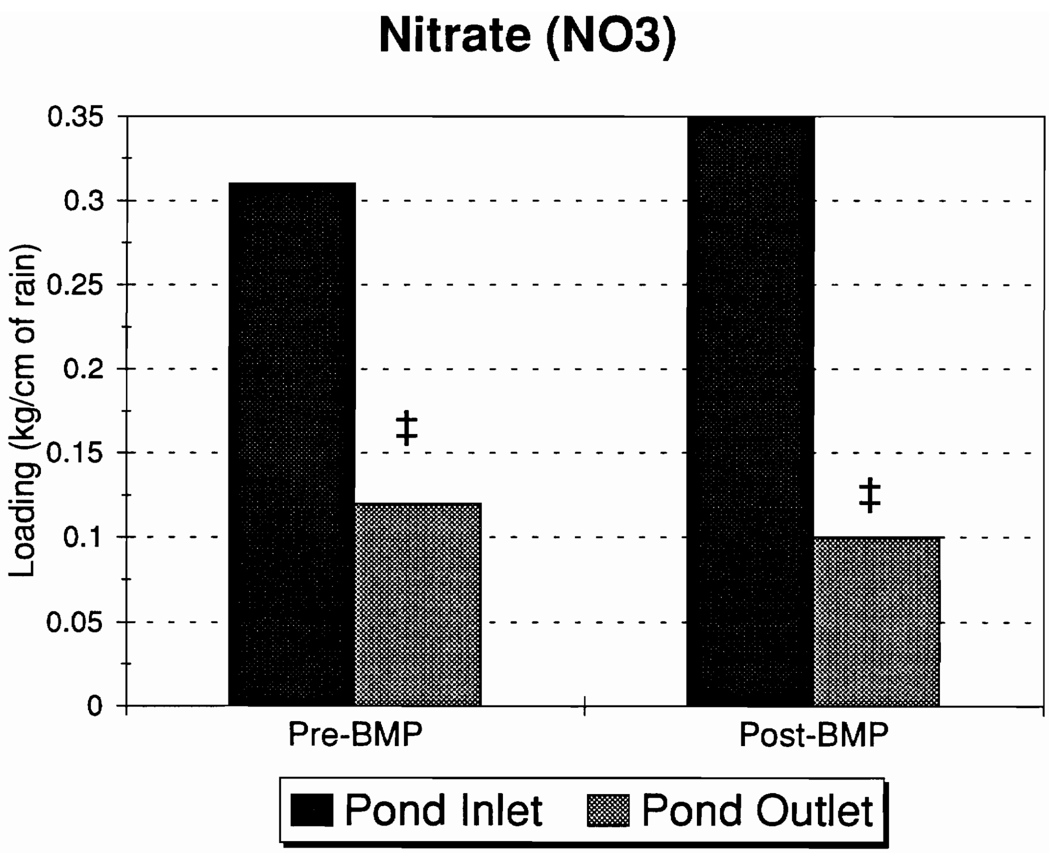


**Figure 4-16. Nitrate loading at the River Ridge pond inlet and outlet during the pre- and post-BMP treatment periods.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

streptococci were found at the pond outlet both during the pre- and post-BMP treatment periods (Figure 4-17). The 86% and 34% reductions in total coliform during the pre- and post-BMP treatment periods were not statistically significant.

The results of this study indicate that the installation of an off-stream water source for grazing cattle is effective in reducing the level of sediment-bound and fecal bacteria pollutants within a rotational grazing system. The results also indicate that improper management methods would significantly impact the effectiveness of the BMP. Water quality comparisons indicate that water from a spring-fed water trough may be significantly less contaminated by fecal bacteria than water in a nearby stream. A farm pond was effective in reducing the loading of nitrate and fecal bacteria within the rotational grazing system during the periods that cattle did and did not have access to an off-stream water source.

The implementation of the conclusions drawn from this study are limited by several factors. First, the study was conducted for a relatively short time of about 14 months. Seasonal variation of cattle behavior, rainfall patterns and runoff nutrient concentrations may significantly alter the conclusions drawn from this study if data were taken for longer durations. However, it must be noted that since the post-BMP treatment period of this study was conducted during the warmer summer months of the year, during which greater sediment, nutrient and bacteria concentrations are expected. thus, BMP impacts reported in this study are conservative. Had the post-BMP treatment period been conducted during the winter

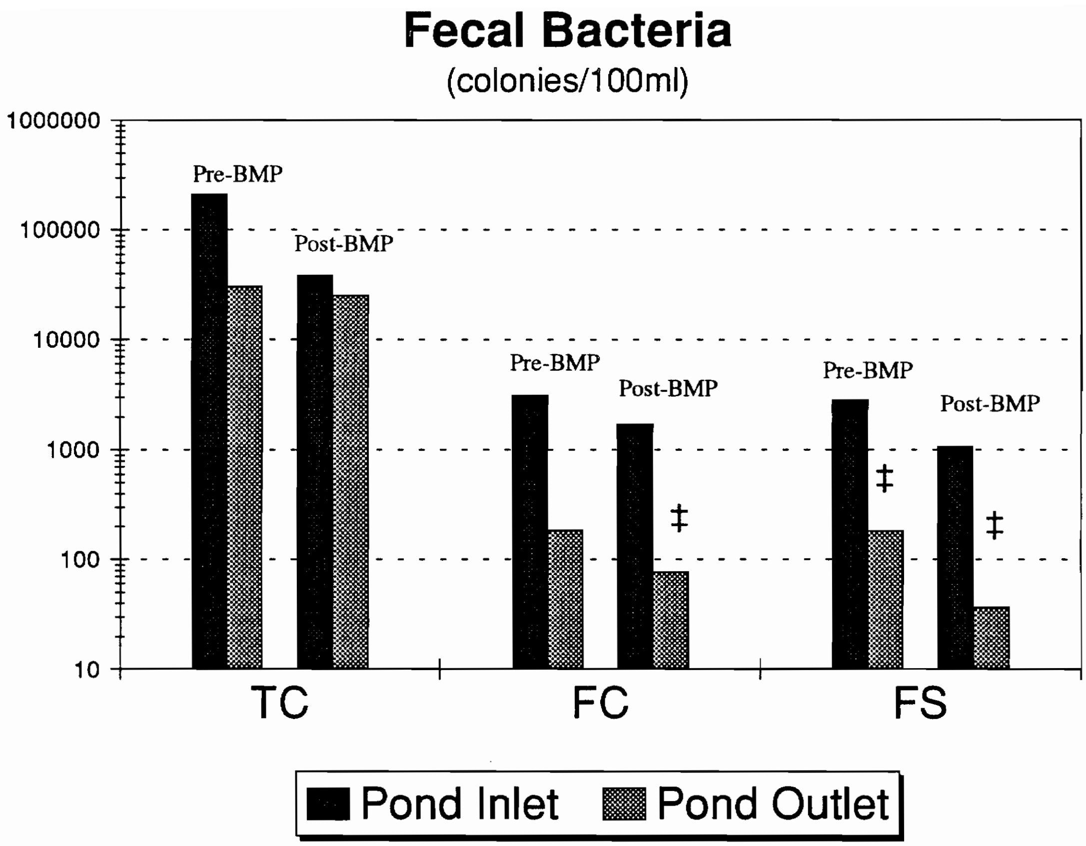


**Figure 4-17. Fecal bacteria concentrations at the River Ridge pond inlet and outlet during the pre- and post-BMP treatment periods.** ‡ = Significant difference between means at $\alpha = 0.05$ level.

months, greater BMP impacts (more reductions in water quality concentrations and loadings) would have been resulted. In spite of these limitations, this study has clearly shown that the installation of off-stream water sources for grazing cattle is quite effective in reducing the amount of sediment bound and fecal bacteria contributed to streams without resorting to stream bank fencing.

## Economic Analysis

Seven streams, with a total length of 28,092 ft (8,562 m), were identified on 8 pastures on the 464 acre (187 ha) Bender Farm in Floyd County, Virginia. Thirteen streams, with a total length of 51,948 ft (15,833 m) (Figure 4-18), were identified on the 337 acre (136 ha) River Ridge Farm in Grayson County, Virginia (Figure 4-19). The total length of buffer perimeter fencing, the enclosed area, and the percent of decreased grazing area for 10-ft (3.1-m), 50-ft (15.2-m), 100-ft (30.5-m) and 200-ft (61.0-m) buffer zones along all streams, as well as the information for the Fencing BMP-1 and BMP-2 scenerios for both farms, are presented in Table 4-17. For the first buffer combination (Fencing BMP-1) all streams of first- and second-order were assumed to have buffer lengths of 50 ft (15. 2 m). Third order streams were given buffer lengths of 100 ft (30.5 m) and streams larger than third order were assumed to be protected by fenced buffers of 200 ft (61.0 m). The second buffer combination (Fencing

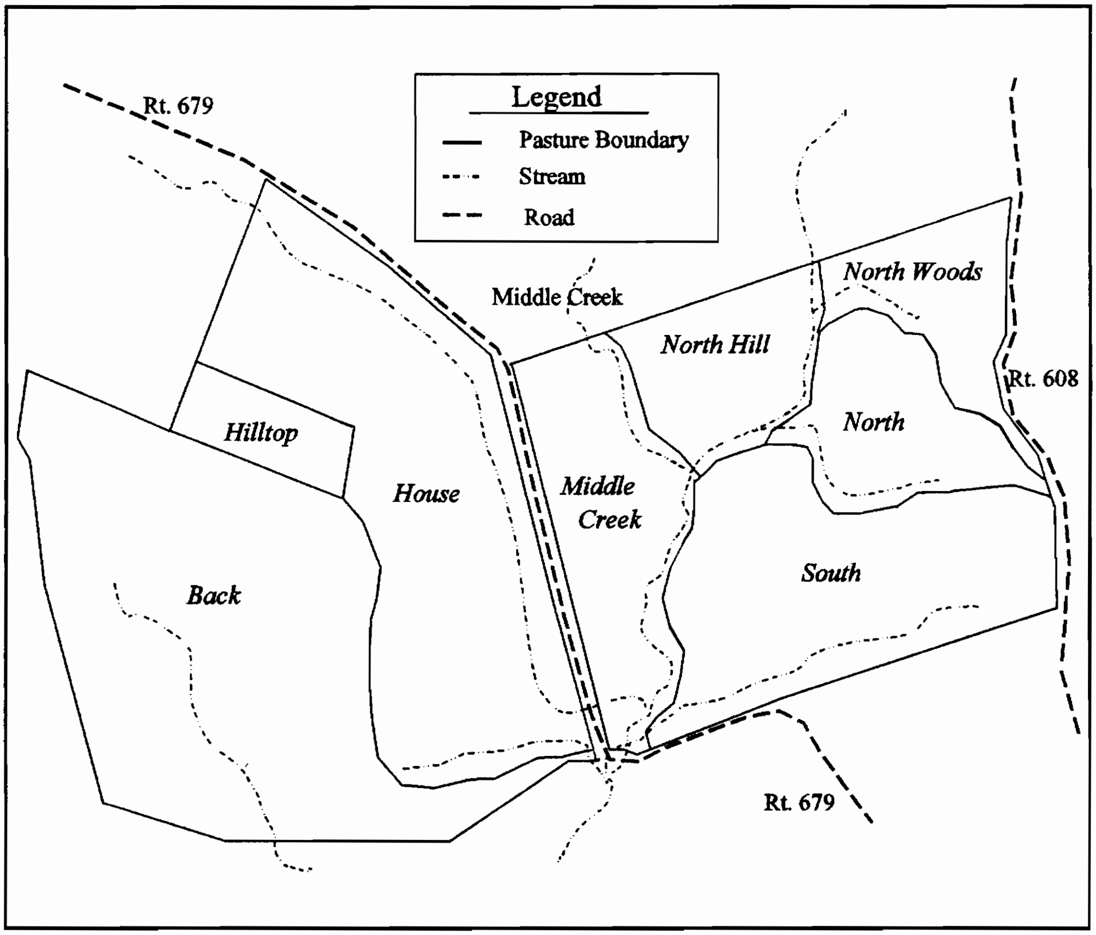


**Figure 4-17. Map of the Bender Farm.**

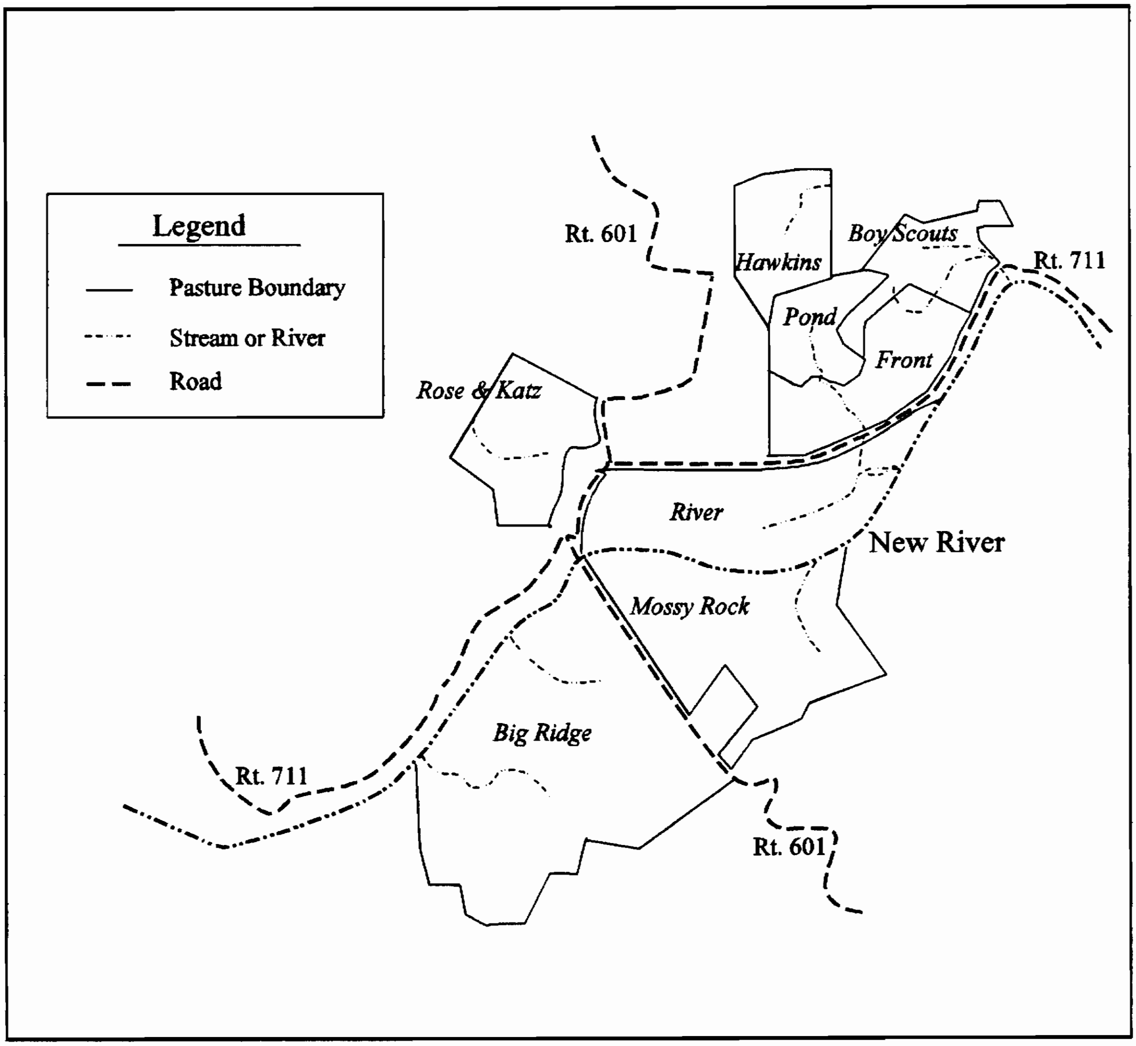


**Figure 4-19. Map of the River Ridge Farm.**

BMP-2) was the same as Fencing BMP-1, except that all the streams equal to or greater than third-order were bounded with 100-ft (30.5-m) fenced buffers.

**Table 4-17. Length of perimeter fencing, enclosed area and percent of lost grazing area for six stream bank buffer zones.**

| | Bender Farm | | | River Ridge Farm | | |
|---|---|---|---|---|---|---|
| Buffer Zone | Length of Fence around Stream (ft) | Area Enclosed within Fence (ac) | % Grazing Area Lost to Fencing | Length of Fence around Stream (ft) | Area Enclosed within Fence (ac) | % Grazing Area Lost to Fencing |
| 10-ft | 56,404 | 12.9 | 2.8 | 81,055 | 18.6 | 5.5 |
| 50-ft | 57,283 | 65.1 | 14.0 | 82,751 | 93.8 | 27.8 |
| 100-ft | 58,383 | 131.5 | 28.3 | 84,872 | 190.0 | 56.4 |
| 200-ft | 60,582 | 268.1 | 57.8 | 89,113 | 389.7 | 100.0 |
| Fencing BMP 1[a] | 57,443 | 60.8 | 16.3 | 83,458 | 175.9 | 52.2 |
| Fencing BMP 2[b] | 57,443 | 60.8 | 16.3 | 83,987 | 120.9 | 35.9 |

(a) 1st and 2nd order streams = 50ft buffer, 3rd order = 100ft buffer, > 3rd order = 200ft buffer. (b) 1st and 2nd order streams = 50ft buffer, >2nd order = 100ft buffer.

The length of fencing needed to protect the streams for the four fixed-width buffers were estimated and ranged from 56,404 ft (17,192 m) to 60,582 ft (18,465 m) and 81,055 ft (24,706 m) to 89,113 ft (27,162 m) for the Bender Farm and River Ridge Farm, respectively. The associated area that would be lost from grazing due to fencing ranged from 12.9 ac (5.2 ha) to 268.1 ac (108.6 ha) and 18.6 ac (7.5 ha) to 389.7 ac (157.8 ha) for the respective farms. These exclosed areas would effectively reduce the available grazing area on the

Bender and River Ridge farms by 2.8% to 57.8% and 5.5% to 100%, respectively. Although theoretically, 100% of the grazing area on the River Ridge Farm would be lost due to the implementation of a 200-ft (61.0-m) fixed-width buffer, the actual loss of grazing area would be less due to the layout of streams and existing pasture boundaries.

The two variable-width fencing BMP scenerios (Fencing BMP 1 & 2) were selected to strike a compromise between the effects of implementing the 50-ft (15.2-m) and 100-ft (30.5-m) fixed-width stream buffers. No difference between the two fencing BMPs was found on the Bender Farm because no streams larger than third-order were present on the farm. The implementation of Fencing BMP 1 or 2 would result in 57,443 ft (17,509 m) of fences to be constructed this would enclose 60.8 ac(24.6 ha) of the farm, effectively reducing the available grazing area by 16.3%. The implementation of Fencing BMP 1 or 2 on the River Ridge Farm would result in the construction of 83,458 ft (25,438 m) and 83,987 ft (25,600 m) of fence to enclose 175.9 ac (71.2 ha) and 120.9 ac (49.0 ha) on the farm, thereby reducing the available grazing area by 52.2% and 35.9%, respectively. Implementation of Fencing BMP 1 or 2 on the River Ridge Farm would require less fencing and would enclose less area to provide either a 100-ft (30.5-m) or 200-ft (61.0-m) buffer along larger order streams.

It should also be noted that the impacts of reduced available grazing area do not simply equate to the need to find additional grazing area in order to maintain a constant stocking rate. The loss of stream bank or riparian zone grazing in some circumstances may be unacceptable. This study and others conducted by Marlow et al. (1986) and Smith et al. (1992) indicate an increased dependency of cattle on riparian forage when there is insufficient quantity of upland forage. The loss of the potential to graze riparian forages, as a result of implementing stream bank fencing, would result in decreased cattle productivity.

The cost of implementing the four fixed-width and two variable-width stream bank buffers on the two farms was estimated by assuming a cost of $1.30/ft ($4.27/m) for the installation of the perimeter fencing, $2.60/ft ($8.53/m) for 20 years of fence maintenance and $15/ac/yr ($37/ha/yr) for lost grazing. These costs were combined and are presented in Table 4-18. Table 4-18 also presents the cost of implementing the buffers per foot of stream and per acre of the entire farm.

The total cost of implementing the fixed-width fenced buffer zones ranged from $84,534 to $167,050 and $121,476 to $244,335 for the Bender and River Ridge farms, respectively. The cost of implementing the fixed-width buffer zones per foot of stream protected ranged from $3.01 ($9.88/m) to $5.95 ($19.52/m)and $2.34 ($7.38/m) to $4.70 ($15.42/m) for the two farms, respectively. The cost of stream bank fencing per acre of the entire farm ranged from $182 ($449/ha) to $360 ($889/ha) and $360 ($889/ha) and $725 (1,790/ha) for fixed-width buffer zones on the Bender and River Ridge farms, respectively. The increased cost per acre of farm land for the River Ridge Farm, compared to the Bender Farm, is due to the 23,265 ft (7,091 m) of one-sided stream bank buffers which would be constructed along the New

River on the River Ridge Farm.

**Table 4-18. Cost of fencing-off six stream bank buffer zones on the Bender and River Ridge farms.**

| | Bender Farm | | | River Ridge Farm | | |
|---|---|---|---|---|---|---|
| Buffer Zone | Total Cost ($) | Cost per foot of Stream ($) | Cost per acre of farm ($) | Total Cost ($) | Cost per foot of Stream ($) | Cost per acre of farm ($) |
| 10-ft | 84,534 | 3.01 | 182.19 | 121,476 | 2.34 | 360.46 |
| 50-ft | 101,452 | 3.16 | 218.65 | 146,465 | 2.82 | 434.61 |
| 100-ft | 122,939 | 4.38 | 264.95 | 178,358 | 3.43 | 529.25 |
| 200-ft | 167,050 | 5.95 | 360.02 | 244,335 | 4.70 | 725.03 |
| Fencing BMP 1[a] | 94,251 | 3.21 | 203.13 | 119,776 | 2.31 | 355.42 |
| Fencing BMP 2[b] | 94,251 | 32.1 | 203.13 | 125,019 | 2.41 | 370.98 |

(a) 1st and 2nd order streams = 50ft buffer, 3rd order = 100ft buffer, > 3rd order = 200ft buffer.
(b) 1st and 2nd order streams = 50ft buffer, >2nd order = 100ft buffer.

Seven and fifteen water troughs are needed on the Bender and River Ridge farms, respectively. The required number of spring development and low-flow solar pump systems, as well as water troughs for the two farms, is presented in Table 4-19. The difference in the number of systems and troughs required is a result of differences in the site-specific design considerations for each of the systems. Some systems within a pasture, due to the volume of water flow and pasture layout, are able to support two or three troughs in series on one spring development system, while other pastures may not be able to support more than one trough. In this case, a single spring development would only be able to support a single trough resulting in a significant cost increase (Table 3-3 and 4-20).

**Table 4-19. Number of water development systems and troughs required for the Bender and River Ridge farms.**

| | Bender Farm | | River Ridge Farm | |
|---|---|---|---|---|
| System Type | # of Systems | # of Troughs | # of Systems | # of Troughs |
| Spring Development | 3 | 5 | 10 | 14 |
| Low-Flow Solar Pump | 2 | 2 | 1 | 1 |
| Total | 5 | 7 | 11 | 15 |

The cost of developing water sources, as described in Table 3-4, on all grazed pastures on the two farms is given in Table 4-20. Table 4-20 includes the installation costs of the spring development and low-flow solar pump systems per foot of stream to be protected and for each acre of the entire farm.

The total cost of water development for grazing cattle was estimated to be $18,307 and $34,073 for the 7 and 15 troughs to be installed on the Bender and River Ridge farms, respectively. The cost of water development per foot of stream was estimated to be $0.62 ($2.03/m) and $0.66 ($2.67/m) for the two farms, respectively. The cost per acre of the entire farm to install the required water troughs was found to be $39 ($97/ha) and $101

($250/ha) for the Bender and River Ridge farms, respectively.

**Table 4-20. Cost of water development for the Bender and River Ridge farms.**

| | Bender Farm | | | River Ridge Farm | | |
|---|---|---|---|---|---|---|
| System Type | Total Cost ($) | Cost per foot of Stream ($) | Cost per acre of farm ($) | Total Cost ($) | Cost per foot of Stream ($) | Cost per acre of farm ($) |
| Spring Development | 9,814 | 0.61 | 32.50 | 29,827 | 0.68 | 98.76 |
| Low-Flow Solar Pump | 8,493 | 0.64 | 52.43 | 4,246 | 0.51 | 121.31 |
| **Total** | **18,307** | **0.62** | **39.46** | **34,073** | **0.66** | **101.11** |

The costs for implementing each of the six stream bank buffer zones and the development of off-stream water sources are presented in Table 4-21 for the two farms. Table 4-21 also shows the percent of savings due to the development of off-stream water sources as compared to stream bank fencing in order to protect water resources and decrease stream bank erosion. The cost per foot of protected stream, and the cost per acre of entire farm and trough to be installed on the two farms are also included in Table 4-21.

The installation of off-stream water sources for grazing cattle would result in a savings of 78.34% to 98.04% and 71.95% to 86.05% of the cost to implement fixed- or variable-width stream bank fencing on the Bender or River Ridge farms, respectively. Installation of off-stream water sources was found to save 79.40% to 89.58% and 71.79% to 85.96% of the cost of implementing fixed- or variable-width stream bank buffer zones per foot of the stream on the Bender and River Ridge Farms, respectively.

**Table 4-21. Cost and savings of developing off stream waters sources for grazing cattle compared to the cost of implementing fenced stream bank buffers.**

| Farm | Proposed BMP | Total Cost[1] ($) | Total Savings (%) | Cost per foot of Stream ($) | Savings per foot of Stream (%) | Cost per acre of farm ($) | Savings per acre of farm (%) |
|---|---|---|---|---|---|---|---|
| Bender | 10-ft Buffer | 84,534 | 78.34 | 3.01 | 79.40 | 182.19 | 78.34 |
| | 50-ft Buffer | 101,452 | 81.96 | 3.61 | 82.83 | 218.65 | 81.95 |
| | 100-ft Buffer | 122,939 | 85.11 | 4.38 | 85.84 | 365.95 | 89.22 |
| | 200-ft Buffer | 167,050 | 98.04 | 5.95 | 89.58 | 360.02 | 89.04 |
| | Fencing BMP 1 | 94,251 | 80.58 | 3.21 | 80.69 | 203.13 | 80.57 |
| | Fencing BMP 2 | 94,251 | 80.58 | 3.21 | 80.69 | 203.13 | 80.57 |
| | Off Stream Water Development | 18,307 | | 0.62 | | 39.46 | |
| River Ridge | 10-ft Buffer | 121,476 | 71.95 | 2.34 | 71.79 | 360.46 | 71.95 |
| | 50-ft Buffer | 146,465 | 76.74 | 2.82 | 76.60 | 434.61 | 76.74 |
| | 100-ft Buffer | 178,358 | 80.90 | 3.43 | 80.76 | 529.25 | 80.90 |
| | 200-ft Buffer | 244,335 | 86.05 | 4.70 | 85.96 | 725.03 | 86.05 |
| | Fencing BMP 1 | 119,776 | 71.55 | 2.31 | 71.43 | 335.42 | 71.55 |
| | Fencing BMP 2 | 125,019 | 72.75 | 2.41 | 72.61 | 370.98 | 72.75 |
| | Off Stream Water Development | 34,073 | | 0.66 | | 101.11 | |

(1) Savings found if off-stream water sources were implemented in place of the proposed BMP.

