ATRAZINE BEST MANAGEMENT PRACTICES: IMPACT ON WATER QUALITY

by

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Abstract

Wichita, Kansas water supply is derived from multiple sources. Unfortunately, these sources are not expected to meet the future needs of the population. This predicted water shortage led to the development of the *Equus* Beds Recharge Project, to investigate artificial recharge as a solution to meet future water demands. This project focuses on the Little Arkansas River as a source of this recharge water. The Kansas Department of Health and Environment set a daily 3μg/L standard for the recharged water as opposed to surface waters used directly for drinking water which can't exceed a yearly average atrazine concentration of 3μg/L. During 2005, five sub-watersheds within the Little Arkansas River watershed were instrumented to collect water quality samples and measure flow rate to calculate daily contaminant loadings. Three of the sub-watersheds used atrazine best management practices (BMPs) applied to grain sorghum while the remaining two sub-watersheds maintained existing farm practices. During 2007, monitoring continued and additional atrazine BMPs were applied to corn grown in the treated sub-watersheds. During both 2006 and 2007, water quality monitoring was used to examine water quality parameters throughout the entire watershed. Watershed-scale monitoring allowed for pollutant transport patterns to emerge both spatially and temporally and indicated potential sources of the pollutants. In this particular study, atrazine and sediment loss were the two most important water quality parameters. Results from this study showed that by using BMPs the concentration of atrazine was decreased by greater than 40% in 2006 when compared to the atrazine concentration from those areas without BMPs. A 5% reduction was seen in 2007, which was due to differences in precipitation and runoff between the two years. There was no reduction in sediment losses between the treated and untreated watersheds during 2006, leading to the conclusion that additional practices would be needed to reduce sediment losses as well as any pollutants associated with sediment loss (ex nutrients absorbed to the sediments). During 2007, sediment, nitrogen, and phosphorus were 66%, 60%, and 55% lower respectively in the treated versus untreated sub-watershed. These 2007 differences were related to rainfall pattern differences in the sub-watersheds.

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CHAPTER 1 - Introduction and Literature Review

Introduction

Water is arguably one of the most important natural resources essential for sustaining life on earth. However, as the earth's population grows, the quality and quantity of the world's water resources are diminishing. Today, technology and natural systems are being researched and designed with the hope of providing solutions to correct the damages associated with the human population.

Each individual surface water source must be appropriate for its intended use, which can be one of the following: drinking, crop irrigation, bioremediation application, or the support of aquatic life (Tollner, 2002). Under the Clean Water Act each state is required to assess their surface water quality and report the findings to the U.S. Environmental Protection Agency (EPA) and the reports are compiled into the National Water Quality Inventory. According to the National Water Quality Inventory report, 39% of the almost 700,000 miles of rivers assessed were considered polluted and unfit for their intended uses, and 45% of over 17,000,000 acres of lakes were considered to be polluted and unfit for their intended uses (USEPA, 2000). When compared to a similar report compiled in 1998 there was a substantial increase in polluted water unfit for their intended uses (USEPA, 1998).

Many forms of pollution exist with the potential to impair water quality. Pollution is defined by the Clean Water Act (USC, 1977) as "man-made or man-induced alteration of chemical, physical, biological, and radiological integrity of water." In general, there are two types of pollution, non-point source (NPS) pollution and point source pollution. The largest amount of water quality impairment is caused by non-point source pollution (EPA, 2003). The EPA (1994) defines NPS pollution as "pollution from many diffuse sources caused by rainfall or snowmelt moving over and through the ground."

NPS pollution must be controlled through pollution prevention rather than treatment, in order to control NPS pollution, it is essential to understand the transport of pollutants through runoff. NPS pollution begins with precipitation (Tollner, 2002). As runoff occurs, it will pick up and transport natural as well as man-made pollutants. The runoff will eventually deposit the pollutants into lakes, rivers, and wetlands causing contamination of these surface waters. The major contaminants within NPS are sediment, nutrients, pathogens, pesticides, herbicides, and various pollutants associated with urban and rural runoff. Many cities within the United States obtain their drinking water from surface waters. Any contamination due to NPS pollution has the potential to greatly deteriorate drinking water quality and increase treatment costs for many cities across the United States.

City of Wichita, Kansas

The City of Wichita, Kansas is located in south central Kansas in Sedgwick County shown in Figure 1-1. Sedgwick County has a population of approximately 474,500, with 360,410 individuals residing in the City of Wichita. The City of Wichita has experienced significant growth over the last ten years, and city officials predict by the year 2030 the City of Wichita will have a population of approximately 412,460 and Sedgwick County predicts a population of 567,033. The City of Wichita obtains drinking water from three sources, the Wichita Well field, Cheney Reservoir and the Equus Beds aquifer. Cheney Reservoir contributed 65%, wells surrounding the Wichita water treatment facility 3% and the Equus Beds aquifer the remaining 32% of Wichita's drinking water. Currently the City of Wichita uses 60 million gallons per day on average. Unfortunately, as the population continues to grow city officials fear water use will exceed the capacity of their water supplies. The predicted water shortage led to the development of the *Equus* Beds Ground Water Recharge Project, which investigates artificial recharge as a solution to meet future water-supply demands.