The costs for water development for each acre of farm on the Bender and River Ridge farms were estimated to be 78% to 89% and 72% to 86%, less than the cost of implementing stream bank fencing, respectively.

In summary, economic analyses showed that the cost for developing off-stream water sources averaged 84% less than the cost for implementing six different widths of fenced stream bank buffer zones for protecting water resources. The average cost of developing off-stream water troughs on the two farms per foot of protected stream and the cost per acre of the two farms was 82% and 81% less than the cost of implementing the six fencing scenarios, respectively.

# V. Summary and Conclusions

A study was conducted to evaluate the effect of installing off-stream water sources on grazing cattle behavior, stream bank erosion and water quality as an alternative to stream bank fencing. The study was conducted on two commercial cow-calf operations in southwest Virginia which utilize rotational grazing. Field observations of cattle behavior were conducted when cattle did (post-BMP) and did not (pre-BMP) have access to an off-stream water source. Measurements of stream bank erosion were made from established cross-sections along three streams during both the pre- and post-BMP treatment periods. Water quality samples from two streams were taken semi-monthly over the fourteen month study period for analysis of sediment bound and dissolved nutrients, minerals and fecal bacteria. An economic analysis was also preformed to compare the cost of implementing several fenced buffer zones to the cost of developing off-stream water sources on the two farms.

The presence of an off-stream water source for grazing cattle reduced the time which cattle spent in the stream area as well as the time which they spent drinking from the stream. When given the choice, cattle were observed to drink from a spring-fed water trough 91.7% of the time, as compared to the time which they spent drinking from the stream. Cattle use of the stream area, for activities other than drinking water, increased by 132%, while the overall use of the stream area reduced by 58.2%, when an off-stream water source was made availible.

These results were observed on study pastures with a high percentage of fescue endophyte infection.

Due to the dramatic reductions in time which cattle spent within the stream area, stream bank erosion was also significantly reduced. Stream bank erosion reduced by 77% on the River Ridge Farm in Independence, Virginia as well as 61% and 40% on two streams on the Bender Farm in Floyd, Virginia. The effect of the BMP was diminished when cattle were required to graze within the stream area and stream crossings were not present.

The presence of an off-stream water source significantly reduced the loading of sediment, sediment-bound nutrients and fecal bacteria on the River Ridge Farm. Concentrations of total suspended solids, total nitrogen, ammonium, sediment-bound nitrogen, total phosphorus and sediment-bound phosphorus were reduced by 90%, 54%, 70%, 68%, 81% and 75%, respectively, due to the installation of an off-stream water source. Concentrations of dissolved nutrients such as nitrate and orthophosphates, were adversely affected by the implementation of the BMP. Concentrations of fecal coliform and fecal streptococci were reduced by an average of 51% and 77%, respectively, on all the River Ridge sampling stations due to the use of off-stream water sources. The effect of the BMP on the Bender Farm was diminished due to improper management techniques such as improper reseeding of disturbed areas after water trough installation and cutting hay proir to grazing.

Water from a spring-fed water trough had significantly lower concentrations of fecal coliform and fecal streptococci as compared to water from a nearby stream. Fecal coliform and fecal streptococci concentrations were reduced by 94% and 75%, respectively. A farm pond was effective in reducing the loadings of nitrate, fecal coliform and fecal streptococci by 66%, 95%, and 97%, respectively, within a rotatational grazing system during the periods that cattle did and did not have access to an off-stream water source.

Lastly, an economic analysis indicated that the cost of developing off-stream water sources would be 84% less than the cost of implementing six different width fenced stream bank buffer zones in order to protect water resources. The average cost of developing off-stream water troughs on the two farms per foot of stream to be protected and per farm acre were 82% and 81%, respectively, less than the cost of implementing the six fencing scenarios.

The presence of an off-stream water source for grazing cattle greatly reduced the impact which grazing cattle have upon stream bank erosion and water quality. Cattle were observed to prefer to drink from an off-stream water source over that of an adjacent stream. The installation of an off-stream water source reduced the total time which cattle spent within the stream area and thereby reduced the amount of stream bank erosion. Sediment, sediment bound nutrients, and fecal bacteria were reduced due to BMP installation. Lastly, the results show that development of off-stream water sources would be more economically attractive than mandated stream bank fencing. The results of this study indicate that the development of off-stream water sources would be a sustainable investment for cattle producers, providing water while protecting the environment.

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# Appendix A

Stocking Records

# Appendix A

## River Ridge Stocking Record

GD : Total number of grazing days

TD : Total number days in period, beginning from the first day of grazing (Oct 25, 94)

ND : Total number of non-disturbed days, i.e. no cattle (TD-GD)

UD : Unit days, product of the number of grazing days and number of cow units

GI : Average grazing intensity on grazing days (UD / GD)

SI : Stocking Intensity, cow units per acre of accessible pasture

SR : Stocking Rate, average cow units per 337 acres in grazing system

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 25-Oct | 31-Oct | 6 | | 202 | 150 | 0.5 | 277 | 1662 | 7.91 |
| 01-Nov | 04-Nov | | 3 | | | | | | |
| 05-Nov | 01-Feb | 88 | | 33 | 1 | | 33.5 | 2948 | 0.96 |
| 02-Feb | 18-Mar | | 44 | | | | | | |

| PRE-BMP | Start | End | GD | TD | ND | UD | GI | Avg. SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 25-Oct | 18-Mar | 94 | 141 | 47 | 4610 | 49 | 4.09 | 0.39 |

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 19-Mar | 21-Mar | 2 | | 42 | 41 | 0.5 | 62.5 | 125 | 1.79 |
| 22-Mar | 28-Mar | 6 | | 84 | 84 | | 126 | 756 | 3.60 |
| 29-Mar | 05-Apr | 7 | | 126 | 126 | | 189 | 1323 | 5.40 |
| 06-Apr | 11-Apr | 5 | | 168 | 168 | | 252 | 1260 | 7.20 |
| 12-Apr | 27-Apr | | 15 | | | | | | |
| 28-Apr | 09-May | 11 | | 14 | 14 | | 21 | 231 | 0.60 |
| 10-May | 12-May | 2 | | 107 | 107 | | 160.5 | 321 | 4.59 |
| 13-May | 23-May | 10 | | 60 | 23 | | 71.5 | 715 | 2.04 |
| 24-May | 26-Jun | | 33 | | | | | | |
| 27-Jun | 05-Jul | 8 | | 109 | 102 | | 160 | 1280 | 4.57 |
| 06-Jul | 01-Aug | | 26 | | | | | | |
| 02-Aug | Aug-95 | 2 | | 78 | 78 | | 117 | 234 | 3.34 |
| 05-Aug | 10-Aug | 5 | | 82 | 83 | | 123.5 | 617.5 | 3.53 |
| 11-Aug | 03-Sep | | 23 | | | | | | |
| 04-Sep | 11-Sep | 7 | | 82 | 83 | | 123.5 | 864.5 | 1.69 |
| 12-Sep | 22-Sep | | 10 | | | | | | |
| 23-Sep | 15-Oct | 22 | | 82 | 83 | | 123.5 | 2717 | 3.53 |

| POST-BMP | Start | End | GD | TD | ND | UD | GI | Avg. SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 19-Mar | 15-Oct | 103 | 210 | 107 | 10444 | 101 | 3.49 | 0.39 |

# Appendix A

## North Bender Stocking Record

GD : Total number of grazing days

TD : Total number days in period, begining from the first day of grazing (Oct 25, 94)

ND : Total number of non-disturbed days, i.e. no cattle (TD-GD)

UD : Unit days, product of the number of grazing days and number of cow units

GI : Average grazing intensity on grazing days (UD / GD)

SI : Stocking Intensity, cow units per acre of accessible grazing

SR : Stocking Rate : average cow units per 384 acres in grazing system

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 11-Dec | 31-Jan | 51 | | 67 | 62 | 0.5 | 98 | 4998 | 7.00 |
| 01-Feb | 12-Mar | | 39 | | | | | | |
| 13-Mar | 14-Mar | 1 | | 87 | 61 | | 117.5 | 117.5 | 8.39 |
| 15-Mar | 18-Mar | | 3 | | | | | | |
| 19-Mar | 08-Apr | 20 | | 72 | 60 | | 102 | 2040 | 7.29 |
| 09-Apr | 17-Apr | | 8 | | | | | | |

| PRE-BMP | Start | End | GD | TD | ND | UD | GI | Avg SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 11-Dec | 17-Apr | 122 | 172 | 50 | 7155.5 | 58.65 | 7.56 | 0.28 |

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 18-Apr | 05-Jun | | 48 | | | | | | |
| 06-Jun | 16-Jun | 10 | | 72 | 60 | 0.5 | 102 | 1020 | 7.29 |
| 17-Jun | 31-Jul | | 44 | | | | | | |
| 01-Aug | 07-Aug | 6 | | 81 | | | 81 | 486 | 5.79 |
| 08-Aug | 13-Aug | 5 | | 149 | 30 | | 164 | 820 | 4.46 |
| 14-Aug | 17-Aug | 3 | | 68 | 35 | | 85.5 | 256.5 | 3.17 |
| 18-Aug | 15-Oct | | 58 | | | | | | |

| POST-BMP | Start | End | GD | TD | ND | UD | GI | Avg SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 18-Apr | 15-Oct | 174 | 266 | 92 | 2582.5 | 14.84 | 5.18 | 0.28 |

# South Bender Stocking Record Appendix A

GD : Total number of grazing days

TD : Total number days in period, begining from the first day of grazing (Oct 25, 94)

ND : Total number of non-disturbed days, i.e. no cattle (TD-GD)

UD : Unit days, product of the number of grazing days and number of cow units

GI : Average grazing intensity on grazing days (UD / GD)

SI : Stocking Intensity, cow units per acre of accessible grazing

SR : Stocking Rate, average cow units per 384 acres in grazing system

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 02-Nov | 10-Dec | 38 | | 67 | 62 | 0.5 | 98 | 3724 | 2.39 |
| 11-Dec | 18-Dec | | 7 | | | | | | |
| 18-Dec | 31-Jan | | 44 | | | | | | |
| 01-Feb | 03-Feb | 2 | | 67 | 62 | | 98 | 196 | 2.39 |
| 04-Feb | 10-Feb | 6 | | 88 | 62 | | 119 | 714 | 2.90 |
| 11-Feb | 10-Mar | 27 | | 87 | 62 | | 118 | 3186 | 2.88 |
| 11-Mar | 12-Mar | 2 | | 87 | 61 | | 117.5 | 235 | 2.87 |
| 13-Mar | 17-Mar | | 5 | | | | | | |
| 18-Mar | 06-Apr | 19 | | 40 | 21 | | 50.5 | 959.5 | 1.23 |
| 07-Apr | 08-Apr | | 2 | | | | | | |
| 09-Apr | 14-Apr | 5 | | 72 | 60 | | 102 | 510 | 2.49 |
| 15-Apr | 17-Apr | | 3 | | | | | | |

| PRE-BMP | Start | End | GD | TD | ND | UD | GI | Avg. SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 02-Nov | 17-Apr | 99 | 161 | 62 | 9524.5 | 96.21 | 2.45 | 0.28 |

| Date On | Date Off | # Days Grazed | # Days Not Disturbed | Cows | Calves | Calf Equiv. | Cow Units | Unit Days | Stocking Intensity |
|---|---|---|---|---|---|---|---|---|---|
| 18-Apr | 13-Aug | | 120 | | | 0.5 | | | |
| 14-Aug | 17-Aug | 4 | | 81 | | | 81 | 324 | 3.52 |
| 18-Aug | 20-Aug | 3 | | 146 | 35 | | 163.5 | 490.5 | 6.93 |
| 21-Aug | 24-Aug | 3 | | 146 | 35 | | 163.5 | 490.5 | 7.03 |
| 25-Aug | 30-Aug | 6 | | 68 | 35 | | 85.5 | 513 | 3.56 |
| 31-Aug | 23-Sep | | 24 | | | | | | |
| 24-Sep | 28-Sep | 4 | | 68 | 45 | | 90.5 | 362 | 3.77 |
| 29-Sep | 04-Oct | 6 | | 68 | 45 | | 90.5 | 543 | 11.31 |
| 05-Oct | 15-Oct | | 10 | | | | | | |

| POST-BMP | Start | End | GD | TD | ND | UD | GI | Avg. SI | SR |
|---|---|---|---|---|---|---|---|---|---|
| | 18-Apr | 15-Oct | 26 | 180 | 154 | 2723 | 104.73 | 6.02 | 0.28 |

# Appendix B

Water Quality

## River Ridge Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S. B. N. (ppm) | TP (ppm) | PO4 (ppm) | FTP (ppm) | S. B. P. (ppm) | Ca (ppm) | Mg (ppm) | K (ppm) | Na (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17-Aug | QRR1 | 0.00 | 0.000 | 0.228 | 0.000 | 0.715 | 0.943 | 0.715 | 0.225 | 0.038 | 0.010 | 0.215 | 5.002 | 2.664 | 7.541 | 3.736 | 3.229 |
| 17-Aug | QRR2 | 21.00 | 0.000 | 0.957 | 0.000 | 0.259 | 1.216 | 0.259 | 0.140 | 0.006 | 0.000 | 0.140 | 4.566 | 2.168 | 6.222 | 4.366 | 2.044 |
| 17-Aug | QRR3 | 18.00 | 0.000 | 0.550 | 0.000 | 0.683 | 1.233 | 0.683 | 0.135 | 0.000 | 0.000 | 0.135 | 4.584 | 2.402 | 7.001 | 3.934 | 2.470 |
| 17-Aug | QRR4 | 23.00 | 0.000 | 0.361 | 0.162 | 0.325 | 0.686 | 0.163 | 0.080 | 0.000 | 0.000 | 0.080 | 3.927 | 1.964 | 4.624 | 4.200 | 1.442 |
| 17-Aug | QRR6 | 13.00 | 0.007 | 0.536 | 0.000 | 0.552 | 1.088 | 0.552 | 0.215 | 0.007 | 0.000 | 0.215 | 5.093 | 2.361 | 5.079 | 3.172 | 0.784 |
| 18-Aug | QRR1 | 25.00 | 0.000 | 0.236 | 0.000 | 0.194 | 0.430 | 0.194 | 0.140 | 0.005 | 0.020 | 0.120 | 3.834 | 1.818 | 4.500 | 4.415 | 1.887 |
| 18-Aug | QRR2 | 113.00 | 0.003 | 0.767 | 0.000 | 0.910 | 1.677 | 0.910 | 0.220 | 0.000 | 0.000 | 0.220 | 3.907 | 1.867 | 6.654 | 4.791 | 1.881 |
| 18-Aug | QRR7 | 14.00 | 0.000 | 0.544 | 0.000 | 0.845 | 1.389 | 0.845 | 0.115 | 0.005 | 0.010 | 0.105 | 4.294 | 2.025 | 5.218 | 2.877 | 1.085 |
| 05-Sep | QRR1 | 23.00 | 0.000 | 0.121 | 0.000 | 0.162 | 0.283 | 0.162 | 0.120 | 0.010 | 0.030 | 0.090 | 3.447 | 1.278 | 1.351 | 4.402 | 0.176 |
| 05-Sep | QRR2 | 9.00 | 0.012 | 0.007 | 0.455 | 0.000 | 0.007 | 0.000 | 0.025 | 0.000 | 0.000 | 0.025 | 5.685 | 2.863 | 5.419 | 3.482 | 0.709 |
| 05-Sep | QRR3 | 18.00 | 0.064 | 0.135 | 0.000 | 0.000 | 0.135 | 0.000 | 0.070 | 0.008 | 0.000 | 0.070 | 4.891 | 1.964 | 2.300 | 4.640 | 0.389 |
| 05-Sep | QRR4 | 1.00 | 0.000 | 0.052 | 0.000 | 0.000 | 0.052 | 0.000 | 0.045 | 0.000 | 0.000 | 0.045 | 4.816 | 1.731 | 1.335 | 3.668 | 0.251 |
| 05-Sep | QRR6 | 4.00 | 0.013 | 0.029 | 0.000 | 0.000 | 0.029 | 0.000 | 0.010 | 0.004 | 0.075 | 0.000 | 5.042 | 2.001 | 1.590 | 4.023 | 0.245 |
| 05-Sep | QRR7 | 2.00 | 0.220 | 0.000 | 0.914 | 1.031 | 1.031 | 0.117 | 0.767 | 0.000 | 1.160 | 0.000 | 4.591 | 2.168 | 3.705 | 3.361 | 0.451 |
| 12-Sep | QRR1 | 100.00 | 0.000 | 0.139 | 0.797 | 1.031 | 1.170 | 0.234 | 1.169 | 0.025 | 0.714 | 0.455 | 3.057 | 1.192 | 1.544 | 4.231 | 0.226 |
| 12-Sep | QRR3 | 0.00 | 0.013 | 0.176 | 0.797 | 2.123 | 2.299 | 1.326 | 1.739 | 0.016 | 0.794 | 0.945 | 3.877 | 1.575 | 1.559 | 4.319 | 0.238 |
| 12-Sep | QRR4 | 58.00 | 0.012 | 0.061 | 0.524 | 0.680 | 0.741 | 0.156 | 0.955 | 0.006 | 0.856 | 0.098 | 4.619 | 1.618 | 1.196 | 3.843 | 0.188 |
| 12-Sep | QRR6 | 21.00 | 0.009 | 0.026 | 0.524 | 0.329 | 0.355 | 0.000 | 0.856 | 0.009 | 0.767 | 0.089 | 5.189 | 1.966 | 1.397 | 4.697 | 1.279 |
| 12-Sep | QRR7 | 0.00 | 0.110 | 0.000 | 0.719 | 0.719 | 0.719 | 0.000 | 1.097 | 0.018 | 0.830 | 0.268 | 5.181 | 2.295 | 3.520 | 3.409 | 0.332 |
| 02-Oct | QRR1 | 319.00 | 0.027 | 0.132 | 0.797 | 1.928 | 2.060 | 1.131 | 1.900 | 0.038 | 0.901 | 0.999 | 3.804 | 1.457 | 1.474 | 4.625 | 0.163 |
| 02-Oct | QRR3 | 5.00 | 0.017 | 0.085 | 0.563 | 0.290 | 0.375 | 0.000 | 0.865 | 0.028 | 0.678 | 0.187 | 4.289 | 1.679 | 1.806 | 4.374 | 0.251 |
| 02-Oct | QRR4 | 30.00 | 0.014 | 0.040 | 0.602 | 0.368 | 0.408 | 0.000 | 0.928 | 0.015 | 0.910 | 0.018 | 4.709 | 1.625 | 1.258 | 3.652 | 0.232 |
| 02-Oct | QRR6 | 10.00 | 0.025 | 0.023 | 0.485 | 0.290 | 0.313 | 0.000 | 0.741 | 0.016 | 0.723 | 0.018 | 4.911 | 1.840 | 1.621 | 4.267 | 0.232 |
| 02-Oct | QRR7 | 5.00 | 0.171 | 0.000 | 1.265 | 1.187 | 1.187 | 0.000 | 0.812 | 0.011 | 0.919 | 0.000 | 4.945 | 2.200 | 3.041 | 3.967 | 0.326 |
| 09-Oct | QRR1 | 76.00 | 0.030 | 0.016 | 0.078 | 0.941 | 0.957 | 0.863 | 0.250 | 0.022 | 0.065 | 0.185 | 4.154 | 1.636 | 1.953 | 5.139 | 0.364 |
| 09-Oct | QRR3 | 15.00 | 0.016 | 0.127 | 0.000 | 0.064 | 0.191 | 0.064 | 1.659 | 0.026 | 1.094 | 0.565 | 3.985 | 1.583 | 1.698 | 4.676 | 0.270 |
| 09-Oct | QRR4 | 32.00 | 0.012 | 0.010 | 0.000 | 0 | 0.010 | 0.000 | 1.201 | 0.017 | 0.832 | 0.369 | 4.458 | 1.668 | 1.644 | 4.366 | 0.301 |
| 09-Oct | QRR6 | 20.00 | 0.037 | 0.000 | 0.000 | 0.311 | 0.311 | 0.311 | 1.299 | 0.014 | 0.668 | 0.631 | 4.816 | 1.897 | 1.822 | 4.499 | 0.270 |
| 09-Oct | QRR7 | 20.00 | 0.052 | 0.000 | 0.311 | 0.064 | 0.064 | 0.000 | 0.529 | 0.011 | 0.816 | 0.000 | 4.960 | 2.160 | 2.841 | 3.933 | 0.263 |
| 27-Oct | QRR1 | 605.00 | 0.550 | 0.045 | 0.000 | 3.345 | 3.390 | 3.345 | 1.010 | 0.000 | 0.000 | 1.010 | 3.157 | 1.595 | 3.667 | 4.764 | 0.433 |
| 27-Oct | QRR2 | 5994.00 | 0.778 | 0.006 | 0.243 | 7.314 | 7.320 | 7.071 | 2.035 | 0.000 | 0.000 | 2.035 | 4.235 | 2.223 | 11.770 | 5.992 | 1.197 |
| 27-Oct | QRR3 | 435.00 | 19.268 | 0.006 | 0.927 | 20.955 | 20.961 | 20.028 | 0.865 | 0.134 | 0.000 | 0.865 | 8.321 | 5.173 | 32.890 | 6.277 | 1.918 |
| 27-Oct | QRR4 | 2418.00 | 6.187 | 0.000 | 8.455 | 19.860 | 19.860 | 11.405 | 2.820 | 0.001 | 0.000 | 2.820 | 7.702 | 4.257 | 22.680 | 7.516 | 1.480 |
| 27-Oct | QRR6 | 434.00 | 2.630 | 0.000 | 7.451 | 11.511 | 11.511 | 4.060 | 0.820 | 0.000 | 0.000 | 0.820 | 5.956 | 2.972 | 16.940 | 5.290 | 1.223 |
| 27-Oct | QRR7 | 2.00 | 0.000 | 0.002 | 0.000 | 0.973 | 0.975 | 0.973 | 0.000 | 0.000 | 0.000 | 0.000 | 4.759 | 2.045 | 2.972 | 4.711 | 0.238 |
| 30-Oct | QRR1 | 126.00 | 0.082 | 0.061 | 0.608 | 0.517 | 0.578 | 0.000 | 0.175 | 0.000 | 0.055 | 0.120 | 3.010 | 1.135 | 2.354 | 7.849 | 0.295 |
| 30-Oct | QRR3 | 195.00 | 1.886 | 0.183 | 0.106 | 2.752 | 2.935 | 2.646 | 0.600 | 0.008 | 0.000 | 0.600 | 6.185 | 3.160 | 7.966 | 5.897 | 0.589 |
| 30-Oct | QRR4 | 704.00 | 1.138 | 0.079 | 0.000 | 17.807 | 17.886 | 17.807 | 1.150 | 0.002 | 0.000 | 1.150 | 5.768 | 2.863 | 7.680 | 5.476 | 0.577 |
| 30-Oct | QRR6 | 2468.00 | 2.771 | 0.000 | 6.904 | 11.101 | 11.101 | 4.197 | 1.075 | 0.000 | 0.000 | 1.075 | 8.240 | 3.870 | 17.160 | 7.231 | 1.292 |

## River Ridge Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S. B. N. (ppm) | TP (ppm) | PO4 (ppm) | FTP (ppm) | S. B. P. (ppm) | Ca (ppm) | Mg (ppm) | K (ppm) | Na (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30-Oct | QRR7 | 9.00 | 0.000 | 0.000 | 0.000 | 7.399 | 7.399 | 7.399 | 0.000 | 0.000 | 0.000 | 0.000 | 4.886 | 2.131 | 3.311 | 3.780 | 0.445 |
| 14-Nov | QRR1 | 332.00 | 0.000 | 0.106 | 0.728 | 1.601 | 1.707 | 0.873 | 0.350 | 0.052 | 0.000 | 0.350 | 5.254 | 2.332 | 4.076 | 4.015 | 0.213 |
| 14-Nov | QRR3 | 354.00 | 0.038 | 0.166 | 1.310 | 1.310 | 1.476 | 0.000 | 0.305 | 0.043 | 0.000 | 0.305 | 5.772 | 2.434 | 3.458 | 4.174 | 0.571 |
| 14-Nov | QRR4 | 0.00 | 0.045 | 0.115 | 1.261 | 0.243 | 0.358 | 0.000 | 0.085 | 0.007 | 0.000 | 0.085 | 5.587 | 2.126 | 2.686 | 3.654 | 0.483 |
| 14-Nov | QRR6 | 67.00 | 0.118 | 0.105 | 0.679 | 1.261 | 1.366 | 0.582 | 0.045 | 0.005 | 0.000 | 0.045 | 5.616 | 2.244 | 2.895 | 3.697 | 0.345 |
| 14-Nov | QRR7 | 0.00 | 0.021 | 0.023 | 3.346 | 0.728 | 0.751 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.775 | 2.149 | 3.404 | 4.370 | 0.357 |
| 28-Nov | QRR1 | 59.00 | 0.120 | 0.085 | 0.000 | 0.348 | 0.433 | 0.348 | 0.360 | 0.043 | 0.000 | 0.360 | 3.078 | 1.239 | 2.424 | 4.701 | 0.433 |
| 28-Nov | QRR3 | 234.00 | 0.188 | 0.585 | 0.000 | 0.000 | 0.585 | 0.000 | 0.130 | 0.022 | 0.000 | 0.130 | 6.841 | 2.946 | 5.241 | 4.542 | 2.301 |
| 28-Nov | QRR4 | 0.00 | 0.092 | 0.289 | 0.000 | 0.000 | 0.289 | 0.000 | 0.075 | 0.000 | 0.000 | 0.075 | 5.675 | 2.431 | 4.215 | 3.953 | 1.060 |
| 28-Nov | QRR6 | 188.00 | 0.169 | 0.268 | 0.000 | 0.000 | 0.268 | 0.000 | 0.120 | 0.004 | 0.000 | 0.120 | 6.639 | 3.023 | 5.303 | 4.241 | 1.034 |
| 28-Nov | QRR7 | 0.00 | 0.158 | 0.052 | 0.000 | 0.000 | 0.052 | 0.000 | 0.015 | 0.000 | 0.000 | 0.015 | 4.422 | 1.985 | 3.203 | 4.354 | 0.426 |
| 11-Dec | QRR1 | 227.00 | 0.286 | 0.377 | 0.000 | 0.000 | 0.377 | 0.000 | 0.275 | 0.005 | 0.000 | 0.275 | 4.210 | 1.975 | 3.589 | 4.115 | 0.940 |
| 11-Dec | QRR2 | 129.00 | 0.182 | 0.608 | 0.000 | 0.000 | 0.608 | 0.000 | 0.175 | 0.000 | 0.060 | 0.115 | 4.239 | 2.321 | 7.125 | 3.191 | 1.379 |
| 11-Dec | QRR3 | 212.00 | 0.191 | 0.385 | 0.000 | 0.000 | 0.385 | 0.000 | 0.010 | 0.010 | 0.105 | 0.000 | 4.560 | 2.137 | 3.906 | 4.239 | 1.028 |
| 11-Dec | QRR4 | 0.00 | 0.180 | 0.243 | 0.000 | 0.000 | 0.243 | 0.000 | 0.070 | 0.005 | 0.060 | 0.010 | 4.641 | 1.912 | 2.570 | 3.607 | 0.671 |
| 11-Dec | QRR6 | 331.00 | 0.274 | 0.261 | 0.000 | 0.000 | 0.261 | 0.000 | 0.100 | 0.002 | 0.005 | 0.095 | 5.208 | 2.264 | 3.126 | 3.928 | 0.777 |
| 11-Dec | QRR7 | 0.00 | 0.143 | 0.096 | 0.177 | 0.000 | 0.096 | 0.000 | 0.005 | 0.000 | 0.000 | 0.005 | 4.452 | 1.952 | 3.219 | 4.133 | 0.621 |
| 18-Dec | QRR1 | 21.00 | 0.094 | 0.225 | 0.000 | 0.000 | 0.225 | 0.000 | 0.085 | 0.016 | 0.000 | 0.085 | 3.028 | 1.111 | 1.598 | 5.136 | 0.295 |
| 18-Dec | QRR3 | 1.00 | 0.127 | 0.299 | 0.000 | 0.000 | 0.299 | 0.000 | 0.095 | 0.000 | 0.000 | 0.095 | 4.294 | 1.705 | 1.768 | 4.749 | 0.326 |
| 18-Dec | QRR4 | 369.00 | 0.144 | 0.328 | 0.000 | 0.223 | 0.551 | 0.223 | 0.660 | 0.000 | 0.005 | 0.655 | 4.722 | 1.838 | 1.698 | 4.014 | 0.326 |
| 18-Dec | QRR6 | 27.00 | 0.216 | 0.235 | 0.000 | 0.000 | 0.235 | 0.000 | 0.045 | 0.000 | 0.080 | 0.000 | 5.159 | 2.119 | 1.961 | 3.961 | 0.320 |
| 18-Dec | QRR7 | 5.00 | 0.190 | 0.137 | 0.000 | 0.000 | 0.137 | 0.000 | 0.010 | 0.000 | 0.045 | 0.000 | 4.330 | 1.992 | 3.358 | 3.599 | 0.608 |
| 08-Jan | QRR1 | 51.00 | 0.167 | 0.313 | 0.000 | 0.832 | 1.145 | 0.832 | 0.090 | 0.012 | 0.030 | 0.060 | 2.189 | 0.951 | 2.161 | 3.829 | 1.310 |
| 08-Jan | QRR2 | 154.00 | 0.687 | 0.571 | 0.000 | 1.598 | 2.169 | 1.598 | 0.145 | 0.000 | 0.035 | 0.110 | 3.850 | 2.192 | 7.325 | 3.842 | 1.461 |
| 08-Jan | QRR3 | 17.00 | 0.469 | 0.335 | 0.000 | 2.173 | 2.508 | 2.173 | 0.125 | 0.009 | 0.045 | 0.080 | 3.416 | 1.943 | 5.033 | 3.440 | 1.066 |
| 08-Jan | QRR4 | 28.00 | 0.192 | 0.183 | 0.000 | 1.708 | 1.891 | 1.708 | 0.050 | 0.000 | 0.035 | 0.015 | 4.307 | 1.831 | 2.570 | 3.933 | 0.602 |
| 08-Jan | QRR6 | 5.00 | 0.334 | 0.194 | 0.504 | 1.653 | 1.847 | 1.149 | 0.060 | 0.000 | 0.015 | 0.045 | 4.425 | 1.996 | 3.026 | 3.819 | 0.614 |
| 08-Jan | QRR7 | 5.00 | 0.077 | 0.114 | 0.449 | 0.969 | 1.083 | 0.520 | 0.000 | 0.000 | 0.105 | 0.000 | 4.312 | 1.924 | 3.342 | 3.929 | 0.608 |
| 21-Jan | QRR1 | 1.00 | 0.000 | 0.509 | 0.856 | 1.195 | 1.704 | 0.339 | 0.045 | 0.021 | 0.000 | 0.045 | 3.112 | 1.492 | 2.455 | 4.049 | 0.947 |
| 21-Jan | QRR2 | 44.00 | 0.000 | 1.054 | 1.985 | 1.674 | 2.728 | 0.000 | 0.075 | 0.000 | 0.025 | 0.050 | 3.532 | 1.840 | 4.415 | 3.003 | 0.997 |
| 21-Jan | QRR3 | 8.00 | 0.025 | 0.689 | 1.082 | 0.884 | 1.573 | 0.000 | 0.015 | 0.009 | 0.005 | 0.010 | 3.770 | 1.895 | 3.497 | 3.968 | 0.940 |
| 21-Jan | QRR4 | 75.00 | 0.079 | 0.361 | 0.941 | 1.223 | 1.584 | 0.282 | 0.425 | 0.003 | 0.000 | 0.425 | 3.676 | 1.688 | 2.331 | 3.211 | 0.683 |
| 21-Jan | QRR6 | 2.00 | 0.134 | 0.309 | 0.884 | 1.110 | 1.419 | 0.226 | 0.025 | 0.004 | 0.015 | 0.010 | 4.450 | 2.097 | 2.980 | 3.240 | 0.696 |
| 21-Jan | QRR7 | 25.00 | 0.391 | 0.320 | 1.138 | 1.533 | 1.853 | 0.395 | 0.130 | 0.062 | 0.125 | 0.005 | 3.852 | 2.255 | 5.457 | 2.327 | 1.078 |
| 12-Feb | QRR3 | 162.00 | 0.084 | 0.359 | 0.482 | 0.707 | 1.066 | 0.225 | 0.195 | 0.010 | 0.000 | 0.195 | 2.997 | 1.351 | 2.138 | 3.381 | 0.583 |
| 12-Feb | QRR4 | 9.00 | 0 | 0.213 | 0.426 | 0.707 | 0.920 | 0.281 | 0 | 0.021 | 0.000 | 0.000 | 3.806 | 1.491 | 1.436 | 3.422 | 0.401 |
| 12-Feb | QRR6 | 5.00 | 0.096 | 0.216 | 0.201 | 0.454 | 0.670 | 0.253 | 0 | 0.002 | 0.000 | 0.000 | 4.313 | 1.825 | 1.698 | 3.839 | 0.389 |
| 12-Feb | QRR7 | 1.00 | 0.253 | 0.222 | 0.736 | 0.651 | 0.873 | 0.000 | 0.015 | 0.015 | 0.000 | 0.015 | 4.859 | 2.396 | 3.844 | 3.137 | 0.765 |

## River Ridge Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S. B. N. (ppm) | TP (ppm) | PO4 (ppm) | FTP (ppm) | S. B. P. (ppm) | Ca (ppm) | Mg (ppm) | K (ppm) | Na (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05-Mar | QRR1 | 0.00 | 0.000 | 0.490 | 0.000 | 0.000 | 0.490 | 0.000 | 0.000 | 0.023 | 0.000 | 0.000 | 3.251 | 1.462 | 1.760 | 4.031 | 0.796 |
| 05-Mar | QRR2 | 75.00 | 0.022 | 0.278 | 0.000 | 0.000 | 0.278 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 3.160 | 1.656 | 2.648 | 3.289 | 0.746 |
| 05-Mar | QRR3 | 165.00 | 0.042 | 0.359 | 0.000 | 0.000 | 0.359 | 0.000 | 0.125 | 0.004 | 0.000 | 0.125 | 3.513 | 1.644 | 2.130 | 4.198 | 0.721 |
| 05-Mar | QRR4 | 56.00 | 0.013 | 0.252 | 0.000 | 0.000 | 0.252 | 0.000 | 0.010 | 0.000 | 0.000 | 0.010 | 4.058 | 1.625 | 1.575 | 3.461 | 0.433 |
| 05-Mar | QRR6 | 0.00 | 0.063 | 0.228 | 0.000 | 0.000 | 0.228 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.487 | 1.929 | 1.706 | 3.863 | 0.533 |
| 05-Mar | QRR7 | 6.00 | 0.157 | 0.235 | 0.000 | 0.000 | 0.235 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.019 | 2.405 | 3.543 | 3.642 | 0.828 |
| 18-Mar | QRR1 | 3.00 | 0.041 | 0.350 | 0.000 | 0.000 | 0.350 | 0.000 | 0.000 | 0.008 | 0.010 | 0.000 | 6.385 | 1.579 | 0.957 | 2.478 | 1.022 |
| 18-Mar | QRR2 | 12.00 | 0.054 | 0.260 | 0.000 | 0.000 | 0.260 | 0.000 | 0.095 | 0.000 | 0.000 | 0.095 | 2.877 | 1.192 | 1.513 | 3.598 | 0.439 |
| 18-Mar | QRR3 | 26.00 | 0.025 | 0.290 | 0.000 | 0.000 | 0.290 | 0.000 | 0.150 | 0.000 | 0.000 | 0.150 | 3.050 | 1.475 | 2.694 | 3.145 | 0.765 |
| 18-Mar | QRR4 | 11.00 | 0.010 | 0.174 | 0.000 | 0.000 | 0.174 | 0.000 | 0.065 | 0.000 | 0.000 | 0.065 | 3.949 | 1.523 | 1.505 | 3.956 | 0.690 |
| 18-Mar | QRR6 | 7.00 | 0.039 | 0.163 | 0.000 | 0.000 | 0.163 | 0.000 | 0.045 | 0.000 | 0.000 | 0.045 | 4.499 | 1.872 | 1.791 | 3.692 | 0.414 |
| 18-Mar | QRR7 | 15.00 | 0.084 | 0.166 | 0.000 | 0.000 | 0.166 | 0.000 | 0.035 | 0.000 | 0.000 | 0.035 | 4.617 | 2.188 | 3.342 | 2.801 | 0.821 |
| 18-Mar | WT3 | 7.00 | 0.011 | 0.440 | 0.000 | 0.000 | 0.440 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.014 | 1.731 | 1.698 | 3.138 | 0.727 |
| 02-Apr | QRR1 | 0.00 | 0.007 | 0.286 | 0.000 | 8.006 | 8.292 | 8.006 | 0.000 | 0.016 | 0.010 | 0.000 | 2.842 | 1.094 | 1.281 | 3.806 | 0.376 |
| 02-Apr | QRR2 | 28.00 | 0.016 | 0.057 | 0.000 | 0.000 | 0.057 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.960 | 1.481 | 2.447 | 4.314 | 0.734 |
| 02-Apr | QRR3 | 0.00 | 0.015 | 0.233 | 0.000 | 1.616 | 1.849 | 1.616 | 0.000 | 0.001 | 0.000 | 0.000 | 3.528 | 1.426 | 1.528 | 6.508 | 0.382 |
| 02-Apr | QRR4 | 22.00 | 0.007 | 0.100 | 0.000 | 0.000 | 0.100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 3.861 | 1.481 | 1.274 | 3.737 | 0.288 |
| 02-Apr | QRR6 | 9.00 | 0.016 | 0.081 | 0.000 | 0.000 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.272 | 1.769 | 1.598 | 3.660 | 0.295 |
| 02-Apr | QRR7 | 0.00 | 0.016 | 0.061 | 0.000 | 0.000 | 0.061 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.662 | 2.178 | 3.080 | 3.728 | 0.740 |
| 02-Apr | WT3 | 0.00 | 0.000 | 0.318 | 0.000 | 0.000 | 0.318 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.014 | 1.883 | 1.698 | 3.625 | 0.495 |
| 15-Apr | QRR1 | 0.00 | 0.000 | 0.322 | 0.477 | 0.052 | 0.374 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 2.677 | 0.987 | 1.405 | 4.410 | 0.420 |
| 15-Apr | QRR2 | 32.00 | 0.000 | 0.194 | 0.000 | 0.080 | 0.274 | 0.080 | 0.010 | 0.000 | 0.000 | 0.010 | 3.531 | 1.635 | 3.227 | 3.276 | 0.533 |
| 15-Apr | QRR3 | 84.00 | 0.000 | 0.420 | 0.137 | 0.420 | 0.840 | 0.283 | 0.000 | 1.490 | 0.000 | 0.000 | 3.377 | 1.429 | 2.038 | 3.910 | 0.370 |
| 15-Apr | QRR4 | 14.00 | 0.000 | 0.242 | 0.080 | 0.000 | 0.242 | 0.000 | 0.000 | 0.006 | 0.000 | 0.000 | 4.059 | 1.455 | 1.297 | 3.896 | 0.270 |
| 15-Apr | QRR6 | 0.00 | 0.000 | 0.202 | 0.052 | 0.000 | 0.202 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 4.735 | 1.866 | 1.544 | 3.640 | 0.288 |
| 15-Apr | QRR7 | 0.00 | 0.022 | 0.038 | 0.505 | 0.000 | 0.038 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.036 | 2.307 | 3.064 | 3.853 | 0.558 |
| 15-Apr | WT3 | 10.00 | 0.000 | 0.318 | 0.194 | 0.222 | 0.540 | 0.028 | 0.010 | 0.000 | 0.000 | 0.010 | 5.085 | 1.708 | 1.536 | 4.154 | 0.451 |
| 30-Apr | QRR1 | 18.00 | 0.027 | 0.129 | 0.501 | 0.877 | 1.006 | 0.377 | 0.000 | 0.002 | 0.000 | 0.000 | 3.329 | 1.195 | 1.058 | 4.659 | 0.257 |
| 30-Apr | QRR2 | 120.00 | 0.031 | 0.178 | 0.187 | 1.832 | 2.010 | 1.645 | 0.120 | 0.004 | 0.000 | 0.120 | 4.039 | 1.966 | 3.744 | 3.973 | 0.640 |
| 30-Apr | QRR3 | 18.00 | 0.029 | 0.275 | 0.000 | 1.386 | 1.661 | 1.386 | 0.050 | 0.028 | 0.000 | 0.050 | 4.174 | 1.671 | 1.590 | 5.321 | 0.357 |
| 30-Apr | QRR4 | 46.00 | 0.000 | 0.278 | 0.000 | 0.000 | 0.278 | 0.000 | 0.040 | 0.013 | 0.000 | 0.040 | 4.879 | 1.762 | 1.351 | 4.432 | 0.245 |
| 30-Apr | QRR6 | 22.00 | 0.000 | 0.211 | 0.000 | 0.156 | 0.367 | 0.156 | 0.000 | 0.009 | 0.000 | 0.000 | 4.854 | 1.874 | 1.505 | 4.035 | 0.270 |
| 30-Apr | QRR7 | 48.00 | 0.002 | 0.012 | 0.093 | 0.000 | 0.012 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 5.136 | 2.388 | 2.671 | 3.754 | 0.357 |
| 30-Apr | WT3 | 224.00 | 0.094 | 0.000 | 0.187 | 14.684 | 14.684 | 14.497 | 6.865 | 0.022 | 0.000 | 6.865 | 11.070 | 2.575 | 2.694 | 4.528 | 0.370 |
| 14-May | QRR1 | 7.00 | 0.482 | 0.275 | 1.512 | 0.883 | 1.158 | 0.000 | 0.145 | 0.050 | 0.030 | 0.115 | 4.253 | 1.883 | 5.334 | 3.568 | 1.436 |
| 14-May | QRR2 | 27.00 | 0.170 | 0.323 | 4.341 | 1.041 | 1.364 | 0.000 | 0.155 | 0.026 | 0.000 | 0.155 | 4.305 | 2.088 | 6.422 | 2.425 | 1.216 |
| 14-May | QRR3 | 7.00 | 0.351 | 0.367 | 1.763 | 6.698 | 7.065 | 4.935 | 0.145 | 0.045 | 0.000 | 0.145 | 5.506 | 2.448 | 7.086 | 3.809 | 1.768 |
| 14-May | QRR4 | 133.00 | 0.985 | 0.420 | 4.152 | 4.906 | 5.326 | 0.754 | 0.470 | 0.055 | 0.085 | 0.385 | 4.740 | 2.414 | 8.738 | 4.150 | 1.881 |
| 14-May | QRR6 | 167.00 | 0.557 | 0.421 | 11.790 | 2.675 | 3.096 | 0.000 | 0.510 | 0.059 | 0.015 | 0.495 | 5.049 | 2.508 | 7.271 | 3.869 | 1.386 |
| 14-May | QRR7 | 0.00 | 0.064 | 0.036 | 0.393 | 0.538 | 0.574 | 0.145 | 0.035 | 0.009 | 0.000 | 0.035 | 5.040 | 2.289 | 2.663 | 3.833 | 0.445 |
| 14-May | WT3 | 0.00 | 0.000 | 0.278 | 0.475 | 0.000 | 0.278 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 6.138 | 2.031 | 1.937 | 3.897 | 0.602 |

## River Ridge Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S. B. N. (ppm) | TP (ppm) | PO4 (ppm) | FTP (ppm) | S. B. P. (ppm) | Ca (ppm) | Mg (ppm) | K (ppm) | Na (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29-May | QRR1 | 1.00 | 0.086 | 0.143 | 0.148 | 0.118 | 0.261 | 0.000 | 0.090 | 0.038 | 0.030 | 0.060 | 3.813 | 1.362 | 1.297 | 4.240 | 0.270 |
| 29-May | QRR3 | 73.00 | 0.066 | 0.276 | 0.208 | 0.360 | 0.636 | 0.151 | 0.225 | 0.009 | 0.000 | 0.225 | 4.208 | 1.579 | 1.675 | 4.208 | 0.320 |
| 29-May | QRR4 | 17.00 | 0.000 | 0.160 | 0.239 | 0.178 | 0.338 | 0.000 | 0.030 | 0.000 | 0.010 | 0.020 | 5.324 | 2.025 | 1.528 | 3.927 | 0.288 |
| 29-May | QRR6 | 12.00 | 0.059 | 0.156 | 0.481 | 1.147 | 1.303 | 0.666 | 0.030 | 0.000 | 0.035 | 0.000 | 4.904 | 2.404 | 2.431 | 3.879 | 0.282 |
| 29-May | QRR7 | 0.00 | 0.000 | 0.019 | 0.481 | 0.299 | 0.318 | 0.000 | 0.040 | 0.000 | 0.010 | 0.030 | 4.511 | 2.290 | 2.246 | 3.745 | 0.245 |
| 29-May | WT3 | 2.00 | 0.000 | 0.133 | 0.451 | 0.118 | 0.251 | 0.000 | 0.085 | 0.000 | 0.000 | 0.085 | 7.055 | 2.218 | 1.953 | 3.843 | 0.345 |
| 11-Jun | QRR1 | 89.00 | 0.000 | 0.245 | 0.538 | 1.637 | 1.882 | 1.100 | 0.000 | 0.031 | 0.000 | 0.000 | 4.020 | 1.440 | 1.266 | 4.022 | 0.238 |
| 11-Jun | QRR3 | 15.00 | 0.000 | 0.066 | 0.538 | 2.147 | 2.213 | 1.609 | 0.380 | 0.006 | 0.000 | 0.380 | 4.279 | 1.616 | 1.443 | 3.962 | 0.288 |
| 11-Jun | QRR4 | 0.00 | 0.000 | 0.248 | 0.591 | 1.664 | 1.912 | 1.073 | 0.065 | 0.000 | 0.000 | 0.065 | 4.682 | 1.668 | 1.096 | 3.860 | 0.194 |
| 11-Jun | QRR6 | 0.00 | 0.000 | 0.209 | 1.101 | 1.369 | 1.578 | 0.268 | 0.000 | 0.000 | 0.000 | 0.000 | 5.230 | 1.998 | 1.297 | 4.318 | 0.219 |
| 11-Jun | QRR7 | 277.00 | 0.000 | 0.112 | 1.182 | 1.396 | 1.508 | 0.215 | 0.000 | 0.000 | 0.000 | 0.000 | 4.473 | 2.287 | 1.737 | 3.974 | 0.213 |
| 11-Jun | WT3 | 0.00 | 0.000 | 0.232 | 0.779 | 1.396 | 1.628 | 0.617 | 0.000 | 0.000 | 0.000 | 0.000 | 7.394 | 2.093 | 1.822 | 3.621 | 0.401 |
| 27-Jun | QRR1 | 6.00 | ND | 0.299 | 0.132 | 0.000 | 0.299 | 0.000 | 0.105 | 0.001 | 0.000 | 0.105 | 4.276 | 1.859 | 2.690 | 5.725 | 1.316 |
| 27-Jun | QRR2 | 42.00 | 0.008 | 0.094 | 0.422 | 0.190 | 0.284 | 0.000 | 0.090 | 0.000 | 0.000 | 0.090 | 4.502 | 1.993 | 3.294 | 5.424 | 1.130 |
| 27-Jun | QRR3 | 2.00 | 0.065 | 0.199 | 0.190 | 0.000 | 0.199 | 0.000 | 0.070 | 0.004 | 0.000 | 0.070 | 4.628 | 1.946 | 2.531 | 5.707 | 0.881 |
| 27-Jun | QRR4 | 4.00 | 0.000 | 0.198 | 0.248 | 0.000 | 0.198 | 0.000 | 0.050 | 0.006 | 0.000 | 0.050 | 4.572 | 1.821 | 1.783 | 5.348 | 0.518 |
| 27-Jun | QRR6 | 0.00 | 0.028 | 0.182 | 0.828 | 0.000 | 0.182 | 0.000 | 0.035 | 0.000 | 0.000 | 0.035 | 5.151 | 2.329 | 2.206 | 5.305 | 0.508 |
| 27-Jun | QRR7 | 0.00 | 0.048 | 0.024 | 0.625 | 0.000 | 0.024 | 0.000 | 0.035 | 0.000 | 0.000 | 0.035 | 3.774 | 2.117 | 1.655 | 5.647 | 0.176 |
| 27-Jun | QRRWT3 | 0.00 | 0.008 | 0.252 | 0.074 | 0.000 | 0.252 | 0.000 | 0.020 | 0.000 | 0.000 | 0.020 | 6.842 | 2.391 | 2.297 | 5.017 | 0.798 |
| 29-Jun | QRR1 | 10.00 | 0.222 | 0.189 | 0.222 | 0.645 | 0.834 | 0.423 | 0.140 | 0.052 | 0.000 | 0.140 | 4.475 | 1.886 | 2.713 | 5.641 | 0.311 |
| 29-Jun | QRR2 | 78.00 | 0.192 | 0.124 | 0.271 | 0.000 | 0.124 | 0.000 | 0.130 | 0.013 | 0.000 | 0.130 | 4.873 | 2.316 | 3.551 | 5.843 | 0.591 |
| 29-Jun | QRR3 | 36.00 | 0.336 | 0.259 | 0.246 | 0.072 | 0.331 | 0.000 | 0.170 | 0.053 | 0.000 | 0.170 | 4.476 | 1.971 | 2.864 | 6.309 | 0.332 |
| 29-Jun | QRR4 | 24.00 | 0.171 | 0.197 | 0.271 | 0.000 | 0.197 | 0.000 | 0.060 | 0.029 | 0.000 | 0.060 | 5.243 | 1.991 | 2.811 | 6.932 | 0.332 |
| 29-Jun | QRR6 | 8.00 | 0.593 | 0.148 | 1.342 | 0.000 | 0.148 | 0.000 | 0.035 | 0.027 | 0.000 | 0.035 | 5.859 | 2.545 | 5.145 | 5.580 | 0.705 |
| 29-Jun | QRR7 | 0.00 | 0.050 | 0.038 | 0.869 | 0.022 | 0.060 | 0.000 | 0.000 | 0.012 | 0.000 | 0.000 | 5.218 | 2.363 | 1.640 | 5.738 | 0.218 |
| 29-Jun | QRRWT3 | 24.00 | 0.613 | 0.193 | 0.919 | 5.175 | 5.368 | 4.257 | 0.320 | 0.044 | 0.000 | 0.320 | 7.928 | 2.886 | 4.178 | 6.090 | 0.860 |
| 09-Jul | QRR1 | 0.00 | 0.169 | 0.198 | 0.172 | 1.391 | 1.589 | 1.220 | 0.030 | 0.041 | 0.000 | 0.030 | 3.018 | 1.468 | 2.425 | 6.514 | 0.290 |
| 09-Jul | QRR2 | 60.00 | 0.054 | 0.164 | 0.670 | 1.989 | 2.153 | 1.319 | 0.060 | 0.014 | 0.000 | 0.060 | 4.988 | 2.189 | 3.604 | 5.057 | 0.570 |
| 09-Jul | QRR3 | 0.00 | 0.108 | 0.289 | 0.694 | 1.441 | 1.730 | 0.747 | 0.020 | 0.030 | 0.000 | 0.020 | 4.360 | 1.930 | 2.682 | 5.677 | 0.290 |
| 09-Jul | QRR4 | 0.00 | 0.038 | 0.185 | 0.446 | 0.670 | 0.855 | 0.224 | 0.000 | 0.018 | 0.000 | 0.000 | 4.111 | 1.768 | 1.964 | 5.217 | 0.238 |
| 09-Jul | QRR6 | 2.00 | 0.256 | 0.182 | 0.744 | 0.968 | 1.150 | 0.224 | 0.000 | 0.025 | 0.000 | 0.000 | 6.444 | 2.554 | 2.652 | 5.378 | 0.280 |
| 09-Jul | QRR7 | 4.00 | 0.113 | 0.030 | 0.719 | 1.192 | 1.222 | 0.473 | 0.065 | 0.013 | 0.000 | 0.065 | 5.188 | 2.487 | 4.345 | 5.124 | 0.415 |
| 09-Jul | QRRWT3 | 0.00 | 0.004 | 0.282 | 0.520 | 1.367 | 1.649 | 0.846 | 0.000 | 0.011 | 0.105 | 0.000 | 6.999 | 2.345 | 2.184 | 5.771 | 0.663 |
| 23-Jul | QRR1 | 8.00 | 0.000 | 0.377 | 0.000 | 0.000 | 0.377 | 0.000 | 0.125 | 0.032 | 0.045 | 0.080 | 4.210 | 1.630 | 1.919 | 6.449 | 0.259 |
| 23-Jul | QRR3 | 10.00 | 0.000 | 0.292 | 0.000 | 0.000 | 0.292 | 0.000 | 0.100 | 0.005 | 0.000 | 0.100 | 4.340 | 1.636 | 1.602 | 5.388 | 0.155 |
| 23-Jul | QRR4 | 10.00 | 0.000 | 0.092 | 0.000 | 0.000 | 0.092 | 0.000 | 0.045 | 0.000 | 0.000 | 0.045 | 4.786 | 1.677 | 1.292 | 4.839 | 0.187 |
| 23-Jul | QRR6 | 0.00 | 0.000 | 0.099 | 0.000 | 0.165 | 0.264 | 0.165 | 0.075 | 0.000 | 0.010 | 0.065 | 5.206 | 1.893 | 1.488 | 6.753 | 0.249 |
| 23-Jul | QRR7 | 0.00 | 0.000 | 0.060 | 0.000 | 0.000 | 0.060 | 0.000 | 0.055 | 0.000 | 0.010 | 0.045 | 5.416 | 2.538 | 4.299 | 6.128 | 0.155 |
| 23-Jul | QRRWT3 | 0.00 | 0.000 | 0.016 | 0.000 | 0.944 | 0.960 | 0.944 | 0.030 | 0.000 | 0.150 | 0.000 | 6.380 | 1.833 | 1.783 | 6.588 | 0.301 |