Figure 1-1. Map of the state of Kansas.

Equus Beds

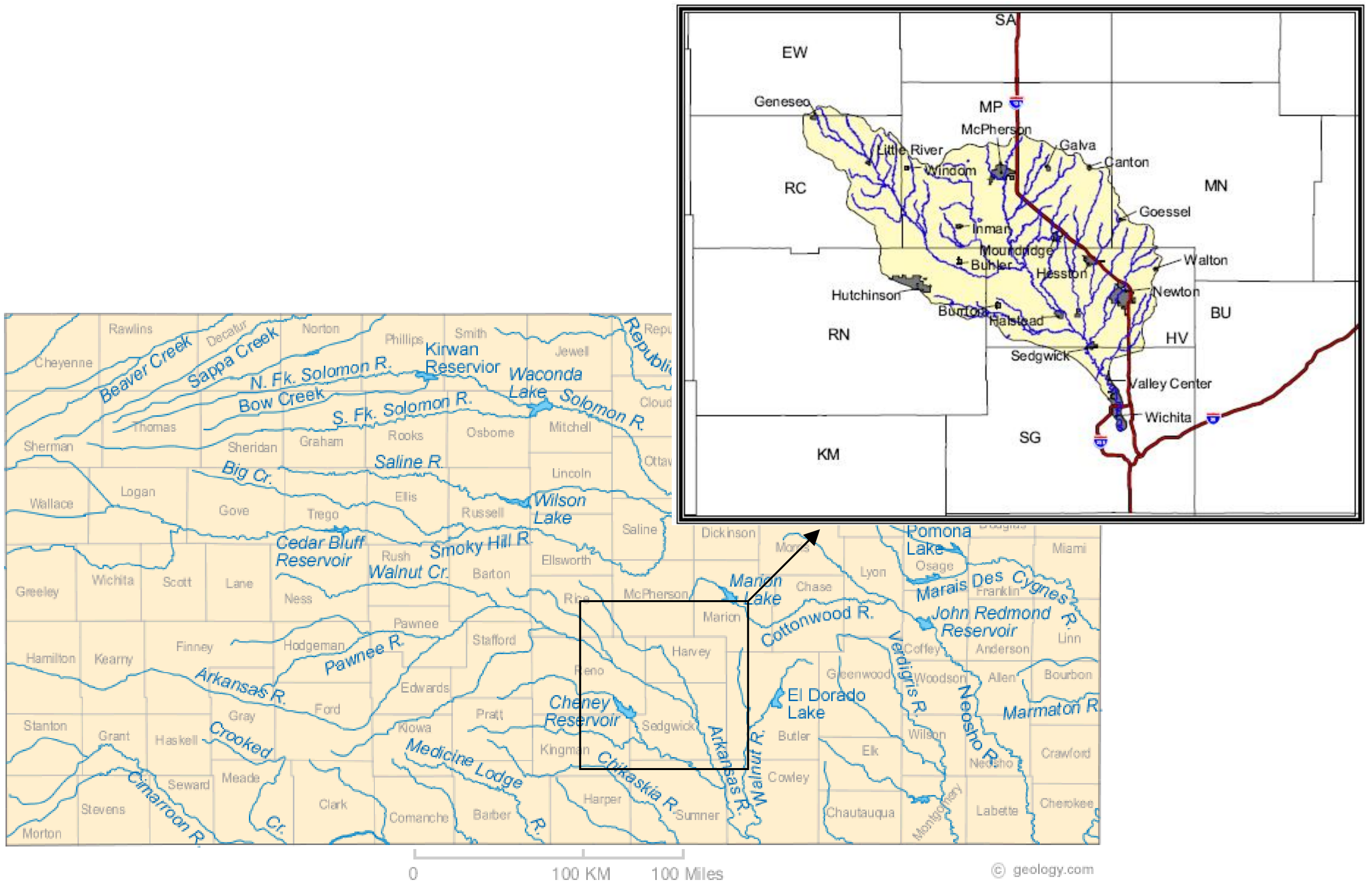
The *Equus* Beds aquifer is part of the High Plains aquifer consisting of river deposited sediments of sand and gravel blended with clay and silt (USGS, 2001). The Wichita Well field is located in the *Equus* Beds and was developed to supply water to the city. Pumping began in 1940 and in 1965 the water supply was supplemented with water from Cheney Reservoir. Even with the addition of water from Cheney Reservoir, the Equus Beds experienced an increase in the water-table decline due to increased irrigation in south central Kansas. The *Equus* Beds Groundwater Management District No. 2 was established in 1975 to manage and optimize water usage from the aquifer and, most importantly, to preserve the aquifer for future-generations. Since 1995, the city of Wichita and the U.S. Geological Survey have been investigating the probability of using artificial ground-water recharge processes in order to meet future demands (Hansen, 2006).