# Appendix B

## River Ridge Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S. B. N. (ppm) | TP (ppm) | PO4 (ppm) | FTP (ppm) | S. B. P. (ppm) | Ca (ppm) | Mg (ppm) | K (ppm) | Na (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20-Aug | QRR3 | 28.00 | 0.000 | 0.299 | 0.645 | 0.000 | 0.299 | 0.000 | 0.018 | 0.000 | 0.000 | 0.018 | 4.941 | 1.821 | 2.796 | 7.417 | 0.352 |
| 20-Aug | QRR4 | 12.00 | 0.000 | 0.093 | 0.360 | 0.000 | 0.093 | 0.000 | 0.008 | 0.000 | 0.000 | 0.008 | 5.145 | 1.753 | 1.473 | 7.046 | 0.207 |
| 20-Aug | QRR6 | 24.00 | 0.031 | 0.075 | 0.000 | 0.000 | 0.075 | 0.000 | 0.013 | 0.000 | 0.017 | 0.000 | 5.298 | 2.008 | 2.010 | 6.582 | 0.218 |
| 20-Aug | QRR7 | 8.00 | 0.024 | 0.033 | 1.708 | 1.966 | 1.999 | 0.258 | 0.060 | 0.000 | 0.000 | 0.060 | 5.972 | 2.712 | 4.994 | 5.633 | 0.104 |
| 20-Aug | QRRWT3 | 8.00 | 0.000 | 0.021 | 1.568 | 1.779 | 1.800 | 0.211 | 0.075 | 0.000 | 0.000 | 0.075 | 5.753 | 1.724 | 2.010 | 6.267 | 0.425 |
| 05-Sep | QRR3 | 6.00 | 0.000 | 0.276 | 1.170 | 1.943 | 2.219 | 0.773 | 0.095 | 0.005 | 0.000 | 0.095 | 5.265 | 1.928 | 1.760 | 5.715 | 0.114 |
| 05-Sep | QRR4 | 6.00 | 0.000 | 0.070 | 1.193 | 1.755 | 1.825 | 0.562 | 0.110 | 0.000 | 0.000 | 0.110 | 4.849 | 1.685 | 1.345 | 5.134 | 0.155 |
| 05-Sep | QRR6 | 8.00 | 0.000 | 0.000 | 5.431 | 2.200 | 2.200 | 0.000 | 0.085 | 0.000 | 0.000 | 0.085 | 6.724 | 2.772 | 5.516 | 5.030 | 0.104 |
| 05-Sep | QRR7 | 0.00 | 0.060 | 0.040 | 2.645 | 2.621 | 2.661 | 0.000 | 0.000 | 0.000 | 0.175 | 0.000 | 5.345 | 2.104 | 3.302 | 5.093 | 0.207 |
| 17-Sep | QRR1 | 16.00 | 0.000 | 0.890 | 1.008 | 3.547 | 4.437 | 2.539 | 0.160 | 0.000 | 0.000 | 0.160 | 4.913 | 2.657 | 6.929 | 4.303 | 2.373 |
| 17-Sep | QRR2 | 38.00 | 0.000 | 1.218 | 0.767 | 2.371 | 3.589 | 1.604 | 0.110 | 0.000 | 0.000 | 0.110 | 4.066 | 2.013 | 9.082 | 3.725 | 2.176 |
| 17-Sep | QRR3 | 0.00 | 0.000 | 0.893 | 0.741 | 2.264 | 3.157 | 1.523 | 0.080 | 0.000 | 0.000 | 0.080 | 5.118 | 2.481 | 7.548 | 4.285 | 2.073 |
| 17-Sep | QRR4 | 0.00 | 0.000 | 0.517 | 0.313 | 1.890 | 2.407 | 1.577 | 0.070 | 0.000 | 0.000 | 0.070 | 4.219 | 1.950 | 4.322 | 3.218 | 1.316 |
| 17-Sep | QRR6 | 0.00 | 0.020 | 0.471 | 0.607 | 1.783 | 2.254 | 1.176 | 0.085 | 0.000 | 0.000 | 0.085 | 5.437 | 2.423 | 5.357 | 3.396 | 1.658 |
| 17-Sep | QRR7 | 18.00 | 0.299 | 0.018 | 0.554 | 2.237 | 2.255 | 1.684 | 0.135 | 0.000 | 0.040 | 0.095 | 5.405 | 2.354 | 6.913 | 3.188 | 0.622 |
| 17-Sep | QRRWT3 | 4.00 | 0.019 | 0.803 | 1.035 | 1.756 | 2.559 | 0.722 | 0.140 | 0.000 | 0.000 | 0.140 | 5.776 | 2.026 | 3.755 | 3.437 | 1.855 |
| 26-Sep | QRR1 | 4.00 | 0.000 | 0.384 | 0.000 | 1.202 | 1.586 | 1.202 | 0.105 | 0.022 | 0.000 | 0.105 | 3.656 | 1.496 | 2.713 | 4.875 | 0.332 |
| 26-Sep | QRR3 | 17.00 | 0.000 | 0.455 | 0.000 | 1.905 | 2.360 | 1.905 | 0.150 | 0.011 | 0.000 | 0.150 | 4.371 | 2.019 | 3.733 | 4.866 | 0.788 |
| 26-Sep | QRR4 | 0.00 | 0.000 | 0.231 | 0.000 | 2.129 | 2.360 | 2.129 | 0.020 | 0.054 | 0.000 | 0.020 | 4.613 | 1.884 | 3.121 | 4.034 | 0.518 |
| 26-Sep | QRR6 | 4.00 | 0.414 | 0.192 | 1.287 | 3.112 | 3.304 | 1.826 | 0.070 | 0.033 | 0.000 | 0.070 | 6.551 | 2.759 | 6.029 | 4.946 | 0.591 |
| 26-Sep | QRR7 | 4.00 | 0.131 | 0.011 | 0.556 | 3.281 | 3.292 | 2.725 | 0.035 | 0.017 | 0.000 | 0.035 | 5.431 | 2.387 | 6.120 | 3.715 | 0.269 |
| 26-Sep | QRRWT3 | 0.00 | 0.064 | 0.277 | 0.613 | 3.478 | 3.755 | 2.865 | 0.125 | 0.029 | 0.020 | 0.105 | 4.925 | 2.276 | 2.629 | 4.614 | 0.674 |
| 02-Oct | QRR1 | 5.00 | 0.000 | 0.388 | 0.893 | 2.017 | 2.405 | 1.124 | 0.140 | 0.043 | 0.040 | 0.100 | 4.328 | 1.719 | 2.803 | 5.140 | 0.187 |
| 02-Oct | QRR3 | 15.00 | 0.024 | 0.367 | 0.584 | 2.270 | 2.637 | 1.685 | 0.205 | 0.026 | 0.160 | 0.045 | 4.305 | 1.846 | 2.372 | 4.711 | 0.311 |
| 02-Oct | QRR4 | 1.00 | ND | 0.304 | 0.641 | 0.304 | 0.608 | 0.000 | 0.000 | 0.014 | 0.165 | 0.000 | 4.096 | 1.730 | 2.244 | 4.108 | 0.228 |
| 02-Oct | QRR6 | 5.00 | 0.012 | 0.299 | 0.210 | 0.157 | 0.456 | 0.000 | 0.100 | 0.012 | 0.000 | 0.100 | 4.770 | 2.073 | 2.833 | 4.330 | 0.249 |
| 02-Oct | QRR7 | 4.00 | 0.229 | ND | 0.715 | 0.715 | 0.715 | 0.000 | 0.095 | 0.016 | 0.000 | 0.095 | 6.013 | 2.483 | 6.249 | 3.546 | 0.290 |
| 02-Oct | QRRWT3 | 0.00 | 0.000 | 0.271 | 0.210 | 0.396 | 0.667 | 0.186 | 0.095 | 0.037 | 0.000 | 0.095 | 4.923 | 1.893 | 2.335 | 4.341 | 0.425 |
| 15-Oct | QRR1 | 6.00 | 0.000 | 0.174 | 0.263 | 0.423 | 0.597 | 0.160 | 0.090 | 0.003 | 0.040 | 0.050 | 3.405 | 1.556 | 2.818 | 4.650 | 0.342 |
| 15-Oct | QRR2 | 6.00 | 0.108 | 0.151 | 0.449 | 0.502 | 0.653 | 0.053 | 0.000 | 0.000 | 0.130 | 0.000 | 4.111 | 2.129 | 7.027 | 4.174 | 1.233 |
| 15-Oct | QRR3 | 13.00 | 0.080 | 0.239 | 0.103 | 0.449 | 0.688 | 0.346 | 0.000 | 0.000 | 0.100 | 0.000 | 4.606 | 2.098 | 3.884 | 4.401 | 0.580 |
| 15-Oct | QRR4 | 9.00 | 0.000 | 0.112 | 0.000 | 0.241 | 0.353 | 0.241 | 0.135 | 0.000 | 0.000 | 0.135 | 4.815 | 1.995 | 2.864 | 4.021 | 0.415 |
| 15-Oct | QRR6 | 6.00 | 0.061 | 0.106 | 0.032 | 0.371 | 0.477 | 0.339 | 0.075 | 0.000 | 0.000 | 0.075 | 6.060 | 2.512 | 3.397 | 4.192 | 0.453 |
| 15-Oct | QRR7 | 16.00 | 0.857 | 0.519 | 1.674 | 1.857 | 2.376 | 0.182 | 0.425 | 0.156 | 0.115 | 0.310 | 5.310 | 2.579 | 9.350 | 2.868 | 0.663 |
| 15-Oct | QRRWT3 | 4.00 | 0.000 | 0.418 | 0.684 | 0.554 | 0.972 | 0.000 | 0.105 | 0.030 | 0.000 | 0.105 | 5.437 | 1.841 | 2.747 | 4.527 | 0.832 |

## River Ridge Water Quality Parameters: Fecal Bacteria

(TC): Total Coliform, (FC): Fecal Coliform, (FS): Fecal Streptococci
All expressed as # of colonies per 100 ml
— : No Sample Collected

| DATE | Station | TC | FC | FS | Station | TC | FC | FS | Station | TC | FC | FS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/2/94 | QRR1 | 41000 | 2400 | 90 | QRR2 | — | — | — | QRR3 | 12000 | 901 | 0 |
| 10/27/94 | QRR1 | 60000 | 90 | 0 | QRR2 | 440000 | 90 | 25000 | QRR3 | 680000 | 15315 | 15315 |
| 10/30/34 | QRR1 | 1802 | 90 | 0 | QRR2 | — | — | — | QRR3 | 128500 | 30000 | 8108 |
| 11/28/94 | QRR1 | 22000 | 14000 | 20000 | QRR2 | — | — | — | QRR3 | 25000 | 1802 | 2000 |
| 12/11/94 | QRR1 | 72000 | 541 | 7200 | QRR2 | 70000 | 360 | 5500 | QRR3 | 35000 | 0 | 2072 |
| 1/08/95 | QRR1 | 33000 | 360 | 520 | QRR2 | 77000 | 0 | 290 | QRR3 | 420000 | 270 | 160 |
| 2/12/95 | QRR1 | — | — | — | QRR2 | — | — | — | QRR3 | 3900 | 9 | 9 |
| 3/19/95 | QRR1 | 3100 | 9 | 54 | QRR2 | 7300 | 1300 | 1500 | QRR3 | 3200 | 108 | 240 |
| 4/02/95 | QRR1 | 4400 | 1900 | 5600 | QRR2 | 7300 | 81 | 153 | QRR3 | 2300 | 0 | 290 |
| 4/30/95 | QRR1 | 41000 | 1600 | 2700 | QRR2 | 3400 | 590 | 171 | QRR3 | 4300 | 0 | 9 |
| 5/30/95 | QRR1 | 16000 | 180 | 3600 | QRR2 | — | — | — | QRR3 | 46000 | 1800 | 3000 |
| 6/27/95 | QRR1 | 80000 | 9000 | 3000 | QRR2 | 49000 | 510 | 720 | QRR3 | 59000 | 3500 | 750 |
| 6/30/95 | QRR1 | 320000 | 27000 | 2200 | QRR2 | 56000 | 4500 | 580 | QRR3 | 120000 | 5800 | 570 |
| 9/26/95 | QRR1 | 51000 | 173 | 2800 | QRR2 | — | — | — | QRR3 | 80000 | 2900 | 2700 |
| 10/02/95 | QRR1 | 14545 | 220 | 80 | QRR2 | — | — | — | QRR3 | 6000 | 126 | 600 |
| 10/15/95 | QRR1 | 25000 | 146 | 127 | QRR2 | 42000 | 64 | 210 | QRR3 | 22000 | 100 | 370 |

| DATE | Station | TC | FC | FS | Station | TC | FC | FS | Station | TC | FC | FS | Station | TC | FC | FS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/2/94 | QRR4 | 14000 | 1982 | 1081 | QRR5 | 31000 | 991 | 541 | QRR6 | 3600 | 1261 | 0 | QRRWT3 | — | — | — |
| 10/27/94 | QRR4 | 140000 | 92793 | 20000 | QRR5 | 440000 | 12613 | 2703 | QRR6 | 3604 | 0 | 0 | QRRWT3 | — | — | — |
| 10/30/34 | QRR4 | 460000 | 46000 | 6306 | QRR5 | 700000 | 10811 | 14414 | QRR6 | 0 | 0 | 0 | QRRWT3 | — | — | — |
| 11/28/94 | QRR4 | 210000 | 2200 | 3200 | QRR5 | 330000 | 180 | 3300 | QRR6 | 21000 | 90 | 360 | QRRWT3 | — | — | — |
| 12/11/94 | QRR4 | 48000 | 451 | 2400 | QRR5 | 160500 | 0 | 1171 | QRR6 | 29000 | 0 | 721 | QRRWT3 | — | — | — |
| 1/08/95 | QRR4 | 27000 | 360 | 2072 | QRR5 | 20000 | 0 | 450 | QRR6 | 180180 | 0 | 360 | QRRWT3 | — | — | — |
| 2/12/95 | QRR4 | 2900 | 700 | 198 | QRR5 | 2200 | 63 | 36 | QRR6 | 631 | 117 | 0 | QRRWT3 | — | — | — |
| 3/19/95 | QRR4 | 3600 | 27 | 81 | QRR5 | 2700 | 63 | 54 | QRR6 | 4300 | 0 | 0 | QRRWT3 | 0 | 0 | 0 |
| 4/02/95 | QRR4 | 3100 | 1000 | 81 | QRR5 | 2100 | 117 | 81 | QRR6 | 1171 | 0 | 0 | QRRWT3 | 180 | 0 | 0 |
| 4/30/95 | QRR4 | 7500 | 3100 | 3000 | QRR5 | 20000 | 800 | 580 | QRR6 | 3600 | 36 | 9 | QRRWT3 | 2600 | 0 | 54 |
| 5/30/95 | QRR4 | 24000 | 300 | 1400 | QRR5 | 30000 | 1000 | 600 | QRR6 | 80000 | 0 | 0 | QRRWT3 | 78000 | 0 | 0 |
| 6/27/95 | QRR4 | 38000 | 1300 | 1100 | QRR5 | 40000 | 1400 | 610 | QRR6 | 18000 | 18 | 63 | QRRWT3 | 36000 | 300 | 810 |
| 6/30/95 | QRR4 | 52000 | 14000 | 500 | QRR5 | 83000 | 4600 | 570 | QRR6 | 7000 | 0 | 9 | QRRWT3 | 58000 | 350 | 910 |
| 9/26/95 | QRR4 | 63000 | 1900 | 1800 | QRR5 | 80000 | 3400 | 1900 | QRR6 | 18182 | 410 | 158 | QRRWT3 | 24000 | 182 | 240 |
| 10/02/95 | QRR4 | 31000 | 2000 | 2100 | QRR5 | 22000 | 2100 | 4000 | QRR6 | 11818 | 81 | 0 | QRRWT3 | 26000 | 0 | 90 |
| 10/15/95 | QRR4 | 31000 | 136 | 250 | QRR5 | 28000 | 109 | 210 | QRR6 | 62000 | 73 | 55 | QRRWT3 | 8000 | 55 | 55 |

# Appendix B

## North Bender Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S.B.N. (ppm) | FTP (ppm) | TP (ppm) | PO4 (ppm) | S.B.P. (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 02-Oct | QNB1 | 58.00 | 0.010 | 0.028 | 0.563 | 1.304 | 1.332 | 0.741 | 0.687 | 1.409 | 0.007 | 0.722 |
| 02-Oct | QNB2 | 36.00 | 0.023 | 0.000 | 0.407 | 0.446 | 0.446 | 0.039 | 0.678 | 1.044 | 0.008 | 0.366 |
| 02-Oct | QNB3 | 9.00 | 0.013 | 0.007 | 0.524 | 0.446 | 0.453 | 0.000 | 0.642 | 0.972 | 0.004 | 0.330 |
| 02-Oct | QNB4 | 20.00 | 0.011 | 0.037 | 0.602 | 0.095 | 0.132 | 0.000 | 0.660 | 0.848 | 0.008 | 0.187 |
| 09-Oct | QNB1 | 77.00 | 0.025 | 0.023 | 0.000 | 0.530 | 0.553 | 0.530 | 0.000 | 0.225 | 0.026 | 0.225 |
| 09-Oct | QNB2 | 57.00 | 0.027 | 0.000 | 0.000 | 0.078 | 0.078 | 0.078 | 0.000 | 0.105 | 0.017 | 0.105 |
| 09-Oct | QNB3 | 21.00 | 0.012 | 0.011 | 0.000 | 0.000 | 0.011 | 0.000 | 0.015 | 0.025 | 0.016 | 0.010 |
| 09-Oct | QNB4 | 32.00 | 0.027 | 0.042 | 0.000 | 0.036 | 0.078 | 0.036 | 0.010 | 0.070 | 0.014 | 0.060 |
| 30-Oct | QNB1 | 39.00 | 0.042 | 0.071 | 0.930 | 0.139 | 0.210 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30-Oct | QNB2 | 47.00 | 0.016 | 0.050 | 0.000 | 4.674 | 4.724 | 4.674 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30-Oct | QNB3 | 17.00 | 0.034 | 0.027 | 0.000 | 0.000 | 0.027 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30-Oct | QNB4 | 6.00 | 0.001 | 0.094 | 0.000 | 5.881 | 5.975 | 5.881 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14-Nov | QNB2 | 462.00 | 0.000 | 0.075 | 0.776 | 2.619 | 2.694 | 1.843 | 0.000 | 0.840 | 0.000 | 0.840 |
| 14-Nov | QNB3 | 11.00 | 0.000 | 0.118 | 0.776 | 1.649 | 1.767 | 0.873 | 0.000 | 0.135 | 0.000 | 0.135 |
| 14-Nov | QNB4 | 0.00 | 0.000 | 0.169 | 0.728 | 1.261 | 1.430 | 0.533 | 0.000 | 0.115 | 0.000 | 0.115 |
| 28-Nov | QNB3 | 271.00 | 0.007 | 0.092 | 0.000 | 1.487 | 1.579 | 1.487 | 0.000 | 0.685 | 0.000 | 0.685 |
| 28-Nov | QNB4 | 0.00 | 0.025 | 0.140 | 0.000 | 0.000 | 0.140 | 0.000 | 0.000 | 0.060 | 0.000 | 0.060 |
| 11-Dec | QNB2 | 345.00 | 0.001 | 0.170 | 0.000 | 1.099 | 1.269 | 1.099 | 0.000 | 0.855 | 0.000 | 0.855 |
| 11-Dec | QNB3 | 12.00 | 0.004 | 0.135 | 0.000 | 0.000 | 0.135 | 0.000 | 0.015 | 0.040 | 0.000 | 0.025 |
| 11-Dec | QNB4 | 20.00 | 0.005 | 0.182 | 0.000 | 0.000 | 0.182 | 0.000 | 0.000 | 0.045 | 0.000 | 0.045 |
| 18-Dec | QNB1 | 216.00 | 0.082 | 0.189 | 0.000 | 2.173 | 2.362 | 2.173 | 0.000 | 0.445 | 0.000 | 0.445 |
| 18-Dec | QNB2 | 42.00 | 1.010 | 0.123 | 0.176 | 2.036 | 2.159 | 1.860 | 0.000 | 0.225 | 0.000 | 0.225 |
| 18-Dec | QNB3 | 146.00 | 4.175 | 0.137 | 7.452 | 13.060 | 13.197 | 5.608 | 0.135 | 0.715 | 0.005 | 0.580 |
| 18-Dec | QNB4 | 30.00 | 1.460 | 0.284 | 0.217 | 1.902 | 2.186 | 1.686 | 0.030 | 0.145 | 0.000 | 0.115 |
| 08-Jan | QNB1 | 19.00 | 0.209 | 0.365 | 0.000 | 1.025 | 1.390 | 1.025 | 0.000 | 0.075 | 0.000 | 0.075 |
| 08-Jan | QNB2 | 15.00 | 0.269 | 0.209 | 0.772 | 1.025 | 1.234 | 0.254 | 0.000 | 0.070 | 0.000 | 0.070 |
| 08-Jan | QNB3 | 8.00 | 0.449 | 0.167 | 1.449 | 1.054 | 1.221 | 0.000 | 0.000 | 0.060 | 0.000 | 0.060 |
| 08-Jan | QNB4 | 4.00 | 0.210 | 0.256 | 0.884 | 1.082 | 1.338 | 0.197 | 0.000 | 0.070 | 0.001 | 0.070 |
| 21-Jan | QNB1 | 11.00 | 0.052 | 0.368 | 0.631 | 0.969 | 1.337 | 0.339 | 0.050 | 0.000 | 0.000 | 0.000 |
| 21-Jan | QNB2 | 4.00 | 0.000 | 0.232 | 0.454 | 0.229 | 0.461 | 0.000 | 0.000 | 0.120 | 0.000 | 0.120 |
| 21-Jan | QNB3 | 3.00 | 0.116 | 0.201 | 0.454 | 0.426 | 0.627 | 0.000 | 0.000 | 0.040 | 0.000 | 0.040 |
| 21-Jan | QNB4 | 2.00 | 0.000 | 0.240 | 0.679 | 0.000 | 0.240 | 0.000 | 0.000 | 0.005 | 0.004 | 0.005 |
| 12-Feb | QNB1 | 81.00 | 0.000 | 0.247 | 0.000 | 0.268 | 0.515 | 0.268 | 0.000 | 0.145 | 0.000 | 0.145 |
| 12-Feb | QNB2 | 0.00 | 0.000 | 0.199 | 0.000 | 0.000 | 0.199 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12-Feb | QNB3 | 0.00 | 0.019 | 0.170 | 0.000 | 0.000 | 0.170 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| 12-Feb | QNB4 | 0.00 | 0.000 | 0.208 | 0.000 | 0.000 | 0.208 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 05-Mar | QNB1 | 8.00 | 0.022 | 0.320 | 0.000 | 0.000 | 0.320 | 0.000 | 0.000 | 0.020 | 0.000 | 0.020 |
| 05-Mar | QNB2 | 7.00 | 0.000 | 0.213 | 0.000 | 0.000 | 0.213 | 0.000 | 0.000 | 0.030 | 0.000 | 0.030 |
| 05-Mar | QNB3 | 6.00 | 0.000 | 0.172 | 0.000 | 0.000 | 0.172 | 0.000 | 0.000 | 0.060 | 0.000 | 0.060 |
| 05-Mar | QNB4 | 9.00 | 0.000 | 0.193 | 2.454 | 0.000 | 0.193 | 0.000 | 0.000 | 0.025 | 0.001 | 0.025 |

# Appendix B

## North Bender Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S.B.N. (ppm) | FTP (ppm) | TP (ppm) | PO4 (ppm) | S.B.P. (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-Mar | QNB1 | 8.00 | 0.138 | 0.259 | 7.919 | 0.000 | 0.259 | 0.000 | 0.000 | 0.050 | 0.000 | 0.050 |
| 18-Mar | QNB2 | 19.00 | 0.777 | 0.201 | 4.915 | 5.298 | 5.499 | 0.384 | 0.000 | 0.050 | 0.000 | 0.050 |
| 18-Mar | QNB3 | 4.00 | 0.070 | 0.202 | 0.408 | 0.536 | 0.738 | 0.128 | 0.000 | 0.040 | 0.010 | 0.040 |
| 18-Mar | QNB4 | 0.00 | 0.044 | 0.173 | 0.000 | 0.000 | 0.173 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 02-Apr | QNB1 | 384.00 | 0.088 | 0.205 | 0.000 | 2.749 | 2.954 | 2.749 | 0.005 | 1.040 | 0.000 | 1.035 |
| 02-Apr | QNB2 | 9.00 | 0.000 | 0.174 | 0.000 | 0.000 | 0.174 | 0.000 | 0.060 | 0.160 | 0.001 | 0.100 |
| 02-Apr | QNB3 | 3.00 | 0.011 | 0.188 | 0.000 | 0.000 | 0.188 | 0.000 | 0.160 | 0.040 | 0.006 | 0.000 |
| 02-Apr | QNB4 | 5.00 | 0.007 | 0.251 | 0.000 | 0.000 | 0.251 | 0.000 | 0.165 | 0.000 | 0.000 | 0.000 |
| 15-Apr | QNB1 | 40.00 | 0.000 | 0.252 | 0.279 | 0.562 | 0.814 | 0.283 | 0.000 | 0.000 | 0.000 | 0.000 |
| 15-Apr | QNB2 | 16.00 | 0.000 | 0.160 | 0.279 | 0.222 | 0.382 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 15-Apr | QNB3 | 0.00 | 0.000 | 0.201 | 0.052 | 0.052 | 0.253 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 15-Apr | QNB4 | 6.00 | 0.000 | 0.169 | 0.000 | 0.024 | 0.193 | 0.024 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30-Apr | QNB1 | 2.00 | 0.000 | 0.000 | 0.375 | 1.150 | 1.150 | 0.775 | 0.000 | 0.020 | 0.000 | 0.020 |
| 30-Apr | QNB2 | 12.00 | 0.000 | 0.064 | 0.000 | 0.000 | 0.064 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30-Apr | QNB3 | 36.00 | 0.000 | 0.091 | 0.815 | 0.000 | 0.091 | 0.000 | 0.000 | 0.025 | 0.003 | 0.025 |
| 30-Apr | QNB4 | 22.00 | 0.000 | 0.115 | 0.815 | 0.030 | 0.145 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 |
| 14-May | QNB1 | 17.00 | 0.000 | 0.043 | 0.000 | 1.701 | 1.744 | 1.701 | 0.005 | 0.065 | 0.000 | 0.060 |
| 14-May | QNB2 | 21.00 | 0.000 | 0.145 | 0.000 | 0.000 | 0.145 | 0.000 | 0.065 | 0.055 | 0.000 | 0.000 |
| 14-May | QNB3 | 0.00 | 0.000 | 0.189 | 0.129 | 0.000 | 0.189 | 0.000 | 0.040 | 0.000 | 0.000 | 0.000 |
| 14-May | QNB4 | 13.00 | 0.000 | 0.220 | 0.299 | 0.299 | 0.519 | 0.000 | 0.000 | 0.075 | 0.000 | 0.075 |
| 29-May | QNB1 | 31.00 | 0.260 | 0.027 | 0.784 | 0.935 | 0.962 | 0.151 | 0.005 | 0.140 | 0.000 | 0.135 |
| 29-May | QNB2 | 17.00 | 0.602 | 0.115 | 2.025 | 1.480 | 1.595 | 0.000 | 0.020 | 0.055 | 0.000 | 0.035 |
| 29-May | QNB3 | 14.00 | 0.569 | 0.160 | 1.389 | 1.086 | 1.246 | 0.000 | 0.040 | 0.075 | 0.000 | 0.035 |
| 29-May | QNB4 | 32.00 | 0.191 | 0.361 | 1.086 | 0.814 | 1.175 | 0.000 | 0.000 | 0.120 | 0.000 | 0.120 |
| 11-Jun | QNB1 | 265.00 | 0.912 | 0.955 | 4.373 | 5.634 | 6.589 | 1.261 | 0.180 | 0.455 | 0.182 | 0.275 |
| 11-Jun | QNB2 | 289.00 | 0.559 | 0.967 | 3.515 | 5.258 | 6.225 | 1.743 | 0.225 | 0.560 | 0.252 | 0.335 |
| 11-Jun | QNB3 | 313.00 | 0.899 | 0.906 | 3.542 | 5.124 | 6.030 | 1.582 | 0.300 | 0.920 | 0.293 | 0.620 |
| 11-Jun | QNB4 | 481.00 | 0.355 | 0.897 | 2.764 | 4.561 | 5.458 | 1.797 | 0.270 | 0.915 | 0.295 | 0.645 |
| 28-Jun | QNB1 | 8.00 | 0.084 | 0.244 | 0.000 | 0.000 | 0.244 | 0.000 | 0.000 | 0.030 | 0.000 | 0.030 |
| 28-Jun | QNB2 | 12.00 | 0.000 | 0.218 | 0.000 | 0.103 | 0.321 | 0.103 | 0.105 | 0.000 | 0.001 | 0.000 |
| 28-Jun | QNB3 | 18.00 | 0.000 | 0.209 | 0.000 | 0.045 | 0.254 | 0.045 | 0.125 | 0.000 | 0.010 | 0.000 |
| 28-Jun | QNB4 | 24.00 | 0.000 | 0.180 | 0.197 | 0.919 | 1.099 | 0.722 | 0.000 | 0.135 | 0.009 | 0.135 |
| 09-Jul | QNB1 | 0.00 | 0.009 | 0.020 | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.045 | 0.014 | 0.045 |
| 09-Jul | QNB2 | 10.00 | 0.027 | 0.066 | 0.000 | 0.000 | 0.066 | 0.000 | 0.000 | 0.070 | 0.017 | 0.070 |
| 09-Jul | QNB3 | 0.00 | 0.017 | 0.079 | 0.000 | 0.000 | 0.079 | 0.000 | 0.000 | 0.060 | 0.017 | 0.060 |
| 09-Jul | QNB4 | 24.00 | 0.000 | 0.112 | 0.000 | 0.000 | 0.112 | 0.000 | 0.000 | 0.100 | 0.015 | 0.100 |
| 23-Jul | QNB1 | 2.00 | 0.000 | 0.034 | 1.423 | 0.101 | 0.135 | 0.000 | 0.000 | 0.006 | 0.000 | 0.006 |
| 23-Jul | QNB2 | 0.00 | 0.000 | 0.100 | 1.371 | 0.956 | 1.056 | 0.000 | 0.000 | 0.010 | 0.000 | 0.010 |
| 23-Jul | QNB3 | 16.00 | 0.000 | 0.124 | 0.386 | 0.697 | 0.821 | 0.311 | 0.000 | 0.007 | 0.000 | 0.007 |
| 23-Jul | QNB4 | 20.00 | 0.000 | 0.130 | 0.386 | 0.000 | 0.130 | 0.000 | 0.000 | 0.009 | 0.000 | 0.009 |
| 07-Aug | QNB1 | 42.00 | 0.000 | 0.053 | 0.309 | 0.000 | 0.053 | 0.000 | 0.000 | 0.008 | 0.000 | 0.008 |