Equus Beds Ground Water Recharge Project

The *Equus* Beds Ground Water Recharge Project is a cooperative effort between the City of Wichita, Kansas and the U. S. Geological Survey to investigate the use of artificial recharge as a solution to meet future water-supply demands. The *Equus* Beds Water Recharge Project focuses on the Little Arkansas River Watershed located in central Kansas (Figure 1-2).

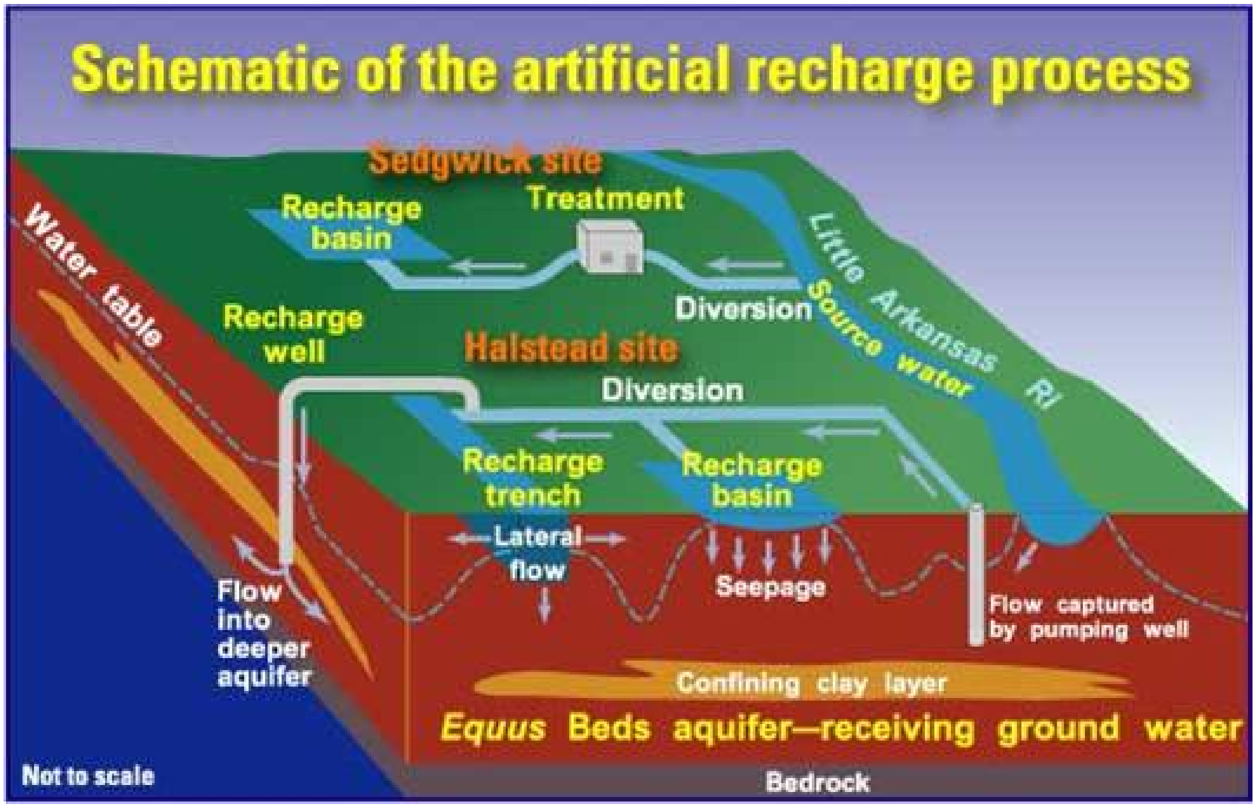
When excessive flow rates are experienced in the Little Arkansas River, water is diverted for the artificial recharge project according to standards established by the Kansas Department of Agriculture and the Kansas Division of Water Resources (USGS, 2001). The Little Arkansas River Watershed is an intensely agricultural watershed, with 95% percent of the land area in the watershed in agricultural production, 78% cropland and 19% grassland (KDHE, 2001). The Little Arkansas Watershed is ranked fourteenth in priority of restoration, with approximately 67% of the total stream miles not meeting the designated uses. The designated uses for the watershed are: aquatic life habitat, food procurement, industrial water supply, irrigation use, and recreational uses (KDHE, 2001). More importantly, the Little Arkansas Watershed provides a major contribution to drinking water by supplying water to 205 public water suppliers. The most common pollutants within the watershed are bacteria, excess nutrients, atrazine herbicide, and sediment. Approximately, 52% of the rivers and streams require total maximum daily loads (TMDLs) (Devlin *et al.*, 2006).