# Appendix B

## North Bender Water Quality Parameters

| Date | Station | TSS (ppm) | NH4 (ppm) | NO3-N (ppm) | FTKN (ppm) | TKN (ppm) | TN (ppm) | S.B.N. (ppm) | FTP (ppm) | TP (ppm) | PO4 (ppm) | S.B.P. (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 07-Aug | QNB2 | 26.00 | 0.000 | 0.122 | 0.024 | 0.000 | 0.122 | 0.000 | 0.000 | 0.018 | 0.000 | 0.018 |
| 07-Aug | QNB3 | 20.00 | 0.231 | 0.281 | 0.000 | 0.000 | 0.281 | 0.000 | 0.000 | 0.008 | 0.000 | 0.008 |
| 07-Aug | QNB4 | 42.00 | 0.000 | 0.449 | 0.101 | 0.000 | 0.449 | 0.000 | 0.000 | 0.013 | 0.000 | 0.013 |
| 20-Aug | QNB2 | 20.00 | 0.031 | 0.103 | 1.264 | 2.528 | 2.631 | 1.264 | 0.000 | 0.130 | 0.000 | 0.130 |
| 20-Aug | QNB3 | 12.00 | 0.129 | 0.252 | 1.311 | 1.989 | 2.241 | 0.679 | 0.000 | 0.105 | 0.000 | 0.105 |
| 20-Aug | QNB4 | 30.00 | 0.000 | 0.286 | 1.076 | 2.013 | 2.299 | 0.936 | 0.000 | 0.100 | 0.000 | 0.100 |
| 05-Sep | QNB2 | 42.00 | 0.000 | 0.106 | 0.928 | 1.249 | 1.355 | 0.321 | 0.000 | 0.150 | 0.000 | 0.150 |
| 05-Sep | QNB3 | 32.00 | 0.000 | 0.134 | 0.554 | 1.329 | 1.463 | 0.775 | 0.000 | 0.085 | 0.000 | 0.085 |
| 05-Sep | QNB4 | 0.00 | 0.000 | 0.111 | 0.313 | 1.142 | 1.253 | 0.829 | 0.000 | 0.125 | 0.000 | 0.125 |
| 17-Sep | QNB1 | 11.00 | 1.729 | 2.727 | 2.579 | 3.562 | 6.289 | 0.983 | 0.060 | 0.300 | 0.105 | 0.240 |
| 17-Sep | QNB2 | 13.00 | 2.357 | 0.454 | 7.410 | 8.562 | 9.016 | 1.152 | 0.000 | 0.165 | 0.000 | 0.165 |
| 17-Sep | QNB3 | 9.00 | 0.000 | 0.489 | 0.000 | 0.000 | 0.489 | 0.000 | 0.000 | 0.095 | 0.004 | 0.095 |
| 17-Sep | QNB4 | 32.00 | 0.000 | 0.472 | 0.388 | 1.315 | 1.787 | 0.927 | 0.000 | 0.150 | 0.006 | 0.150 |
| 02-Oct | QNB1 | 15.00 | 0.093 | 0.028 | 0.476 | 0.742 | 0.770 | 0.266 | 0.000 | 0.085 | 0.011 | 0.085 |
| 02-Oct | QNB2 | 8.00 | 0.000 | 0.130 | 0.024 | 0.423 | 0.553 | 0.399 | 0.000 | 0.060 | 0.012 | 0.060 |
| 02-Oct | QNB3 | 25.00 | 0.000 | 0.160 | 0.157 | 0.210 | 0.370 | 0.053 | 0.000 | 0.055 | 0.007 | 0.055 |
| 02-Oct | QNB4 | 21.00 | 0.000 | 0.152 | 0.130 | 0.369 | 0.521 | 0.239 | 0.000 | 0.095 | 0.007 | 0.095 |
| 15-Oct | QNB1 | 9.00 | 0.035 | 0.076 | 0.085 | 0.554 | 0.630 | 0.469 | 0.000 | 0.020 | 0.000 | 0.020 |
| 15-Oct | QNB2 | 24.00 | 0.000 | 0.171 | 0.032 | 0.293 | 0.464 | 0.261 | 0.000 | 0.100 | 0.000 | 0.100 |
| 15-Oct | QNB3 | 13.00 | 0.000 | 0.182 | 0.000 | 1.101 | 1.283 | 1.101 | 0.020 | 0.055 | 0.000 | 0.035 |
| 15-Oct | QNB4 | 39.00 | 0.000 | 0.180 | 0.058 | 0.528 | 0.708 | 0.469 | 0.010 | 0.145 | 0.000 | 0.135 |

# Appendix B

## North Bender Farm Water Quality Parameters: Fecal Bacteria

(TC): Total Coliform, (FC): Fecal Coliform, (FS): Fecal Streptococci
All expressed as # of colonies per 100 ml
----- : No Sample Collected

| DATE | Station | TC | FC | FS | Station | TC | FC | FS |
|---|---|---|---|---|---|---|---|---|
| 10/09/94 | QNB2 | 7500 | 90 | 360 | QNB3 | 16000 | 0 | 270 |
| 11/14/94 | QNB2 | 19000 | 0 | 270 | QNB3 | 5700 | 0 | 0 |
| 12/18/94 | QNB2 | ----- | ----- | ----- | QNB3 | 400000 | 330 | 2900 |
| 1/22/95 | QNB2 | 4300 | 380 | 81 | QNB3 | 2800 | 760 | 81 |
| 3/05/95 | QNB2 | 1712 | 8 | 3 | QNB3 | 721 | 5 | 5 |
| 4/16/95 | QNB2 | 3800 | 124 | 25 | QNB3 | 6300 | 370 | 28 |
| 5/15/95 | QNB2 | 20000 | 700 | 790 | QNB3 | 17000 | 290 | 610 |
| 7/09/95 | QNB2 | 6100 | 760 | 610 | QNB3 | 17272 | 2300 | 116 |
| 7/23/95 | QNB2 | 20000 | 220 | 168 | QNB3 | 28000 | 1000 | 220 |
| 8/07/95 | QNB2 | 52000 | 3200 | 850 | QNB3 | 43000 | 2900 | 580 |
| 8/20/95 | QNB2 | 38000 | 720 | 400 | QNB3 | 45000 | 12000 | 770 |
| 9/05/95 | QNB2 | 280000 | 28000 | 536 | QNB3 | 18182 | 5700 | 630 |
| 9/17/95 | QNB2 | 680000 | 6000 | 7000 | QNB3 | 58000 | 4400 | 3300 |
| 10/15/95 | QNB2 | 12727 | 600 | 200 | QNB3 | ----- | ----- | ----- |

| DATE | Station | TC | FC | FS |
|---|---|---|---|---|
| 10/09/94 | QNB4 | 8000 | 0 | 360 |
| 11/14/94 | QNB4 | 6800 | 9 | 360 |
| 12/18/94 | QNB4 | 100000 | 630 | 2000 |
| 1/22/95 | QNB4 | 3200 | 360 | 18 |
| 3/05/95 | QNB4 | 631 | 8 | 18 |
| 4/16/95 | QNB4 | 3900 | 3100 | 72 |
| 5/15/95 | QNB4 | 11000 | 500 | 820 |
| 7/09/95 | QNB4 | 25000 | 920 | 840 |
| 7/23/95 | QNB4 | 16364 | 260 | 400 |
| 8/07/95 | QNB4 | 58000 | 2800 | 2000 |
| 8/20/95 | QNB4 | 31000 | 10000 | 4100 |
| 9/05/95 | QNB4 | 26000 | 260 | 1800 |
| 9/17/95 | QNB4 | 46000 | 2400 | 3200 |
| 10/15/95 | QNB4 | 11818 | 560 | 320 |

# Appendix C

Cattle Observations

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 11/22/95
Treatment: Pre-BMP
Number of Animals: 129 (67 cows & 62 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 05:50:00 AM | 0 | 0 | — | — | 0 |
| 05:55:00 AM | 0 | 0 | — | — | 0 |
| 06:00:00 AM | 0 | 0 | — | — | 5 |
| 06:05:00 AM | 0 | 0 | — | — | 10 |
| 06:10:00 AM | 0 | 0 | — | — | 10 |
| 06:15:00 AM | 0 | 0 | — | — | 10 |
| 06:20:00 AM | 0 | 0 | — | — | 10 |
| 06:25:00 AM | 0 | 0 | — | — | 15 |
| 06:30:00 AM | 0 | 0 | — | — | 20 |
| 06:35:00 AM | 0 | 0 | — | — | 15 |
| 06:40:00 AM | 0 | 0 | — | — | 80 |
| 06:45:00 AM | 0 | 3 | — | — | 90 |
| 06:50:00 AM | 2 | 5 | — | — | 100 |
| 06:55:00 AM | 5 | 9 | — | — | 100 |
| 07:00:00 AM | 4 | 11 | — | — | 100 |
| 07:05:00 AM | 4 | 11 | — | — | 100 |
| 07:10:00 AM | 0 | 2 | — | — | 100 |
| 07:15:00 AM | 0 | 1 | — | — | 100 |
| 07:20:00 AM | 2 | 5 | — | — | 100 |
| 07:25:00 AM | 1 | 2 | — | — | 100 |
| 07:30:00 AM | 2 | 7 | — | — | 100 |
| 07:35:00 AM | 0 | 2 | — | — | 100 |
| 07:40:00 AM | 2 | 2 | — | — | 100 |
| 07:45:00 AM | 1 | 4 | — | — | 100 |
| 07:50:00 AM | 0 | 2 | — | — | 100 |
| 07:55:00 AM | 0 | 0 | — | — | 100 |
| 08:00:00 AM | 2 | 3 | — | — | 100 |
| 08:05:00 AM | 3 | 7 | — | — | 100 |
| 08:10:00 AM | 3 | 8 | — | — | 100 |
| 08:15:00 AM | 3 | 12 | — | — | 100 |
| 08:20:00 AM | 5 | 16 | — | — | 100 |
| 08:25:00 AM | 3 | 14 | — | — | 100 |
| 08:30:00 AM | 2 | 7 | — | — | 100 |
| 08:35:00 AM | 3 | 5 | — | — | 100 |
| 08:40:00 AM | 0 | 2 | — | — | 100 |
| 08:45:00 AM | 0 | 1 | — | — | 100 |
| 08:50:00 AM | 0 | 0 | — | — | 100 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 11/22/95
Treatment: Pre-BMP
Number of Animals: 129 (67 cows & 62 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 08:55:00 AM | 0 | 0 | — | — | 100 |
| 09:00:00 AM | 0 | 0 | — | — | 100 |
| 09:05:00 AM | 0 | 0 | — | — | 100 |
| 09:10:00 AM | 0 | 0 | — | — | 98 |
| 09:15:00 AM | 0 | 0 | — | — | 99 |
| 09:20:00 AM | 0 | 0 | — | — | 98 |
| 09:25:00 AM | 0 | 0 | — | — | 98 |
| 09:30:00 AM | 0 | 0 | — | — | 96 |
| 09:35:00 AM | 0 | 0 | — | — | 95 |
| 09:40:00 AM | 0 | 0 | — | — | 95 |
| 09:45:00 AM | 0 | 0 | — | — | 96 |
| 09:50:00 AM | 0 | 0 | — | — | 90 |
| 09:55:00 AM | 0 | 0 | — | — | 95 |
| 10:00:00 AM | 0 | 0 | — | — | 90 |
| 10:05:00 AM | 1 | 1 | — | — | 90 |
| 10:10:00 AM | 0 | 1 | — | — | 90 |
| 10:15:00 AM | 1 | 1 | — | — | 90 |
| 10:20:00 AM | 4 | 4 | — | — | 90 |
| 10:25:00 AM | 4 | 4 | — | — | 80 |
| 10:30:00 AM | 3 | 4 | — | — | 80 |
| 10:35:00 AM | 1 | 3 | — | — | 90 |
| 10:40:00 AM | 0 | 0 | — | — | 90 |
| 10:45:00 AM | 0 | 0 | — | — | 95 |
| 10:50:00 AM | 1 | 1 | — | — | 67 |
| 10:55:00 AM | 1 | 1 | — | — | 69 |
| 11:00:00 AM | 0 | 1 | — | — | 62 |
| 11:05:00 AM | 1 | 2 | — | — | 67 |
| 11:10:00 AM | 1 | 1 | — | — | 73 |
| 11:15:00 AM | 0 | 2 | — | — | 75 |
| 11:20:00 AM | 3 | 5 | — | — | 75 |
| 11:25:00 AM | 2 | 5 | — | — | 75 |
| 11:30:00 AM | 2 | 2 | — | — | 85 |
| 11:35:00 AM | 0 | 3 | — | — | 85 |
| 11:40:00 AM | 1 | 2 | — | — | 95 |
| 11:45:00 AM | 0 | 0 | — | — | 100 |
| 11:50:00 AM | 1 | 0 | — | — | 100 |
| 11:55:00 AM | 1 | 1 | — | — | 100 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 11/22/95
Treatment: Pre-BMP
Number of Animals: 129 (67 cows & 62 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 12:00:00 PM | 0 | 2 | — | — | 100 |
| 12:05:00 PM | 0 | 0 | — | — | 100 |
| 12:10:00 PM | 0 | 0 | — | — | 100 |
| 12:15:00 PM | 0 | 0 | — | — | 100 |
| 12:20:00 PM | 0 | 0 | — | — | 100 |
| 12:25:00 PM | 6 | 6 | — | — | 100 |
| 12:30:00 PM | 7 | 7 | — | — | 100 |
| 12:35:00 PM | 1 | 3 | — | — | 70 |
| 12:40:00 PM | 2 | 4 | — | — | 70 |
| 12:45:00 PM | 0 | 0 | — | — | 70 |
| 12:50:00 PM | 1 | 1 | — | — | 80 |
| 12:55:00 PM | 1 | 1 | — | — | 75 |
| 01:00:00 PM | 0 | 1 | — | — | 85 |
| 01:05:00 PM | 0 | 0 | — | — | 85 |
| 01:10:00 PM | 0 | 0 | — | — | 80 |
| 01:15:00 PM | 0 | 0 | — | — | 65 |
| 01:20:00 PM | 0 | 0 | — | — | 45 |
| 01:25:00 PM | 0 | 0 | — | — | 60 |
| 01:30:00 PM | 1 | 1 | — | — | 60 |
| 01:35:00 PM | 3 | 4 | — | — | 60 |
| 01:40:00 PM | 5 | 6 | — | — | 60 |
| 01:45:00 PM | 2 | 4 | — | — | 60 |
| 01:50:00 PM | 3 | 4 | — | — | 60 |
| 01:55:00 PM | 5 | 5 | — | — | 80 |
| 02:00:00 PM | 0 | 3 | — | — | 90 |
| 02:05:00 PM | 0 | 4 | — | — | 90 |
| 02:10:00 PM | 0 | 2 | — | — | 95 |
| 02:15:00 PM | 2 | 4 | — | — | 95 |
| 02:20:00 PM | 0 | 3 | — | — | 90 |
| 02:25:00 PM | 1 | 3 | — | — | 90 |
| 02:30:00 PM | 2 | 2 | — | — | 95 |
| 02:35:00 PM | 0 | 2 | — | — | 100 |
| 02:40:00 PM | 3 | 5 | — | — | 100 |
| 02:45:00 PM | 3 | 4 | — | — | 100 |
| 02:50:00 PM | 2 | 3 | — | — | 100 |
| 02:55:00 PM | 0 | 0 | — | — | 100 |
| 03:00:00 PM | 0 | 0 | — | — | 100 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 11/22/95
Treatment: Pre-BMP
Number of Animals: 129 (67 cows & 62 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 03:05:00 PM | 3 | 3 | — | — | 100 |
| 03:10:00 PM | 2 | 2 | — | — | 90 |
| 03:15:00 PM | 3 | 5 | — | — | 95 |
| 03:20:00 PM | 1 | 5 | — | — | 90 |
| 03:25:00 PM | 1 | 3 | — | — | 95 |
| 03:30:00 PM | 1 | 4 | — | — | 95 |
| 03:35:00 PM | 0 | 2 | — | — | 97 |
| 03:40:00 PM | 0 | 0 | — | — | 97 |
| 03:45:00 PM | 0 | 0 | — | — | 100 |
| 03:50:00 PM | 7 | 8 | — | — | 100 |
| 03:55:00 PM | 1 | 8 | — | — | 100 |
| 04:00:00 PM | 2 | 4 | — | — | 100 |
| 04:05:00 PM | 3 | 7 | — | — | 100 |
| 04:10:00 PM | 0 | 4 | — | — | 100 |
| 04:15:00 PM | 0 | 2 | — | — | 100 |
| 04:20:00 PM | 0 | 0 | — | — | 100 |
| 04:25:00 PM | 2 | 2 | — | — | 100 |
| 04:30:00 PM | 2 | 3 | — | — | 100 |
| 04:35:00 PM | 0 | 1 | — | — | 100 |
| 04:40:00 PM | 2 | 4 | — | — | 100 |
| 04:45:00 PM | 3 | 4 | — | — | 100 |
| 04:50:00 PM | 1 | 2 | — | — | 100 |
| 04:55:00 PM | 0 | 0 | — | — | 100 |
| 05:00:00 PM | 1 | 2 | — | — | 100 |
| 05:05:00 PM | 0 | 0 | — | — | 100 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 12/03/95
Treatment: Pre-BMP
Number of Animals: 32 (30 dry cows + 1 cow & 1 calf)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:50:00 AM | 0 | 0 | — | — | 0 |
| 06:55:00 AM | 0 | 0 | — | — | 0 |
| 07:00:00 AM | 0 | 0 | — | — | 5 |
| 07:05:00 AM | 0 | 0 | — | — | 10 |
| 07:10:00 AM | 0 | 0 | — | — | 10 |
| 07:15:00 AM | 0 | 0 | — | — | 10 |
| 07:20:00 AM | 0 | 0 | — | — | 10 |
| 07:25:00 AM | 0 | 0 | — | — | 15 |
| 07:30:00 AM | 0 | 0 | — | — | 20 |
| 07:35:00 AM | 0 | 0 | — | — | 15 |
| 07:40:00 AM | 0 | 0 | — | — | 80 |
| 07:45:00 AM | 0 | 0 | — | — | 90 |
| 07:50:00 AM | 0 | 0 | — | — | 100 |
| 07:55:00 AM | 0 | 0 | — | — | 100 |
| 08:00:00 AM | 0 | 0 | — | — | 100 |
| 08:05:00 AM | 0 | 0 | — | — | 100 |
| 08:10:00 AM | 2 | 2 | — | — | 100 |
| 08:15:00 AM | 1 | 1 | — | — | 100 |
| 08:20:00 AM | 0 | 2 | — | — | 100 |
| 08:25:00 AM | 0 | 0 | — | — | 100 |
| 08:30:00 AM | 2 | 3 | — | — | 100 |
| 08:35:00 AM | 2 | 2 | — | — | 100 |
| 08:40:00 AM | 0 | 0 | — | — | 100 |
| 08:45:00 AM | 0 | 0 | — | — | 100 |
| 08:50:00 AM | 0 | 1 | — | — | 100 |
| 08:55:00 AM | 1 | 1 | — | — | 100 |
| 09:00:00 AM | 0 | 0 | — | — | 100 |
| 09:05:00 AM | 2 | 2 | — | — | 100 |
| 09:10:00 AM | 0 | 2 | — | — | 98 |
| 09:15:00 AM | 1 | 1 | — | — | 99 |
| 09:20:00 AM | 0 | 0 | — | — | 98 |
| 09:25:00 AM | 0 | 0 | — | — | 98 |
| 09:30:00 AM | 0 | 0 | — | — | 96 |
| 09:35:00 AM | 0 | 0 | — | — | 95 |
| 09:40:00 AM | 0 | 0 | — | — | 95 |
| 09:45:00 AM | 0 | 0 | — | — | 96 |
| 09:50:00 AM | 0 | 0 | — | — | 90 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 12/03/95
Treatment: Pre-BMP
Number of Animals: 32 (30 dry cows + 1 cow & 1 calf)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 09:55:00 AM | 0 | 0 | — | — | 95 |
| 10:00:00 AM | 0 | 0 | — | — | 90 |
| 10:05:00 AM | 0 | 0 | — | — | 90 |
| 10:10:00 AM | 0 | 3 | — | — | 90 |
| 10:15:00 AM | 0 | 1 | — | — | 90 |
| 10:20:00 AM | 0 | 4 | — | — | 90 |
| 10:25:00 AM | 1 | 3 | — | — | 80 |
| 10:30:00 AM | 1 | 3 | — | — | 80 |
| 10:35:00 AM | 0 | 0 | — | — | 90 |
| 10:40:00 AM | 1 | 2 | — | — | 90 |
| 10:45:00 AM | 0 | 0 | — | — | 95 |
| 10:50:00 AM | 0 | 0 | — | — | 67 |
| 10:55:00 AM | 1 | 1 | — | — | 69 |
| 11:00:00 AM | 0 | 1 | — | — | 62 |
| 11:05:00 AM | 1 | 2 | — | — | 67 |
| 11:10:00 AM | 0 | 1 | — | — | 73 |
| 11:15:00 AM | 0 | 1 | — | — | 75 |
| 11:20:00 AM | 2 | 3 | — | — | 75 |
| 11:25:00 AM | 1 | 2 | — | — | 75 |
| 11:30:00 AM | 1 | 1 | — | — | 85 |
| 11:35:00 AM | 0 | 0 | — | — | 85 |
| 11:40:00 AM | 1 | 1 | — | — | 95 |
| 11:45:00 AM | 0 | 0 | — | — | 100 |
| 11:50:00 AM | 1 | 1 | — | — | 100 |
| 11:55:00 AM | 1 | 1 | — | — | 100 |
| 12:00:00 PM | 0 | 2 | — | — | 100 |
| 12:05:00 PM | 0 | 0 | — | — | 100 |
| 12:10:00 PM | 0 | 0 | — | — | 100 |
| 12:15:00 PM | 0 | 2 | — | — | 100 |
| 12:20:00 PM | 0 | 0 | — | — | 100 |
| 12:25:00 PM | 1 | 1 | — | — | 100 |
| 12:30:00 PM | 2 | 2 | — | — | 100 |
| 12:35:00 PM | 1 | 2 | — | — | 70 |
| 12:40:00 PM | 0 | 2 | — | — | 70 |
| 12:45:00 PM | 0 | 0 | — | — | 70 |
| 12:50:00 PM | 1 | 1 | — | — | 80 |
| 12:55:00 PM | 0 | 0 | — | — | 75 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 12/03/95
Treatment: Pre-BMP
Number of Animals: 32 (30 dry cows + 1 cow & 1 calf)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 01:00:00 PM | 0 | 2 | — | — | 85 |
| 01:05:00 PM | 0 | 0 | — | — | 85 |
| 01:10:00 PM | 0 | 0 | — | — | 80 |
| 01:15:00 PM | 0 | 2 | — | — | 65 |
| 01:20:00 PM | 0 | 0 | — | — | 45 |
| 01:25:00 PM | 2 | 2 | — | — | 60 |
| 01:30:00 PM | 1 | 1 | — | — | 60 |
| 01:35:00 PM | 3 | 0 | — | — | 60 |
| 01:40:00 PM | 0 | 0 | — | — | 60 |
| 01:45:00 PM | 0 | 1 | — | — | 60 |
| 01:50:00 PM | 0 | 1 | — | — | 60 |
| 01:55:00 PM | 0 | 0 | — | — | 80 |
| 02:00:00 PM | 0 | 0 | — | — | 90 |
| 02:05:00 PM | 0 | 0 | — | — | 90 |
| 02:10:00 PM | 0 | 3 | — | — | 95 |
| 02:15:00 PM | 0 | 0 | — | — | 95 |
| 02:20:00 PM | 0 | 2 | — | — | 90 |
| 02:25:00 PM | 0 | 0 | — | — | 90 |
| 02:30:00 PM | 2 | 2 | — | — | 95 |
| 02:35:00 PM | 0 | 0 | — | — | 100 |
| 02:40:00 PM | 0 | 0 | — | — | 100 |
| 02:45:00 PM | 1 | 1 | — | — | 100 |
| 02:50:00 PM | 2 | 3 | — | — | 100 |
| 02:55:00 PM | 0 | 3 | — | — | 100 |
| 03:00:00 PM | 0 | 0 | — | — | 100 |
| 03:05:00 PM | 3 | 3 | — | — | 100 |
| 03:10:00 PM | 2 | 2 | — | — | 90 |
| 03:15:00 PM | 0 | 0 | — | — | 95 |
| 03:20:00 PM | 1 | 0 | — | — | 90 |
| 03:25:00 PM | 1 | 1 | — | — | 95 |
| 03:30:00 PM | 1 | 1 | — | — | 95 |
| 03:35:00 PM | 0 | 2 | — | — | 97 |
| 03:40:00 PM | 0 | 0 | — | — | 97 |
| 03:45:00 PM | 0 | 0 | — | — | 100 |
| 03:50:00 PM | 0 | 3 | — | — | 100 |
| 03:55:00 PM | 0 | 2 | — | — | 100 |
| 04:00:00 PM | 2 | 2 | — | — | 100 |

## Cattle Observations

Farm: River Ridge
Date: 12/03/95
Treatment: Pre-BMP
Number of Animals: 32 (30 dry cows + 1 cow & 1 calf)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 04:05:00 PM | 1 | 3 | — | — | 100 |
| 04:10:00 PM | 0 | 0 | — | — | 100 |
| 04:15:00 PM | 0 | 0 | — | — | 100 |
| 04:20:00 PM | 0 | 0 | — | — | 100 |
| 04:25:00 PM | 0 | 0 | — | — | 100 |
| 04:30:00 PM | 1 | 2 | — | — | 100 |
| 04:35:00 PM | 0 | 1 | — | — | 100 |
| 04:40:00 PM | 1 | 1 | — | — | 100 |
| 04:45:00 PM | 0 | 0 | — | — | 100 |
| 04:50:00 PM | 0 | 0 | — | — | 100 |

# Appendix C

## Cattle Observations

Farm: North Bender
Date: 1/10/95
Treatment: Pre-BMP
Number of Animals: 135 (72 cows & 63 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:45:00 AM | 0 | 0 | --------- | --------- | 0 |
| 06:50:00 AM | 0 | 0 | --------- | --------- | 0 |
| 06:55:00 AM | 0 | 0 | --------- | --------- | 5 |
| 07:00:00 AM | 0 | 0 | --------- | --------- | 5 |
| 07:05:00 AM | 0 | 0 | --------- | --------- | 15 |
| 07:10:00 AM | 0 | 0 | --------- | --------- | 25 |
| 07:15:00 AM | 0 | 0 | --------- | --------- | 25 |
| 07:20:00 AM | 0 | 0 | --------- | --------- | 50 |
| 07:25:00 AM | 0 | 1 | --------- | --------- | 100 |
| 07:30:00 AM | 1 | 1 | --------- | --------- | 100 |
| 07:35:00 AM | 0 | 1 | --------- | --------- | 100 |
| 07:40:00 AM | 0 | 2 | --------- | --------- | 100 |
| 07:45:00 AM | 2 | 2 | --------- | --------- | 100 |
| 07:50:00 AM | 0 | 3 | --------- | --------- | 100 |
| 07:55:00 AM | 1 | 1 | --------- | --------- | 100 |
| 08:00:00 AM | 0 | 1 | --------- | --------- | 100 |
| 08:05:00 AM | 2 | 2 | --------- | --------- | 100 |
| 08:10:00 AM | 3 | 4 | --------- | --------- | 100 |
| 08:15:00 AM | 1 | 2 | --------- | --------- | 100 |
| 08:20:00 AM | 0 | 1 | --------- | --------- | 100 |
| 08:25:00 AM | 2 | 2 | --------- | --------- | 100 |
| 08:30:00 AM | 2 | 3 | --------- | --------- | 100 |
| 08:35:00 AM | 0 | 4 | --------- | --------- | 100 |
| 08:40:00 AM | 0 | 3 | --------- | --------- | 100 |
| 08:45:00 AM | 0 | 3 | --------- | --------- | 100 |
| 08:50:00 AM | 1 | 1 | --------- | --------- | 100 |
| 08:55:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:00:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:05:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:10:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:15:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:20:00 AM | 0 | 0 | --------- | --------- | 100 |
| 09:25:00 AM | 0 | 0 | --------- | --------- | 95 |
| 09:30:00 AM | 0 | 0 | --------- | --------- | 95 |
| 09:35:00 AM | 0 | 0 | --------- | --------- | 95 |
| 09:40:00 AM | 0 | 0 | --------- | --------- | 90 |
| 09:45:00 AM | 1 | 1 | --------- | --------- | 85 |

# Appendix C

## Cattle Observations

Farm: North Bender
Date: 1/10/95
Treatment: Pre-BMP
Number of Animals: 135 (72 cows & 63 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 09:50:00 AM | 1 | 1 | --------- | --------- | 80 |
| 09:55:00 AM | 1 | 1 | --------- | --------- | 75 |
| 10:00:00 AM | 0 | 0 | --------- | --------- | 75 |
| 10:05:00 AM | 0 | 0 | --------- | --------- | 70 |
| 10:10:00 AM | 0 | 0 | --------- | --------- | 60 |
| 10:15:00 AM | 0 | 0 | --------- | --------- | 55 |
| 10:20:00 AM | 0 | 0 | --------- | --------- | 55 |
| 10:25:00 AM | 0 | 0 | --------- | --------- | 50 |
| 10:30:00 AM | 0 | 0 | --------- | --------- | 50 |
| 10:35:00 AM | 0 | 2 | --------- | --------- | 50 |
| 10:40:00 AM | 0 | 2 | --------- | --------- | 40 |
| 10:45:00 AM | 0 | 5 | --------- | --------- | 30 |
| 10:50:00 AM | 0 | 2 | --------- | --------- | 20 |
| 10:55:00 AM | 1 | 1 | --------- | --------- | 20 |
| 11:00:00 AM | 0 | 0 | --------- | --------- | 20 |
| 11:05:00 AM | 1 | 1 | --------- | --------- | 30 |
| 11:10:00 AM | 1 | 2 | --------- | --------- | 35 |
| 11:15:00 AM | 1 | 2 | --------- | --------- | 40 |
| 11:20:00 AM | 0 | 0 | --------- | --------- | 30 |
| 11:25:00 AM | 0 | 0 | --------- | --------- | 30 |
| 11:30:00 AM | 0 | 0 | --------- | --------- | 30 |
| 11:35:00 AM | 0 | 0 | --------- | --------- | 100 |
| 11:40:00 AM | 0 | 0 | --------- | --------- | 100 |
| 11:45:00 AM | 0 | 0 | --------- | --------- | 100 |
| 11:50:00 AM | 0 | 0 | --------- | --------- | 100 |
| 11:55:00 AM | 0 | 0 | --------- | --------- | 100 |
| 12:00:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:05:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:10:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:15:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:20:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:25:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:30:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:35:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:40:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:45:00 PM | 0 | 0 | --------- | --------- | 100 |
| 12:50:00 PM | 0 | 0 | --------- | --------- | 100 |

# Appendix C

## Cattle Observations

Farm: North Bender
Date: 1/10/95
Treatment: Pre-BMP
Number of Animals: 135 (72 cows & 63 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 12:55:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:00:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:05:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:10:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:15:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:20:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:25:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:30:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:35:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:40:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:45:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:50:00 PM | 0 | 0 | --------- | --------- | 100 |
| 01:55:00 PM | 0 | 0 | --------- | --------- | 100 |
| 02:00:00 PM | 0 | 0 | --------- | --------- | 100 |
| 02:05:00 PM | 0 | 0 | --------- | --------- | 100 |
| 02:10:00 PM | 0 | 0 | --------- | --------- | 100 |
| 02:15:00 PM | 4 | 4 | --------- | --------- | 100 |
| 02:20:00 PM | 6 | 6 | --------- | --------- | 100 |
| 02:25:00 PM | 9 | 11 | --------- | --------- | 100 |
| 02:30:00 PM | 16 | 23 | --------- | --------- | 100 |
| 02:35:00 PM | 17 | 20 | --------- | --------- | 100 |
| 02:40:00 PM | 15 | 20 | --------- | --------- | 100 |
| 02:45:00 PM | 14 | 19 | --------- | --------- | 100 |
| 02:50:00 PM | 10 | 19 | --------- | --------- | 100 |
| 02:55:00 PM | 5 | 18 | --------- | --------- | 100 |
| 03:00:00 PM | 10 | 14 | --------- | --------- | 100 |
| 03:05:00 PM | 11 | 18 | --------- | --------- | 100 |
| 03:10:00 PM | 6 | 15 | --------- | --------- | 100 |
| 03:15:00 PM | 8 | 13 | --------- | --------- | 100 |
| 03:20:00 PM | 5 | 14 | --------- | --------- | 100 |
| 03:25:00 PM | 3 | 6 | --------- | --------- | 100 |
| 03:30:00 PM | 7 | 8 | --------- | --------- | 100 |
| 03:35:00 PM | 3 | 4 | --------- | --------- | 100 |
| 03:40:00 PM | 3 | 4 | --------- | --------- | 90 |
| 03:45:00 PM | 3 | 4 | --------- | --------- | 90 |
| 03:50:00 PM | 3 | 3 | --------- | --------- | 85 |
| 03:55:00 PM | 1 | 1 | --------- | --------- | 80 |

# Appendix C

## Cattle Observations

Farm: North Bender
Date: 1/10/95
Treatment: Pre-BMP
Number of Animals: 135 (72 cows & 63 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 04:00:00 PM | 4 | 4 | --------- | --------- | 80 |
| 04:05:00 PM | 2 | 2 | --------- | --------- | 100 |
| 04:10:00 PM | 1 | 1 | --------- | --------- | 100 |
| 04:15:00 PM | 1 | 1 | --------- | --------- | 100 |
| 04:20:00 PM | 2 | 2 | --------- | --------- | 100 |
| 04:25:00 PM | 1 | 1 | --------- | --------- | 100 |
| 04:30:00 PM | 0 | 0 | --------- | --------- | 100 |
| 04:35:00 PM | 0 | 0 | --------- | --------- | 100 |
| 04:40:00 PM | 1 | 1 | --------- | --------- | 100 |
| 04:45:00 PM | 1 | 1 | --------- | --------- | 100 |
| 04:50:00 PM | 0 | 0 | --------- | --------- | 100 |
| 04:55:00 PM | 0 | 0 | --------- | --------- | 100 |
| 05:00:00 PM | 0 | 1 | --------- | --------- | 100 |
| 05:05:00 PM | 1 | 2 | --------- | --------- | 100 |
| 05:10:00 PM | 2 | 2 | --------- | --------- | 100 |
| 05:15:00 PM | 0 | 1 | --------- | --------- | 90 |
| 05:20:00 PM | 0 | 2 | --------- | --------- | 85 |
| 05:25:00 PM | 1 | 1 | --------- | --------- | 75 |
| 05:30:00 PM | 2 | 2 | --------- | --------- | 75 |
| 05:35:00 PM | 0 | 1 | --------- | --------- | 70 |
| 05:40:00 PM | 0 | 0 | --------- | --------- | 70 |
| 05:45:00 PM | 0 | 1 | --------- | --------- | 70 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 6/29/95
Treatment: Post-BMP
Number of Animals: 211 (109 cows & 102 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 05:45 AM | 0 | 0 | 0 | 0 | 0 |
| 05:50 AM | 0 | 0 | 0 | 0 | 25 |
| 05:55 AM | 0 | 0 | 0 | 0 | 30 |
| 06:00 AM | 0 | 0 | 0 | 0 | 40 |
| 06:05 AM | 0 | 0 | 0 | 0 | 50 |
| 06:10 AM | 0 | 0 | 0 | 0 | 75 |
| 06:15 AM | 0 | 0 | 0 | 0 | 75 |
| 06:20 AM | 0 | 0 | 0 | 0 | 90 |
| 06:25 AM | 0 | 0 | 0 | 0 | 90 |
| 06:30 AM | 0 | 0 | 0 | 0 | 90 |
| 06:35 AM | 0 | 0 | 0 | 0 | 90 |
| 06:40 AM | 0 | 0 | 0 | 0 | 100 |
| 06:45 AM | 0 | 0 | 4 | 7 | 100 |
| 06:50 AM | 0 | 0 | 7 | 11 | 100 |
| 06:55 AM | 0 | 1 | 2 | 3 | 100 |
| 07:00 AM | 0 | 0 | 2 | 2 | 100 |
| 07:05 AM | 0 | 1 | 3 | 5 | 100 |
| 07:10 AM | 0 | 1 | 4 | 7 | 100 |
| 07:15 AM | 0 | 1 | 3 | 7 | 100 |
| 07:20 AM | 0 | 0 | 2 | 6 | 95 |
| 07:25 AM | 0 | 0 | 1 | 6 | 95 |
| 07:30 AM | 0 | 1 | 2 | 3 | 95 |
| 07:35 AM | 0 | 0 | 4 | 8 | 95 |
| 07:40 AM | 1 | 0 | 2 | 4 | 95 |
| 07:45 AM | 1 | 0 | 0 | 4 | 95 |
| 07:50 AM | 0 | 3 | 2 | 4 | 95 |
| 07:55 AM | 0 | 2 | 1 | 5 | 90 |
| 08:00 AM | 0 | 4 | 3 | 4 | 95 |
| 08:05 AM | 0 | 2 | 2 | 4 | 95 |
| 08:10 AM | 0 | 2 | 1 | 4 | 95 |
| 08:15 AM | 0 | 0 | 0 | 2 | 95 |
| 08:20 AM | 0 | 0 | 0 | 2 | 90 |
| 08:25 AM | 2 | 2 | 2 | 4 | 85 |
| 08:30 AM | 0 | 0 | 0 | 1 | 85 |
| 08:35 AM | 0 | 1 | 0 | 1 | 70 |
| 08:40 AM | 0 | 0 | 0 | 3 | 70 |
| 08:45 AM | 0 | 0 | 0 | 4 | 70 |

## Cattle Observations

Farm: River Ridge
Date: 6/29/95
Treatment: Post-BMP
Number of Animals: 211 (109 cows & 102 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 08:50 AM | 0 | 0 | 0 | 2 | 60 |
| 08:55 AM | 1 | 1 | 0 | 1 | 50 |
| 09:00 AM | 0 | 1 | 2 | 2 | 50 |
| 09:05 AM | 0 | 0 | 0 | 1 | 50 |
| 09:10 AM | 0 | 0 | 0 | 0 | 20 |
| 09:15 AM | 0 | 0 | 0 | 0 | 20 |
| 09:20 AM | 0 | 0 | 0 | 0 | 10 |
| 09:25 AM | 0 | 0 | 0 | 0 | 10 |
| 09:30 AM | 0 | 0 | 0 | 0 | 10 |
| 09:35 AM | 0 | 0 | 0 | 0 | 10 |
| 09:40 AM | 0 | 0 | 0 | 0 | 15 |
| 09:45 AM | 0 | 0 | 0 | 0 | 15 |
| 09:50 AM | 1 | 3 | 0 | 0 | 15 |
| 09:55 AM | 0 | 0 | 0 | 0 | 15 |
| 10:00 AM | 0 | 0 | 0 | 0 | 15 |
| 10:05 AM | 0 | 0 | 0 | 0 | 20 |
| 10:10 AM | 0 | 0 | 0 | 0 | 30 |
| 10:15 AM | 0 | 0 | 0 | 1 | 30 |
| 10:20 AM | 0 | 0 | 0 | 0 | 30 |
| 10:25 AM | 0 | 0 | 0 | 0 | 30 |
| 10:30 AM | 0 | 0 | 2 | 2 | 35 |
| 10:35 AM | 0 | 1 | 0 | 0 | 30 |
| 10:40 AM | 0 | 2 | 0 | 3 | 10 |
| 10:45 AM | 1 | 3 | 0 | 0 | 10 |
| 10:50 AM | 0 | 2 | 0 | 0 | 10 |
| 10:55 AM | 1 | 4 | 4 | 4 | 35 |
| 11:00 AM | 0 | 2 | 4 | 4 | 35 |
| 11:05 AM | 0 | 4 | 1 | 1 | 35 |
| 11:10 AM | 0 | 3 | 0 | 0 | 35 |
| 11:15 AM | 0 | 2 | 0 | 0 | 35 |
| 11:20 AM | 0 | 3 | 0 | 0 | 35 |
| 11:25 AM | 0 | 3 | 0 | 0 | 35 |
| 11:30 AM | 0 | 1 | 1 | 1 | 45 |
| 11:35 AM | 0 | 2 | 1 | 1 | 50 |
| 11:40 AM | 0 | 1 | 0 | 0 | 60 |
| 11:45 AM | 0 | 2 | 2 | 2 | 60 |
| 11:50 AM | 0 | 2 | 4 | 4 | 60 |

## Cattle Observations

Farm: River Ridge
Date: 6/29/95
Treatment: Post-BMP
Number of Animals: 211 (109 cows & 102 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 11:55 AM | 0 | 2 | 0 | 0 | 60 |
| 12:00 PM | 0 | 2 | 0 | 0 | 60 |
| 12:05 PM | 0 | 1 | 3 | 3 | 60 |
| 12:10 PM | 0 | 1 | 1 | 1 | 60 |
| 12:15 PM | 0 | 1 | 0 | 0 | 40 |
| 12:20 PM | 0 | 0 | 1 | 1 | 20 |
| 12:25 PM | 0 | 0 | 1 | 1 | 20 |
| 12:30 PM | 0 | 0 | 0 | 0 | 10 |
| 12:35 PM | 0 | 0 | 0 | 0 | 10 |
| 12:40 PM | 0 | 1 | 0 | 0 | 15 |
| 12:45 PM | 0 | 1 | 2 | 3 | 15 |
| 12:50 PM | 0 | 1 | 0 | 0 | 10 |
| 12:55 PM | 0 | 1 | 0 | 0 | 10 |
| 01:00 PM | 0 | 0 | 2 | 4 | 10 |
| 01:05 PM | 1 | 1 | 4 | 5 | 10 |
| 01:10 PM | 0 | 1 | 0 | 0 | 15 |
| 01:15 PM | 0 | 1 | 3 | 3 | 25 |
| 01:20 PM | 0 | 2 | 6 | 8 | 40 |
| 01:25 PM | 0 | 2 | 8 | 10 | 50 |
| 01:30 PM | 0 | 2 | 4 | 6 | 35 |
| 01:35 PM | 0 | 1 | 1 | 4 | 35 |
| 01:40 PM | 0 | 2 | 2 | 2 | 45 |
| 01:45 PM | 0 | 0 | 6 | 6 | 55 |
| 01:50 PM | 0 | 1 | 4 | 8 | 65 |
| 01:55 PM | 0 | 0 | 4 | 5 | 80 |
| 02:00 PM | 0 | 0 | 1 | 1 | 80 |
| 02:05 PM | 0 | 0 | 1 | 5 | 80 |
| 02:10 PM | 0 | 0 | 5 | 13 | 75 |
| 02:15 PM | 0 | 0 | 5 | 7 | 75 |
| 02:20 PM | 0 | 0 | 4 | 10 | 75 |
| 02:25 PM | 0 | 0 | 4 | 9 | 80 |
| 02:30 PM | 0 | 0 | 6 | 12 | 80 |
| 02:35 PM | 0 | 4 | 7 | 9 | 85 |
| 02:40 PM | 0 | 0 | 5 | 9 | 55 |
| 02:45 PM | 0 | 1 | 10 | 14 | 65 |
| 02:50 PM | 0 | 0 | 12 | 15 | 65 |
| 02:55 PM | 1 | 1 | 4 | 9 | 60 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 6/29/95
Treatment: Post-BMP
Number of Animals: 211 (109 cows & 102 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 03:00 PM | 0 | 3 | 2 | 9 | 40 |
| 03:05 PM | 0 | 0 | 2 | 12 | 50 |
| 03:10 PM | 0 | 0 | 3 | 8 | 50 |
| 03:15 PM | 0 | 0 | 3 | 6 | 70 |
| 03:20 PM | 0 | 0 | 3 | 4 | 60 |
| 03:25 PM | 0 | 0 | 2 | 4 | 50 |
| 03:30 PM | 0 | 0 | 0 | 5 | 45 |
| 03:35 PM | 0 | 0 | 0 | 5 | 50 |
| 03:40 PM | 0 | 0 | 0 | 5 | 60 |
| 03:45 PM | 1 | 1 | 0 | 1 | 70 |
| 03:50 PM | 0 | 0 | 1 | 1 | 80 |
| 03:55 PM | 0 | 0 | 0 | 0 | 80 |
| 04:00 PM | 0 | 2 | 5 | 5 | 80 |
| 04:05 PM | 0 | 0 | 1 | 8 | 70 |
| 04:10 PM | 0 | 0 | 3 | 7 | 80 |
| 04:15 PM | 0 | 1 | 1 | 7 | 80 |
| 04:20 PM | 1 | 1 | 2 | 4 | 90 |
| 04:25 PM | 0 | 0 | 2 | 2 | 90 |
| 04:30 PM | 0 | 1 | 0 | 0 | 80 |
| 04:35 PM | 0 | 1 | 0 | 0 | 80 |
| 04:40 PM | 1 | 1 | 2 | 8 | 80 |
| 04:45 PM | 0 | 0 | 1 | 8 | 70 |
| 04:50 PM | 0 | 0 | 1 | 8 | 70 |
| 04:55 PM | 0 | 0 | 2 | 4 | 60 |
| 05:00 PM | 0 | 0 | 1 | 4 | 50 |
| 05:05 PM | 0 | 0 | 0 | 2 | 50 |
| 05:10 PM | 0 | 0 | 2 | 4 | 50 |
| 05:15 PM | 0 | 0 | 1 | 2 | 55 |
| 05:20 PM | 0 | 0 | 1 | 3 | 55 |
| 05:25 PM | 0 | 0 | 1 | 1 | 60 |
| 05:30 PM | 0 | 0 | 2 | 2 | 60 |
| 05:35 PM | 1 | 1 | 2 | 2 | 60 |
| 05:40 PM | 0 | 0 | 1 | 2 | 70 |
| 05:45 PM | 0 | 0 | 2 | 4 | 70 |
| 05:50 PM | 0 | 0 | 2 | 3 | 60 |
| 05:55 PM | 0 | 0 | 0 | 3 | 60 |
| 06:00 PM | 0 | 0 | 0 | 6 | 50 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 6/29/95
Treatment: Post-BMP
Number of Animals: 211 (109 cows & 102 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:05 PM | 1 | 1 | 3 | 5 | 50 |
| 06:10 PM | 1 | 1 | 1 | 5 | 60 |
| 06:15 PM | 0 | 1 | 4 | 6 | 60 |
| 06:20 PM | 0 | 1 | 3 | 7 | 50 |
| 06:25 PM | 2 | 3 | 6 | 9 | 50 |
| 06:30 PM | 1 | 3 | 3 | 4 | 50 |
| 06:35 PM | 2 | 3 | 8 | 14 | 50 |
| 06:40 PM | 0 | 1 | 5 | 9 | 40 |
| 06:45 PM | 0 | 2 | 3 | 10 | 40 |
| 06:50 PM | 3 | 6 | 5 | 12 | 50 |
| 06:55 PM | 1 | 5 | 3 | 8 | 50 |
| 07:00 PM | 0 | 3 | 0 | 5 | 60 |
| 07:05 PM | 0 | 2 | 3 | 6 | 80 |
| 07:10 PM | 0 | 1 | 1 | 3 | 90 |
| 07:15 PM | 0 | 5 | 0 | 4 | 95 |
| 07:20 PM | 1 | 3 | 0 | 3 | 95 |
| 07:25 PM | 0 | 2 | 2 | 1 | 95 |
| 07:30 PM | 0 | 0 | 1 | 5 | 95 |
| 07:35 PM | 0 | 1 | 1 | 3 | 95 |
| 07:40 PM | 0 | 0 | 4 | 4 | 95 |
| 07:45 PM | 0 | 0 | 0 | 7 | 95 |
| 07:50 PM | 0 | 0 | 0 | 5 | 95 |
| 07:55 PM | 0 | 0 | 0 | 3 | 95 |
| 08:00 PM | 0 | 0 | 0 | 4 | 95 |
| 08:05 PM | 0 | 0 | 0 | 5 | 95 |
| 08:10 PM | 0 | 0 | 0 | 0 | 95 |
| 08:15 PM | 0 | 0 | 0 | 0 | 95 |
| 08:20 PM | 0 | 0 | 0 | 3 | 95 |
| 08:25 PM | 0 | 0 | 0 | 1 | 95 |
| 08:30 PM | 0 | 1 | 1 | 1 | 95 |

## Cattle Observations

Farm: South Bender
Date: 8/22/95
Treatment: Post-BMP
Number of Animals: 65 (65 cows & [31+ calves - not counted])

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:25 AM | 0 | 0 | 0 | 0 | 0 |
| 06:30 AM | 0 | 0 | 0 | 0 | 20 |
| 06:35 AM | 0 | 0 | 0 | 0 | 50 |
| 06:40 AM | 0 | 0 | 1 | 1 | 100 |
| 06:45 AM | 0 | 0 | 2 | 2 | 100 |
| 06:50 AM | 0 | 2 | 1 | 1 | 100 |
| 06:55 AM | 0 | 2 | 2 | 2 | 100 |
| 07:00 AM | 0 | 1 | 1 | 2 | 100 |
| 07:05 AM | 0 | 0 | 1 | 1 | 100 |
| 07:10 AM | 0 | 6 | 2 | 2 | 100 |
| 07:15 AM | 0 | 3 | 2 | 2 | 100 |
| 07:20 AM | 1 | 4 | 0 | 3 | 100 |
| 07:25 AM | 1 | 1 | 2 | 3 | 100 |
| 07:30 AM | 0 | 2 | 3 | 3 | 100 |
| 07:35 AM | 0 | 2 | 2 | 2 | 100 |
| 07:40 AM | 0 | 1 | 2 | 3 | 100 |
| 07:45 AM | 0 | 1 | 2 | 3 | 100 |
| 07:50 AM | 0 | 2 | 2 | 3 | 100 |
| 07:55 AM | 0 | 3 | 2 | 4 | 100 |
| 08:00 AM | 0 | 0 | 2 | 2 | 100 |
| 08:05 AM | 0 | 1 | 0 | 2 | 100 |
| 08:10 AM | 1 | 3 | 3 | 3 | 100 |
| 08:15 AM | 1 | 4 | 3 | 4 | 100 |
| 08:20 AM | 0 | 2 | 3 | 4 | 100 |
| 08:25 AM | 0 | 3 | 2 | 4 | 100 |
| 08:30 AM | 0 | 1 | 1 | 2 | 90 |
| 08:35 AM | 0 | 2 | 2 | 4 | 95 |
| 08:40 AM | 0 | 1 | 3 | 5 | 95 |
| 08:45 AM | 0 | 1 | 1 | 3 | 95 |
| 08:50 AM | 0 | 2 | 1 | 2 | 95 |
| 08:55 AM | 0 | 1 | 1 | 2 | 100 |
| 09:00 AM | 0 | 0 | 3 | 5 | 80 |
| 09:05 AM | 0 | 1 | 4 | 5 | 75 |
| 09:10 AM | 1 | 2 | 3 | 3 | 75 |
| 09:15 AM | 0 | 0 | 0 | 0 | 50 |
| 09:20 AM | 0 | 4 | 0 | 0 | 25 |
| 09:25 AM | 0 | 1 | 0 | 0 | 20 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 8/22/95
Treatment: Post-BMP
Number of Animals: 65 (65 cows & [31+ calves - not counted])

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 09:30 AM | 0 | 0 | 0 | 0 | 10 |
| 09:35 AM | 1 | 3 | 0 | 0 | 10 |
| 09:40 AM | 0 | 1 | 0 | 0 | 10 |
| 09:45 AM | 0 | 1 | 0 | 0 | 10 |
| 09:50 AM | 0 | 1 | 0 | 0 | 50 |
| 09:55 AM | 0 | 0 | 0 | 0 | 10 |
| 10:00 AM | 0 | 0 | 0 | 1 | 30 |
| 10:05 AM | 0 | 0 | 0 | 0 | 50 |
| 10:10 AM | 0 | 0 | 0 | 0 | 50 |
| 10:15 AM | 0 | 1 | 0 | 0 | 50 |
| 10:20 AM | 1 | 1 | 0 | 0 | 50 |
| 10:25 AM | 0 | 0 | 0 | 0 | 50 |
| 10:30 AM | 0 | 1 | 0 | 0 | 15 |
| 10:35 AM | 0 | 0 | 0 | 0 | 10 |
| 10:40 AM | 0 | 0 | 0 | 0 | 0 |
| 10:45 AM | 0 | 0 | 0 | 0 | 0 |
| 10:50 AM | 0 | 0 | 0 | 0 | 0 |
| 10:55 AM | 0 | 0 | 0 | 0 | 0 |
| 11:00 AM | 0 | 0 | 0 | 0 | 0 |
| 11:05 AM | 0 | 0 | 0 | 0 | 0 |
| 11:10 AM | 0 | 0 | 0 | 0 | 0 |
| 11:15 AM | 0 | 0 | 0 | 0 | 0 |
| 11:20 AM | 0 | 0 | 0 | 0 | 0 |
| 11:25 AM | 0 | 0 | 0 | 0 | 0 |
| 11:30 AM | 0 | 0 | 0 | 0 | 0 |
| 11:35 AM | 0 | 2 | 0 | 0 | 5 |
| 11:40 AM | 0 | 2 | 0 | 0 | 5 |
| 11:45 AM | 0 | 0 | 0 | 0 | 10 |
| 11:50 AM | 0 | 0 | 0 | 0 | 10 |
| 11:55 AM | 0 | 0 | 0 | 0 | 10 |
| 12:00 PM | 0 | 0 | 0 | 0 | 0 |
| 12:05 PM | 0 | 0 | 0 | 0 | 10 |
| 12:10 PM | 0 | 0 | 1 | 1 | 5 |
| 12:15 PM | 0 | 0 | 1 | 1 | 5 |
| 12:20 PM | 0 | 0 | 3 | 3 | 5 |
| 12:25 PM | 0 | 0 | 0 | 3 | 5 |
| 12:30 PM | 0 | 2 | 0 | 0 | 10 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 8/22/95
Treatment: Post-BMP
Number of Animals: 65 (65 cows & [31+ calves - not counted])

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 12:35 PM | 0 | 2 | 0 | 0 | 10 |
| 12:40 PM | 0 | 1 | 0 | 0 | 5 |
| 12:45 PM | 0 | 0 | 0 | 0 | 10 |
| 12:50 PM | 1 | 1 | 0 | 0 | 15 |
| 12:55 PM | 1 | 3 | 0 | 0 | 15 |
| 01:00 PM | 0 | 1 | 2 | 2 | 15 |
| 01:05 PM | 0 | 0 | 0 | 1 | 15 |
| 01:10 PM | 0 | 1 | 2 | 2 | 15 |
| 01:15 PM | 0 | 1 | 2 | 3 | 15 |
| 01:20 PM | 1 | 2 | 4 | 6 | 25 |
| 01:25 PM | 0 | 0 | 3 | 3 | 25 |
| 01:30 PM | 0 | 0 | 1 | 1 | 30 |
| 01:35 PM | 0 | 0 | 1 | 1 | 15 |
| 01:40 PM | 0 | 0 | 0 | 0 | 15 |
| 01:45 PM | 0 | 2 | 0 | 0 | 15 |
| 01:50 PM | 0 | 0 | 0 | 0 | 20 |
| 01:55 PM | 0 | 2 | 0 | 0 | 20 |
| 02:00 PM | 0 | 1 | 0 | 0 | 25 |
| 02:05 PM | 0 | 1 | 0 | 0 | 25 |
| 02:10 PM | 0 | 2 | 0 | 2 | 30 |
| 02:15 PM | 0 | 1 | 1 | 2 | 30 |
| 02:20 PM | 0 | 1 | 0 | 2 | 30 |
| 02:25 PM | 0 | 0 | 0 | 0 | 35 |
| 02:30 PM | 0 | 0 | 0 | 0 | 50 |
| 02:35 PM | 0 | 0 | 0 | 2 | 30 |
| 02:40 PM | 0 | 0 | 2 | 2 | 30 |
| 02:45 PM | 0 | 0 | 0 | 1 | 25 |
| 02:50 PM | 1 | 2 | 0 | 0 | 30 |
| 02:55 PM | 0 | 0 | 3 | 3 | 35 |
| 03:00 PM | 0 | 0 | 3 | 4 | 35 |
| 03:05 PM | 0 | 0 | 1 | 2 | 40 |
| 03:10 PM | 0 | 2 | 1 | 1 | 30 |
| 03:15 PM | 0 | 2 | 1 | 1 | 30 |
| 03:20 PM | 0 | 1 | 0 | 0 | 60 |
| 03:25 PM | 0 | 2 | 0 | 2 | 65 |
| 03:30 PM | 0 | 0 | 0 | 2 | 80 |
| 03:35 PM | 0 | 0 | 2 | 2 | 85 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 8/22/95
Treatment: Post-BMP
Number of Animals: 65 (65 cows & [31+ calves - not counted])

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 03:40 PM | 0 | 1 | 1 | 2 | 90 |
| 03:45 PM | 0 | 0 | 1 | 1 | 90 |
| 03:50 PM | 0 | 1 | 0 | 0 | 90 |
| 03:55 PM | 0 | 1 | 0 | 0 | 95 |
| 04:00 PM | 0 | 1 | 1 | 1 | 95 |
| 04:05 PM | 0 | 1 | 2 | 2 | 100 |
| 04:10 PM | 0 | 0 | 2 | 4 | 100 |
| 04:15 PM | 0 | 1 | 4 | 7 | 100 |
| 04:20 PM | 0 | 0 | 3 | 6 | 100 |
| 04:25 PM | 0 | 2 | 5 | 9 | 80 |
| 04:30 PM | 0 | 0 | 2 | 3 | 75 |
| 04:35 PM | 0 | 3 | 2 | 3 | 75 |
| 04:40 PM | 0 | 3 | 0 | 1 | 60 |
| 04:45 PM | 0 | 3 | 1 | 1 | 40 |
| 04:50 PM | 0 | 0 | 0 | 1 | 25 |
| 04:55 PM | 0 | 0 | 0 | 0 | 25 |
| 05:00 PM | 0 | 0 | 0 | 0 | 25 |
| 05:05 PM | 0 | 2 | 1 | 1 | 25 |
| 05:10 PM | 0 | 1 | 0 | 3 | 35 |
| 05:15 PM | 0 | 1 | 3 | 4 | 50 |
| 05:20 PM | 0 | 1 | 1 | 2 | 55 |
| 05:25 PM | 0 | 0 | 1 | 2 | 50 |
| 05:30 PM | 0 | 0 | 0 | 0 | 50 |
| 05:35 PM | 1 | 0 | 0 | 0 | 40 |
| 05:40 PM | 0 | 1 | 0 | 0 | 40 |
| 05:45 PM | 0 | 3 | 0 | 0 | 25 |
| 05:50 PM | 0 | 4 | 0 | 0 | 25 |
| 05:55 PM | 0 | 3 | 0 | 0 | 50 |
| 06:00 PM | 0 | 0 | 4 | 4 | 50 |
| 06:05 PM | 0 | 0 | 4 | 4 | 60 |
| 06:10 PM | 0 | 2 | 4 | 7 | 60 |
| 06:15 PM | 0 | 1 | 3 | 3 | 60 |
| 06:20 PM | 0 | 2 | 2 | 3 | 60 |
| 06:25 PM | 1 | 2 | 3 | 3 | 80 |
| 06:30 PM | 0 | 1 | 3 | 4 | 90 |
| 06:35 PM | 0 | 2 | 0 | 0 | 100 |
| 06:40 PM | 0 | 1 | 1 | 2 | 100 |

# Appendix C

## Cattle Observations

Farm: South Bender
Date: 8/22/95
Treatment: Post-BMP
Number of Animals: 65 (65 cows & [31+ calves - not counted])

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:45 PM | 0 | 0 | 0 | 0 | 100 |
| 06:50 PM | 0 | 1 | 0 | 0 | 100 |
| 06:55 PM | 0 | 2 | 0 | 0 | 100 |
| 07:00 PM | 1 | 2 | 0 | 0 | 100 |
| 07:05 PM | 1 | 1 | 0 | 0 | 100 |
| 07:10 PM | 0 | 0 | 0 | 0 | 100 |
| 07:15 PM | 0 | 1 | 3 | 3 | 100 |
| 07:20 PM | 0 | 0 | 0 | 0 | 100 |
| 07:25 PM | 0 | 0 | 0 | 0 | 100 |
| 07:30 PM | 0 | 0 | 0 | 1 | 100 |
| 07:35 PM | 1 | 2 | 0 | 0 | 100 |
| 07:40 PM | 1 | 1 | 1 | 1 | 100 |
| 07:45 PM | 0 | 0 | 2 | 2 | 100 |
| 07:50 PM | 0 | 0 | 0 | 0 | 100 |
| 07:55 PM | 0 | 0 | 0 | 0 | 100 |
| 08:00 PM | 0 | 0 | 0 | 0 | 100 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 9/26/95
Treatment: Post-BMP
Number of Animals: 164 (82 cows & 82 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:30 AM | 0 | 0 | 0 | 0 | 0 |
| 06:35 AM | 0 | 0 | 0 | 0 | 0 |
| 06:40 AM | 0 | 0 | 0 | 0 | 20 |
| 06:45 AM | 0 | 0 | 0 | 0 | 20 |
| 06:50 AM | 0 | 0 | 0 | 0 | 50 |
| 06:55 AM | 0 | 0 | 0 | 0 | 75 |
| 07:00 AM | 0 | 0 | 0 | 0 | 100 |
| 07:05 AM | 0 | 0 | 0 | 0 | 100 |
| 07:10 AM | 0 | 0 | 0 | 0 | 100 |
| 07:15 AM | 0 | 0 | 0 | 0 | 100 |
| 07:20 AM | 0 | 0 | 0 | 0 | 100 |
| 07:25 AM | 0 | 0 | 0 | 0 | 100 |
| 07:30 AM | 0 | 0 | 0 | 0 | 100 |
| 07:35 AM | 0 | 0 | 0 | 0 | 100 |
| 07:40 AM | 0 | 0 | 0 | 0 | 100 |
| 07:45 AM | 0 | 0 | 3 | 5 | 100 |
| 07:50 AM | 0 | 0 | 2 | 4 | 100 |
| 07:55 AM | 0 | 0 | 2 | 4 | 100 |
| 08:00 AM | 0 | 3 | 5 | 7 | 100 |
| 08:05 AM | 0 | 3 | 5 | 7 | 100 |
| 08:10 AM | 0 | 3 | 2 | 8 | 100 |
| 08:15 AM | 0 | 1 | 2 | 2 | 100 |
| 08:20 AM | 0 | 2 | 1 | 2 | 100 |
| 08:25 AM | 0 | 4 | 0 | 4 | 100 |
| 08:30 AM | 0 | 2 | 0 | 2 | 100 |
| 08:35 AM | 0 | 2 | 0 | 1 | 100 |
| 08:40 AM | 0 | 2 | 0 | 2 | 100 |
| 08:45 AM | 0 | 1 | 0 | 2 | 100 |
| 08:50 AM | 0 | 2 | 0 | 2 | 100 |
| 08:55 AM | 0 | 1 | 0 | 0 | 100 |
| 09:00 AM | 1 | 1 | 0 | 0 | 100 |
| 09:05 AM | 0 | 0 | 0 | 0 | 100 |
| 09:10 AM | 0 | 0 | 0 | 0 | 40 |
| 09:15 AM | 0 | 0 | 0 | 0 | 30 |
| 09:20 AM | 0 | 0 | 0 | 0 | 50 |
| 09:25 AM | 0 | 0 | 1 | 1 | 70 |
| 09:30 AM | 0 | 0 | 0 | 1 | 80 |

## Cattle Observations

Farm: River Ridge
Date: 9/26/95
Treatment: Post-BMP
Number of Animals: 164 (82 cows & 82 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 09:35 AM | 0 | 0 | 0 | 1 | 90 |
| 09:40 AM | 0 | 1 | 0 | 0 | 100 |
| 09:45 AM | 0 | 1 | 1 | 1 | 100 |
| 09:50 AM | 0 | 0 | 0 | 3 | 100 |
| 09:55 AM | 0 | 0 | 0 | 0 | 100 |
| 10:00 AM | 0 | 0 | 0 | 1 | 100 |
| 10:05 AM | 0 | 0 | 0 | 3 | 100 |
| 10:10 AM | 0 | 1 | 0 | 1 | 100 |
| 10:15 AM | 0 | 0 | 2 | 2 | 100 |
| 10:20 AM | 0 | 0 | 0 | 1 | 100 |
| 10:25 AM | 1 | 1 | 0 | 1 | 100 |
| 10:30 AM | 0 | 1 | 0 | 0 | 100 |
| 10:35 AM | 0 | 0 | 0 | 0 | 95 |
| 10:40 AM | 0 | 1 | 0 | 0 | 95 |
| 10:45 AM | 0 | 0 | 0 | 0 | 95 |
| 10:50 AM | 0 | 0 | 0 | 0 | 95 |
| 10:55 AM | 0 | 0 | 1 | 1 | 95 |
| 11:00 AM | 0 | 0 | 0 | 0 | 95 |
| 11:05 AM | 0 | 0 | 0 | 0 | 95 |
| 11:10 AM | 0 | 0 | 0 | 0 | 95 |
| 11:15 AM | 0 | 0 | 0 | 0 | 97 |
| 11:20 AM | 0 | 0 | 0 | 0 | 97 |
| 11:25 AM | 0 | 0 | 0 | 0 | 95 |
| 11:30 AM | 0 | 0 | 0 | 0 | 90 |
| 11:35 AM | 0 | 0 | 0 | 0 | 80 |
| 11:40 AM | 0 | 0 | 0 | 0 | 50 |
| 11:45 AM | 0 | 0 | 1 | 1 | 50 |
| 11:50 AM | 0 | 0 | 0 | 0 | 55 |
| 11:55 AM | 0 | 0 | 0 | 0 | 55 |
| 12:00 PM | 0 | 0 | 0 | 0 | 45 |
| 12:05 PM | 0 | 0 | 1 | 1 | 25 |
| 12:10 PM | 0 | 0 | 1 | 1 | 25 |
| 12:15 PM | 0 | 0 | 0 | 0 | 25 |
| 12:20 PM | 0 | 0 | 0 | 0 | 20 |
| 12:25 PM | 0 | 0 | 0 | 0 | 20 |
| 12:30 PM | 0 | 0 | 2 | 2 | 20 |
| 12:35 PM | 0 | 0 | 1 | 3 | 10 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 9/26/95
Treatment: Post-BMP
Number of Animals: 164 (82 cows & 82 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 12:40 PM | 0 | 0 | 0 | 0 | 10 |
| 12:45 PM | 0 | 0 | 5 | 6 | 40 |
| 12:50 PM | 1 | 1 | 3 | 6 | 60 |
| 12:55 PM | 2 | 4 | 4 | 5 | 70 |
| 01:00 PM | 1 | 5 | 2 | 5 | 65 |
| 01:05 PM | 1 | 4 | 4 | 5 | 60 |
| 01:10 PM | 0 | 4 | 2 | 8 | 60 |
| 01:15 PM | 0 | 4 | 0 | 6 | 20 |
| 01:20 PM | 0 | 3 | 0 | 5 | 20 |
| 01:25 PM | 0 | 3 | 0 | 1 | 10 |
| 01:30 PM | 0 | 5 | 0 | 0 | 10 |
| 01:35 PM | 0 | 3 | 0 | 0 | 10 |
| 01:40 PM | 0 | 3 | 0 | 0 | 10 |
| 01:45 PM | 0 | 2 | 2 | 2 | 10 |
| 01:50 PM | 1 | 5 | 0 | 1 | 15 |
| 01:55 PM | 0 | 2 | 0 | 2 | 15 |
| 02:00 PM | 0 | 2 | 4 | 4 | 20 |
| 02:05 PM | 0 | 0 | 1 | 1 | 25 |
| 02:10 PM | 0 | 0 | 0 | 0 | 25 |
| 02:15 PM | 0 | 0 | 0 | 0 | 25 |
| 02:20 PM | 0 | 0 | 0 | 0 | 5 |
| 02:25 PM | 0 | 0 | 0 | 0 | 5 |
| 02:30 PM | 0 | 0 | 0 | 0 | 5 |
| 02:35 PM | 0 | 0 | 1 | 3 | 15 |
| 02:40 PM | 0 | 0 | 5 | 5 | 25 |
| 02:45 PM | 0 | 1 | 2 | 3 | 25 |
| 02:50 PM | 0 | 0 | 1 | 2 | 35 |
| 02:55 PM | 0 | 0 | 1 | 2 | 40 |
| 03:00 PM | 0 | 0 | 1 | 1 | 45 |
| 03:05 PM | 0 | 1 | 0 | 0 | 50 |
| 03:10 PM | 0 | 1 | 0 | 0 | 50 |
| 03:15 PM | 0 | 1 | 0 | 0 | 60 |
| 03:20 PM | 0 | 2 | 1 | 2 | 65 |
| 03:25 PM | 0 | 0 | 2 | 2 | 65 |
| 03:30 PM | 0 | 1 | 1 | 2 | 75 |
| 03:35 PM | 0 | 0 | 0 | 1 | 80 |
| 03:40 PM | 0 | 0 | 2 | 3 | 80 |

# Appendix C

## Cattle Observations

Farm: River Ridge
Date: 9/26/95
Treatment: Post-BMP
Number of Animals: 164 (82 cows & 82 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 03:45 PM | 0 | 0 | 0 | 0 | 80 |
| 03:50 PM | 0 | 0 | 0 | 1 | 80 |
| 03:55 PM | 0 | 0 | 2 | 3 | 90 |
| 04:00 PM | 0 | 0 | 0 | 1 | 90 |
| 04:05 PM | 0 | 1 | 0 | 0 | 90 |
| 04:10 PM | 0 | 0 | 0 | 1 | 95 |
| 04:15 PM | 0 | 0 | 0 | 0 | 95 |
| 04:20 PM | 0 | 0 | 0 | 0 | 95 |
| 04:25 PM | 0 | 0 | 1 | 1 | 95 |
| 04:30 PM | 0 | 0 | 0 | 0 | 95 |
| 04:35 PM | 0 | 0 | 1 | 2 | 95 |
| 04:40 PM | 0 | 0 | 0 | 0 | 100 |
| 04:45 PM | 0 | 0 | 1 | 1 | 100 |
| 04:50 PM | 0 | 0 | 0 | 0 | 100 |
| 04:55 PM | 0 | 0 | 0 | 0 | 100 |
| 05:00 PM | 0 | 0 | 0 | 0 | 100 |
| 05:05 PM | 0 | 0 | 0 | 0 | 100 |
| 05:10 PM | 0 | 0 | 0 | 0 | 100 |
| 05:15 PM | 0 | 0 | 2 | 2 | 100 |
| 05:20 PM | 0 | 0 | 1 | 2 | 100 |
| 05:25 PM | 0 | 0 | 1 | 4 | 100 |
| 05:30 PM | 0 | 0 | 0 | 0 | 100 |
| 05:35 PM | 0 | 0 | 0 | 1 | 100 |
| 05:40 PM | 0 | 0 | 0 | 0 | 100 |
| 05:45 PM | 0 | 0 | 0 | 0 | 100 |
| 05:50 PM | 0 | 0 | 0 | 0 | 100 |
| 05:55 PM | 0 | 0 | 1 | 1 | 100 |
| 06:00 PM | 0 | 0 | 1 | 1 | 100 |
| 06:05 PM | 0 | 0 | 0 | 0 | 100 |
| 06:10 PM | 0 | 0 | 0 | 0 | 100 |
| 06:15 PM | 0 | 0 | 0 | 0 | 100 |
| 06:20 PM | 0 | 0 | 0 | 0 | 100 |
| 06:25 PM | 0 | 0 | 1 | 1 | 100 |
| 06:30 PM | 0 | 0 | 0 | 0 | 100 |
| 06:35 PM | 0 | 0 | 0 | 0 | 100 |
| 06:40 PM | 0 | 0 | 2 | 2 | 100 |
| 06:45 PM | 0 | 0 | 2 | 3 | 100 |

## Cattle Observations

Farm: River Ridge
Date: 9/26/95
Treatment: Post-BMP
Number of Animals: 164 (82 cows & 82 calves)

| Time | # of Cattle In Stream Drinking | # of Cattle In Stream Area | # of Cattle Trough Drinking | # of Cattle Trough Area | % Cattle Grazing |
|---|---|---|---|---|---|
| 06:50 PM | 0 | 0 | 3 | 6 | 100 |
| 06:55 PM | 0 | 1 | 0 | 1 | 100 |
| 07:00 PM | 0 | 0 | 1 | 1 | 100 |
| 07:05 PM | 0 | 0 | 1 | 1 | 100 |
| 07:10 PM | 0 | 0 | 1 | 1 | 100 |
| 07:15 PM | 0 | 0 | 0 | 0 | 100 |

# Appendix D

## Stream Bank Erosion

# Appendix D

## Cross Section Survey for River Ridge Farm

### Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | 9/12 -> 10/30 | 10/30 -> 12/18 | 12/18 -> 3/18 | **PRE-BMP**<br>**9/12 -> 3/18** |
|---|---|---|---|---|---|
| RR10 | Out-Bank | 0.00 | 1.00 | 0.05 | **1.05** |
| | In-Bank | 2.50 | 2.15 | 1.1 | **5.75** |
| RR20 | Out-Bank | 0.40 | 0.50 | 0 | **0.1** |
| | In-Bank | 0.05 | 0.05 | 0.1 | **0** |
| RR30 | Out-Bank | 1.25 | 0.05 | 0 | **1.3** |
| | In-Bank | 0.95 | 0.10 | 0 | **1.05** |
| RR40 | Out-Bank | 0.00 | 0.00 | 0.05 | **0.05** |
| | In-Bank | 0.05 | 0.05 | 0 | **0** |
| RR50 | Out-Bank | 7.10 | 0.05 | 0.2 | **7.25** |
| | In-Bank | 1.90 | 0.00 | 1.9 | **0** |
| RR60 | Out-Bank | 3.95 | 4.05 | 0.2 | **0.1** |
| | In-Bank | 3.15 | 0.25 | 0.1 | **3.3** |
| RR70 | Out-Bank | 0.65 | 0.05 | 0 | **0.7** |
| | In-Bank | 0.00 | 0.00 | 0.1 | **0.1** |
| RR80 | Out-Bank | 0.00 | 0.10 | 0.15 | **0.05** |
| | In-Bank | 0.90 | 0.00 | 0.2 | **0.7** |
| RR90 | Out-Bank | 0.05 | 0.90 | 0 | **0.95** |
| | In-Bank | 0.10 | 0.05 | 0.3 | **0.15** |
| RR110 | Out-Bank | 0.15 | 0.40 | 0.6 | **1.15** |
| | In-Bank | 0.00 | 0.25 | 0.2 | **0.45** |
| RR120 | Out-Bank | 0.15 | 0.15 | 0 | **0** |
| | In-Bank | 0.05 | 0.15 | 0 | **0.1** |
| RR130 | Out-Bank | 0.05 | 0.00 | 0 | **0.05** |
| | In-Bank | 0.10 | 0.10 | 0 | **0** |
| RR140 | Out-Bank | 0.05 | 0.00 | -- | **4.7** |
| | In-Bank | 0.25 | 0.10 | -- | **4.75** |
| RR150 | Out-Bank | 5.35 | 0.15 | 1.8 | **7** |
| | In-Bank | 0.55 | 0.10 | 2.5 | **3.15** |
| RR160 | Out-Bank | 2.00 | 2.30 | 0.2 | **4.75** |
| | In-Bank | 0.30 | 1.50 | 0.15 | **1.95** |
| RR170 | Out-Bank | 0.15 | 0.60 | 0.6 | **1.35** |
| | In-Bank | 1.65 | 1.70 | 11.1 | **14.45** |
| RR175 | Out-Bank | 0.05 | 0.10 | 0.15 | **0.2** |
| | In-Bank | 0.10 | 0.00 | 0.7 | **0.6** |
| RR180 | Out-Bank | 0.15 | 0.20 | 1 | **0.65** |
| | In-Bank | 0.60 | 8.85 | 0.2 | **9.65** |

-- : Cross section marker unable to be located during time of measurement

# Appendix D

## Cross Section Survey for River Ridge Farm

### Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | | | | POST-BMP |
|---|---|---|---|---|---|
| | | 3/18->5/29 | 5/29->7/9 | 7/9 -> 10/30 | 3/18 -> 10/15 |
| RR10 | Out-Bank | 0.75 | 0 | 0 | 0.05 |
| | In-Bank | 0 | 0 | 0.65 | 0.65 |
| RR20 | Out-Bank | 0.3 | 0.15 | 0.05 | 0.5 |
| | In-Bank | 0.4 | 0 | 0.55 | 0.95 |
| RR30 | Out-Bank | 1.2 | 0 | 0 | 1.2 |
| | In-Bank | 1.6 | 0 | 0.1 | 1.7 |
| RR40 | Out-Bank | 0 | 0.7 | 0.8 | 0.1 |
| | In-Bank | 0 | 0 | 0 | 0 |
| RR50 | Out-Bank | 0.1 | 0.2 | 0 | 0.3 |
| | In-Bank | 0 | 0 | 0.1 | 0.1 |
| RR60 | Out-Bank | 0.2 | 0 | 0 | 0.2 |
| | In-Bank | 1.9 | 0 | 0.05 | 1.95 |
| RR70 | Out-Bank | 0 | 0.1 | 0 | 0.1 |
| | In-Bank | 0 | 0.05 | 0.45 | 0.5 |
| RR80 | Out-Bank | 0.05 | 0 | 0.05 | 0.1 |
| | In-Bank | 0.7 | 0.05 | 0.6 | 0.65 |
| RR90 | Out-Bank | 0 | 0 | 0.05 | 0.05 |
| | In-Bank | 0.8 | 0 | 0.6 | 0.2 |
| RR110 | Out-Bank | 0.5 | 0 | 0.3 | 0.2 |
| | In-Bank | 0 | 0 | 0.35 | 0.35 |
| RR120 | Out-Bank | 0 | 0 | 0 | 0 |
| | In-Bank | 0 | 0.15 | 0.1 | 0.05 |
| RR130 | Out-Bank | 1.25 | 0.3 | 0 | 1.55 |
| | In-Bank | 0.05 | 0.2 | 0.1 | 0.15 |
| RR140 | Out-Bank | 0 | 0 | 0 | 0 |
| | In-Bank | 0.4 | 0.1 | 0.1 | 0.5 |
| RR150 | Out-Bank | 0 | 0.1 | 1.6 | 1.5 |
| | In-Bank | 0 | 0.1 | 0.05 | 0.15 |
| RR160 | Out-Bank | 0 | 1.05 | 0.95 | 0.1 |
| | In-Bank | 1.65 | 0.6 | 0 | 1.05 |
| RR170 | Out-Bank | 0.1 | 0 | 0.1 | 0 |
| | In-Bank | 0.1 | 0 | 0.5 | 0.6 |
| RR175 | Out-Bank | 0 | 0 | 0.15 | 0.15 |
| | In-Bank | 0 | 0 | 1.5 | 1.5 |
| RR180 | Out-Bank | 0 | 0 | 0 | 0 |
| | In-Bank | 0 | 0.1 | 0 | 0.1 |

# Appendix D

## Cross Section Survey for River Ridge Farm

### Streamedge Movement

Values expressed in terms of feet of streamedge movement during expressed period

| | | Pre-BMP<br>9/12 -> 3/18 | Post-BMP<br>3/18 -> 10/15 |
|---|---|---|---|
| RR10 | Out-Stream | 0.4 | 0.75 |
| | In-Stream | 0.5 | 1.8 |
| RR20 | Out-Stream | 0.05 | 0.7 |
| | In-Stream | 0.15 | 0.3 |
| RR30 | Out-Stream | 0.15 | 0.7 |
| | In-Stream | 0.7 | 0 |
| RR40 | Out-Stream | 0.35 | 0.55 |
| | In-Stream | 0.3 | 0.5 |
| RR50 | Out-Stream | 0.35 | 1.8 |
| | In-Stream | 0.4 | 1.2 |
| RR60 | Out-Stream | 0.6 | 0.75 |
| | In-Stream | 1.15 | 0.3 |
| RR70 | Out-Stream | 4.25 | 0.75 |
| | In-Stream | 1.05 | 1.25 |
| RR80 | Out-Stream | 1.8 | 0.7 |
| | In-Stream | 1.05 | 1.05 |
| RR90 | Out-Stream | 4.25 | 0.3 |
| | In-Stream | 1.8 | 2.4 |
| RR110 | Out-Stream | 0.05 | 3.25 |
| | In-Stream | 0.25 | 0.25 |
| RR120 | Out-Stream | 2.85 | 0.6 |
| | In-Stream | 1.6 | 1.2 |
| RR130 | Out-Stream | 0 | 0.15 |
| | In-Stream | 0.25 | 0.2 |
| RR150 | Out-Stream | 1.5 | 0.95 |
| | In-Stream | 1 | 0.9 |
| RR160 | Out-Stream | 0.95 | 1.9 |
| | In-Stream | 0.05 | 1.45 |
| RR170 | Out-Stream | 0.95 | 1.4 |
| | In-Stream | 0.45 | 0.05 |
| RR175 | Out-Stream | 6 | 0.5 |
| | In-Stream | 9.1 | 0.05 |
| RR180 | Out-Stream | 0.25 | 0.25 |
| | In-Stream | 1.65 | 0.6 |
| Average Streamedge Movement (ft.) | | **1.359** | **0.868** |
| | std. | 1.901 | 0.713 |

# Appendix D

Cross Section Survey for River Ridge Farm

Stream Width Variation

Values expressed in terms of feet of streamwidth change during expressed period

| Station | 12-Sep-94 | 30-Oct-94 | 18-Dec-94 | 18-Mar-95 | Pre-BMP | 29-May-95 | 09-Jul-95 | 30-Oct-95 | Post-BMP |
|---|---|---|---|---|---|---|---|---|---|
| RR10 | 1.3 | 7.85 | 0.5 | 1.2 | **2.71** | 1.3 | 1.15 | 2.25 | **1.57** |
| RR20 | 1.45 | 2.65 | 1.9 | 1.65 | **1.91** | 1.5 | 1.3 | 2.05 | **1.62** |
| RR30 | 0.95 | 4.65 | 1.35 | 1.5 | **2.11** | 1.4 | 0.95 | 0.8 | **1.05** |
| RR40 | 0.7 | 1.3 | 2.6 | 0.75 | **1.34** | 0.9 | 2 | 0.8 | **1.23** |
| RR50 | 1 | 1.4 | 1.9 | 0.95 | **1.31** | 1.4 | 1.9 | 3.95 | **2.42** |
| RR60 | 2.35 | 0.95 | 0.7 | 1.8 | **1.45** | 1.4 | 0.5 | 0.75 | **0.88** |
| RR70 | 1.68 | 2.5 | 1.2 | 1.35 | **1.68** | 0.95 | 1.35 | 3.35 | **1.88** |
| RR80 | 4.8 | 1 | 3 | 1.95 | **2.69** | 1.1 | 2.3 | 2.3 | **1.90** |
| RR90 | 2.9 | 2.95 | 1.3 | 1.35 | **2.13** | 0.9 | 0.5 | 4.05 | **1.82** |
| RR110 | 1.2 | 1.75 | 2.1 | 1 | **1.51** | 1.5 | 1.2 | 4.5 | **2.40** |
| RR120 | 2.35 | 2.8 | 2.3 | 3.6 | **2.76** | 3.4 | 3.6 | 5.4 | **4.13** |
| RR130 | 1.55 | 1.7 | 1.5 | 1.3 | **1.51** | 1.3 | 1.7 | 0.95 | **1.32** |
| RR150 | 1.55 | 1.5 | 1.5 | 1.05 | **1.40** | 1.3 | 0.9 | 1 | **1.07** |
| RR160 | 2 | 1.7 | 0.9 | 1 | **1.40** | 2.5 | 2.2 | 4.35 | **3.02** |
| RR170 | 1.55 | 0.9 | 1.8 | 1.05 | **1.32** | 0.6 | 2.3 | 2.4 | **1.77** |
| RR175 | 1.65 | 1.7 | 1.3 | 1.95 | **1.65** | 0.7 | 1.5 | 2.5 | **1.57** |
| RR180 | 4.85 | 2.55 | 1 | 1.1 | **2.37** | 1.1 | 0.7 | 1.45 | **1.08** |
| | | | | Average | **1.84** | | | | **1.81** |
| | | | | st. dev. | 0.51 | | | | 0.80 |

# Appendix D

## Cross Section Survey for Bender Farm - North Pasture

Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | 8/2 -> 12/18 | 12/18 -> 3/11 | 3/11 -> 4/17 | **PRE-BMP 8/02 -> 4/17** |
|---|---|---|---|---|---|
| NBF20 | Out-Bank | 0.05 | 0.05 | 0.10 | **0.10** |
| | In-Bank | 0.20 | 0.15 | 0.10 | **0.25** |
| NBF30A | Out-Bank | 0.35 | 0.15 | 0.05 | **0.55** |
| | In-Bank | 0.05 | 0.10 | 0.45 | **0.30** |
| NBF30B | Out-Bank | 0.00 | 0.10 | 0.30 | **0.40** |
| | In-Bank | 0.00 | 0.80 | 0.40 | **0.40** |
| NBF30C | Out-Bank | 0.10 | 0.50 | 0.30 | **0.90** |
| | In-Bank | 0.00 | 0.00 | 0.15 | **0.15** |
| NBF40 | Out-Bank | 0.20 | 0.35 | 0.35 | **0.90** |
| | In-Bank | 0.55 | 3.10 | 0.00 | **3.65** |
| NBF50 | Out-Bank | 0.00 | 0.00 | 0.20 | **0.20** |
| | In-Bank | 0.10 | 0.30 | 0.05 | **0.45** |
| NBF60 | Out-Bank | 0.15 | 0.40 | 0.05 | **0.50** |
| | In-Bank | 0.10 | 0.60 | 0.80 | **0.30** |
| NBF70 | Out-Bank | 0.10 | 0.50 | 0.15 | **0.75** |
| | In-Bank | 0.10 | 0.65 | 0.10 | **0.85** |
| NBF140 | Out-Bank | 0.00 | 0.00 | 0.00 | **0.00** |
| | In-Bank | 0.35 | 2.60 | 0.60 | **3.55** |
| NBF150 | Out-Bank | 0.00 | 0.05 | 0.25 | **0.30** |
| | In-Bank | 0.00 | 0.90 | 0.40 | **1.30** |
| NBF160 | Out-Bank | 0.00 | 0.00 | 0.30 | **0.30** |
| | In-Bank | 0.10 | 1.10 | 0.10 | **1.30** |

# Appendix D

## Cross Section Survey for Bender Farm - North Pasture

### Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | 4/17 -> 7/09 | 7/09 -> 8/20 | 8/20 -> 10/30 | **POST-BMP 4/17 -> 10/30** |
|---|---|---|---|---|---|
| NBF20 | Out-Bank | ---- | ---- | ---- | **----** |
| | In-Bank | ---- | ---- | ---- | **----** |
| NBF30A | Out-Bank | -- | 0.05 | 0.00 | **0.05** |
| | In-Bank | -- | 0.00 | 0.20 | **0.20** |
| NBF30B | Out-Bank | 1.10 | 0.00 | 0.35 | **1.45** |
| | In-Bank | 0.80 | 0.00 | 0.60 | **0.20** |
| NBF30C | Out-Bank | 0.00 | 0.05 | 0.00 | **0.05** |
| | In-Bank | 0.30 | 0.00 | 0.00 | **0.30** |
| NBF40 | Out-Bank | 0.00 | 0.00 | 0.15 | **0.15** |
| | In-Bank | 1.10 | 0.00 | 0.00 | **1.10** |
| NBF50 | Out-Bank | 0.00 | 0.00 | 0.20 | **0.20** |
| | In-Bank | 0.00 | 0.25 | 0.05 | **0.20** |
| NBF60 | Out-Bank | 0.00 | 0.00 | 0.00 | **0.00** |
| | In-Bank | 0.00 | 0.20 | 0.00 | **0.20** |
| NBF70 | Out-Bank | 0.00 | 0.00 | 0.10 | **0.10** |
| | In-Bank | 0.00 | 0.05 | 0.10 | **0.15** |
| NBF140 | Out-Bank | 0.20 | 0.00 | 0.20 | **0.40** |
| | In-Bank | 0.00 | 0.20 | 0.15 | **0.05** |
| NBF150 | Out-Bank | 0.00 | 0.00 | 0.00 | **0.00** |
| | In-Bank | 0.00 | 0.00 | 0.40 | **0.40** |
| NBF160 | Out-Bank | 0.40 | 0.00 | 0.60 | **1.00** |
| | In-Bank | 0.00 | 0.00 | 0.00 | **0.00** |

---- : Cross section marker lost during BMP installation

-- : Cross section marker unable to be located during time of measurement

# Appendix D

Cross Section Survey for Bender Farm - North Pasture

### Streamedge Movement

Values expressed in terms of feet of streamedge movement (meander) during expressed period

| | | **Pre-BMP** | **Post-BMP** |
|---|---|---|---|
| | | 8/02 -> 4/17 | 4/17 -> 10/30 |
| NBF30A | Out-Stream | 2.4 | 0.4 |
| | In-Stream | 2.1 | 0.2 |
| NBF30B | Out-Stream | 0.05 | 0.45 |
| | In-Stream | 0.1 | 0.15 |
| NBF30C | Out-Stream | 2.5 | 0.6 |
| | In-Stream | 3.05 | 0.45 |
| NBF40 | Out-Stream | 0.3 | 0 |
| | In-Stream | 0.25 | 0.4 |
| NBF50 | Out-Stream | 0.15 | 0.1 |
| | In-Stream | 0.95 | 0.15 |
| NBF60 | Out-Stream | 0.45 | 0.25 |
| | In-Stream | 0.45 | 0.95 |
| NBF70 | Out-Stream | 0.3 | 0.3 |
| | In-Stream | 0.05 | 0.4 |
| NBF140 | Out-Stream | 0.7 | 0.1 |
| | In-Stream | 0.85 | 0.05 |
| NBF150 | Out-Stream | 0.2 | 0 |
| | In-Stream | 0.05 | 1.1 |
| NBF160 | Out-Stream | 0.2 | 0 |
| | In-Stream | 0.6 | 0.1 |
| Average Streamedge Movement (ft.) | | **0.785** | **0.3075** |
| | std. | 0.912 | 0.295 |

# Appendix D

Cross Section Survey for Bender Farm - North Pasture

Stream Width Variation

Values expressed in terms of feet of streamwidth variation during expressed period

## Stream width variation - North Bender Farm

| Station | 02-Aug-94 | 18-Dec-94 | 11-Mar-95 | 17-Apr-95 | Pre-BMP | 09-Jul-95 | 20-Aug-95 | 30-Oct-95 | Post-BMP |
|---|---|---|---|---|---|---|---|---|---|
| NBF30A | 6.2 | 5.85 | 2.2 | 1.7 | **3.99** | 0 | 2.6 | 1.5 | **1.37** |
| NBF30B | 1.25 | 1.3 | 1.15 | 1.2 | **1.22** | 0.9 | 1.1 | 0.6 | **0.87** |
| NBF30C | 1.3 | 1 | 1.15 | 0.75 | **1.05** | 1.2 | 1.1 | 0.6 | **0.97** |
| NBF40 | 1 | 0.9 | 0.9 | 1.05 | **0.96** | 1.05 | 1.1 | 1.45 | **1.20** |
| NBF50 | 0.8 | 1.15 | 1 | 1.6 | **1.14** | 1 | 1 | 1.35 | **1.12** |
| NBF60 | 1.15 | 1.2 | 1.7 | 1.15 | **1.30** | 2.4 | 1.5 | 1.85 | **1.92** |
| NBF70 | 1.05 | 1.1 | 1.15 | 1.3 | **1.15** | 2.2 | 2 | 2 | **2.07** |
| NBF140 | 1.65 | 1.75 | 2 | 1.5 | **1.73** | 2.3 | 1.4 | 1.45 | **1.72** |
| NBF150 | 1.45 | 1.4 | 2 | 1.2 | **1.51** | 1.1 | 1 | 2.3 | **1.47** |
| NBF160 | 2.1 | 1.85 | 1.6 | 1.3 | **1.71** | 1.6 | 1.25 | 1.2 | **1.35** |
| | | | | Average | **1.58** | | | | **1.40** |
| | | | | st. dev. | 0.84 | | | | 0.38 |

# Appendix D

## Cross Section Survey for Bender Farm - South Pasture

### Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | 8/2 -> 12/18 | 12/18 -> 3/18 | 3/18 -> 4/17 | **PRE-BMP 8/2 -> 4/17** |
|---|---|---|---|---|---|
| SBF10 -A | Out-Bank | 0.50 | 0.40 | 0.60 | **1.50** |
| | In-Bank | 0.00 | 0.00 | 0.45 | **0.45** |
| SBF10-B | Out-Bank | 0.00 | 2.00 | 0.55 | **2.55** |
| | In-Bank | 0.00 | 2.40 | 0.05 | **2.35** |
| SBF10-C | Out-Bank | 0.00 | 0.00 | 0.00 | **0.00** |
| | In-Bank | 0.10 | 0.10 | 0.00 | **0.20** |
| SBF20-A | Out-Bank | 0.00 | 0.00 | 0.00 | **0.00** |
| | In-Bank | 0.10 | 0.05 | 0.10 | **0.25** |
| SBF20-B | Out-Bank | 0.70 | 0.65 | 3.65 | **5.00** |
| | In-Bank | 0.40 | 0.00 | 0.30 | **0.10** |
| SBF30 | Out-Bank | 0.10 | 1.00 | 0.00 | **0.90** |
| | In-Bank | 0.10 | 3.10 | 1.00 | **4.20** |
| SBF40-A | Out-Bank | 0.00 | 0.20 | 0.20 | **0.00** |
| | In-Bank | 0.00 | 0.50 | 0.20 | **0.70** |
| SBF40-C | Out-Bank | 0.00 | 0.45 | 1.55 | **2.00** |
| | In-Bank | 0.00 | 0.20 | 0.80 | **1.00** |
| SBF60 | Out-Bank | 0.15 | 0.30 | 0.40 | **0.55** |
| | In-Bank | 0.10 | 0.00 | 0.60 | **0.50** |
| SBF70 | Out-Bank | 1.10 | 0.90 | 3.30 | **3.10** |
| | In-Bank | 0.10 | 0.75 | 1.25 | **1.90** |
| SBF80 | Out-Bank | 0.20 | 0.20 | 7.10 | **7.50** |
| | In-Bank | 0.10 | 0.10 | 0.10 | **0.10** |
| SBF90-A | Out-Bank | 0.00 | 0.30 | 0.00 | **0.30** |
| | In-Bank | 0.00 | 1.93 | 0.00 | **1.93** |
| SBF90-B | Out-Bank | 0.20 | 0.75 | 0.05 | **1.00** |
| | In-Bank | 1.70 | 0.20 | 5.20 | **7.10** |
| SBF110 | Out-Bank | 0.40 | 0.40 | 0.00 | **0.80** |
| | In-Bank | 0.20 | 0.25 | 0.05 | **0.50** |
| SBF120 | Out-Bank | 0.10 | 0.90 | 0.10 | **1.10** |
| | In-Bank | 0.15 | 1.30 | 0.10 | **1.25** |
| SBF130-A | Out-Bank | 0.25 | 0.20 | 0.00 | **0.05** |
| | In-Bank | 0.10 | 0.00 | 0.10 | **0.20** |
| SBF130-B | Out-Bank | 0.90 | 0.90 | 0.00 | **0.00** |
| | In-Bank | 0.60 | 0.55 | 0.15 | **1.00** |
| SBF130-C | Out-Bank | 0.10 | 0.00 | 0.00 | **0.10** |
| | In-Bank | 2.00 | 2.00 | 0.00 | **0.00** |
| SBF130-D | Out-Bank | 0.30 | 1.40 | 0.00 | **1.10** |
| | In-Bank | 0.10 | 0.00 | 0.00 | **0.10** |

# Appendix D

## Cross Section Survey for Bender Farm - South Pasture

### Stream Bank Variation

Values expressed in terms of feet of streambank movement (erosion) during expressed period

| | | 4/17 -> 8/28 | 8/28 -> 10/30 | **POST-BMP**<br>**4/17 -> 10/30** |
|---|---|---|---|---|
| SBF10 -A | Out-Bank | ---- | ---- | **----** |
| | In-Bank | ---- | ---- | **----** |
| SBF10-B | Out-Bank | ---- | ---- | **----** |
| | In-Bank | ---- | ---- | **----** |
| SBF10-C | Out-Bank | ---- | ---- | **----** |
| | In-Bank | ---- | ---- | **----** |
| SBF20-A | Out-Bank | 0.00 | 0.50 | **0.50** |
| | In-Bank | 0.15 | 0.00 | **0.15** |
| SBF20-B | Out-Bank | 2.00 | 0.00 | **2.00** |
| | In-Bank | 2.10 | 1.20 | **3.30** |
| SBF30 | Out-Bank | 0.50 | 3.00 | **3.50** |
| | In-Bank | 0.00 | 0.90 | **0.90** |
| SBF40-A | Out-Bank | 7.70 | 0.00 | **7.70** |
| | In-Bank | 0.10 | 0.05 | **0.15** |
| SBF40-C | Out-Bank | 0.10 | 0.00 | **0.10** |
| | In-Bank | 0.15 | 0.10 | **0.05** |
| SBF60 | Out-Bank | 0.10 | 0.30 | **0.40** |
| | In-Bank | 0.10 | 0.10 | **0.00** |
| SBF70 | Out-Bank | 2.05 | 0.25 | **2.30** |
| | In-Bank | 0.25 | 0.05 | **0.20** |
| SBF80 | Out-Bank | 1.70 | 0.05 | **1.75** |
| | In-Bank | 1.30 | 1.30 | **0.00** |
| SBF90-A | Out-Bank | 0.40 | 0.40 | **0.00** |
| | In-Bank | 0.00 | 0.60 | **0.60** |
| SBF90-B | Out-Bank | 0.05 | 0.25 | **0.30** |
| | In-Bank | 0.20 | 0.00 | **0.20** |
| SBF110 | Out-Bank | 0.20 | 0.20 | **0.00** |
| | In-Bank | 0.00 | 0.05 | **0.05** |
| SBF120 | Out-Bank | 0.05 | 0.00 | **0.05** |
| | In-Bank | 0.35 | 0.10 | **0.45** |
| SBF130-A | Out-Bank | 0.50 | 0.00 | **0.50** |
| | In-Bank | 0.00 | 0.00 | **0.00** |
| SBF130-B | Out-Bank | 0.00 | 0.00 | **0.00** |
| | In-Bank | 1.20 | 1.20 | **0.00** |
| SBF130-C | Out-Bank | 0.10 | 0.10 | **0.00** |
| | In-Bank | 2.00 | 0.05 | **1.95** |
| SBF130-D | Out-Bank | 0.20 | 0.00 | **0.20** |
| | In-Bank | 0.00 | 0.00 | **0.00** |

# Appendix D

## Cross Section Survey for Bender Farm - South Pasture

### Streamedge Movement

Values expressed in terms of feet of streamedge movement (meander) during expressed period

| | | **Pre-BMP** 8/2 -> 4/17 | **Post-BMP** 4/17 -> 10/30 |
|---|---|---|---|
| SBF20-A | Out-Stream | 0.15 | 0.45 |
| | In-Stream | 3.3 | 3.2 |
| SBF20-B | Out-Stream | 0.4 | 1.6 |
| | In-Stream | 1.6 | 0.1 |
| SBF30 | Out-Stream | 0.35 | 0.15 |
| | In-Stream | 0.65 | 0.1 |
| SBF40 -A | Out-Stream | 0.05 | 0.45 |
| | In-Stream | 0.35 | 0.25 |
| SBF40-C | Out-Stream | 0.1 | 0.5 |
| | In-Stream | 0.2 | 0.75 |
| SBF60 | Out-Stream | 0.3 | 0.1 |
| | In-Stream | 1.3 | 1.6 |
| SBF70 | Out-Stream | 0.25 | 0.4 |
| | In-Stream | 0.55 | 0.2 |
| SBF80 | Out-Stream | 1.95 | 0.65 |
| | In-Stream | 0.4 | 0.05 |
| SBF90-A | Out-Stream | 0.4 | 1.3 |
| | In-Stream | 0.05 | 0.55 |
| SBF90-B | Out-Stream | 0.2 | 0.4 |
| | In-Stream | 0.1 | 0.2 |
| SBF110 | Out-Stream | 0.4 | 0 |
| | In-Stream | 0.3 | 0.4 |
| SBF120 | Out-Stream | 0 | 0.3 |
| | In-Stream | 0.6 | 1 |
| SBF130-A | Out-Stream | 0.2 | 0.4 |
| | In-Stream | 0.2 | 0.3 |
| SBF130-B | Out-Stream | 0 | 0.4 |
| | In-Stream | 0.2 | 0.7 |
| SBF130-C | Out-Stream | 1.1 | 0.1 |
| | In-Stream | 1.05 | 0.85 |
| SBF130-D | Out-Stream | 0.15 | 0.7 |
| | In-Stream | 0 | 0.1 |
| Average Streamedge Movement (ft. | | **0.527** | **0.570** |
| | std. | 0.682 | 0.625 |

# Appendix D

Cross Section Survey for Bender Farm - South Pasture

Stream Width Variation

Values expressed in terms of feet of streamwidth variation during expressed period

## Stream width variation - South Bender Farm

| Station | 02-Aug-94 | 18-Dec-94 | 18-Mar-95 | 17-Apr-95 | Pre-BMP | 28-Aug-95 | 30-Oct-95 | Post-BMP |
|---|---|---|---|---|---|---|---|---|
| SBF20-A | 1.10 | 3.00 | 1.65 | 4.25 | **2.50** | 4.55 | 1.50 | **3.02** |
| SBF20-B | 1.00 | 1.40 | 2.40 | 2.20 | **1.75** | 1.65 | 0.70 | **1.18** |
| SBF30 | 2.00 | 1.50 | 1.00 | 1.00 | **1.38** | 0.70 | 0.75 | **0.72** |
| SBF40 -A | 0.80 | 0.80 | 0.80 | 0.50 | **0.73** | 0.90 | 1.20 | **1.05** |
| SBF40-C | 1.10 | 1.10 | 1.30 | 1.00 | **1.13** | 1.20 | 1.25 | **1.23** |
| SBF60 | 1.80 | 1.45 | 3.05 | 2.80 | **2.27** | 1.40 | 1.30 | **1.35** |
| SBF70 | 1.60 | 1.60 | 1.00 | 1.30 | **1.38** | 0.90 | 0.70 | **0.80** |
| SBF80 | 0.90 | 1.10 | 2.40 | 3.25 | **1.91** | 1.60 | 2.55 | **2.07** |
| SBF90-A | 2.40 | 2.30 | 3.85 | 2.75 | **2.82** | 3.00 | 2.00 | **2.50** |
| SBF90-B | 1.50 | 1.20 | 1.70 | 1.60 | **1.50** | 0.75 | 1.00 | **0.88** |
| SBF110 | 1.40 | 0.80 | 1.50 | 1.30 | **1.25** | 1.70 | 1.70 | **1.70** |
| SBF120 | 1.60 | 1.00 | 2.00 | 2.20 | **1.70** | 1.10 | 0.90 | **1.00** |
| SBF130-A | 2.70 | 2.40 | 2.55 | 2.70 | **2.59** | 1.70 | 2.00 | **1.85** |
| SBF130-B | 0.90 | 0.90 | 1.10 | 1.10 | **1.00** | 1.50 | 0.80 | **1.15** |
| SBF130-C | 2.50 | 1.20 | 2.60 | 2.55 | **2.21** | 2.50 | 1.80 | **2.15** |
| SBF130-D | 1.00 | 0.70 | 1.25 | 0.85 | **0.95** | 1.40 | 1.45 | **1.43** |
| | | | | Average | **1.69** | | | **1.50** |
| | | | | st. dev. | 0.62 | | | 0.64 |

# VIII. Vita

Ronald Erle Sheffield was born on December 1, 1969, in Arlington, Virginia, to Ronald and Jacqueline Sheffield. Ron served in the United States Marine Corps from December, 1987 until August, 1990 as an avionics specialist on A-6E aircraft. While in the Marines, Ron got the chance to "see the world" being stationed outside of cities like Boston, Memphis, Seattle, Norfolk, Raleigh and Washington, D.C. as well as Iwakuni and Yokosuka, Japan. Unity College in Unity, Maine awarded him a Bachelor of Science degree in Natural Resource Planning in May of 1993. In August of that same year, Ron began working toward a Master of Science degree in Biological Systems Engineering at Virginia Tech.

Ron is married to Juliana Jeanette (Brown) and they have two overly affectionate golden retrievers named Rusty and Grace. As an Eagle Scout, Ron enjoys camping and hiking with Juliana, Rusty and Grace. Ron enjoys tinkering with 35mm photography and while in college was the chief editor of "The New People Take Root" a half hour documentary, on the 1970's back to the land movement in Maine, which aired on both the Maine and Massachusetts public television networks. He serves the community as an assistant scoutmaster, church youth leader and Habitat for Humanity volunteer. While a graduate student, Ron was awarded the VPI&SU Graduate Student Service Award. After graduation, Ron hopes to find employment in the field of agricultural watershed management.

Ronald Erle Sheffield
Blacksburg, Virginia
April, 1996