Figure 1-2. Map of Little Arkansas River Watershed.



Two sites, one near Sedgwick and one near Halstead, were selected to construct the recharge sites. When flow rates exceed 20 cubic feet per second, water is diverted for recharge purposes. Stream water for recharge destined for the Sedgwick recharge system was treated to reduce turbidity and organic compounds before being pumped to the recharge site. The Sedgwick recharge system consists of surface spreading recharge basins (Schmidt *et al.*, 2007). Near the town of Halstead, there is a diversion well site directly adjacent to the river where water is pumped from the Little Arkansas River during times of high flow. Stream water is then is pumped to the Halstead recharge system. The Halstead recharge system consists of basins, trenches, and wells (USGS, 2001). A schematic of the recharge process is shown in Figure 1-3. In 2007, 209 days experienced excessive flows in the Little Arkansas River allowing stream water to be diverted for recharge purposes. During 2006, low flow rates were experienced due to an exceptionally dry year and no recharge occurred while 2007 experienced excessive precipitation and runoff.

Figure 1-3. Schematic of the artificial recharge process. (USGS, 2001)



The *Equus* Beds Ground-Water Recharge Project is the first of its kind. Due to this fact, the Kansas Department of Health and Environment established a more stringent standard for atrazine concentration in the recharge water. The standard states that the daily average peak cannot exceed 3 micrograms per liter (μg/L) (Christensen and Ziegler, 1998). The normal standard for surface water in the state of Kansas states that the yearly average peak cannot exceed 3 μg/L. Attention must be brought to the difference of a yearly average peak and a daily average peak. A yearly average peak takes into account winter periods of limited runoff and with limited atrazine concentrations. Maintaining a daily average peak equal to or less than 3 μg/L is difficult due to increased runoff during the rainy season, late April through June, and the atrazine appliction during this same period.

In 2007, 350 million gallons of water was injected into the *Equus* Beds aquifer, on average for every million gallons injected the treatment facilities removed approximately 7 tons of sediment. The sediment is comprised on the total suspended solids within the water and other treatment materials, such as activated carbon used to remove the atrazine.

Atrazine

Atrazine is one of the most widely used herbicides in the United States and is most extensively used in Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, Ohio, Texas and Wisconsin (USEPA, 2000). Atrazine helps to selectively control broadleaf weeds such as: pigweed, velvetleaf, and certain grass weeds, in corn and grain sorghum crops. With the use of selective control target weeds are controlled with little to no effect to corn and sorghum crops. Crops such as corn and grain sorghum are able to uptake atrazine and metabolize the herbicide thus deactivating it (Regehr, 1992). Atrazine is a photosynthetic inhibitor, when atrazine is applied to the soil surface or to the plant surface, it can be taken up through the root system or through the foliage. Allowing atrazine to be applied either pre- or postemergence (Devlin *et al.*, 2000).

There are advantages and disadvantages with the use of atrazine. Atrazine is a low-cost herbicide and is an effective control for weeds keeping input costs to a minimum. Atrazine has the ability to be applied in many different ways including early preplant, preplant incorporation, preemergence or postemergence. Concerns surrounding atrazine are its ability to dissolve and enter runoff, increasing the probability of contamination of surface waters. Atrazine is a common contaminant found in NPS pollution, thus it is important to minimize the amount of atrazine in runoff. Atrazine has a half-life of 60 days in topsoil, but when atrazine reaches water the half-life will significantly increase depending on environmental conditions. The EPA originally established a drinking water standard of a yearly average of 150 μg/L and has been recently lowered to a yearly average of 3 μg/L (Devlin *et al.*, 1996).

The amount of atrazine available in runoff is determined by the following criteria: chemical properties of atrazine, soil and site characteristics, tillage practices, rainfall duration, intensity and timing (Devlin *et al.*, 2007b). The chemical characteristics of atrazine affecting runoff are adsorption and persistence. Adsorption is defined as the ability of a chemical to bind to soil particles, mainly clay and organic matter. A chemical with a high adsorption rate will predominantly stay with the soil particle during a storm event. Atrazine has a predominantly weak adsorption rate and tends to leave the field site dissolved in the runoff water (Baker and Mickelson, 1994). Persistence refers to the chemical's half-life, as stated previously atrazine has a rather long half-life when compared to other chemicals (Regehr *et al.*, 1992). In general, soils with a high clay content and sites with a greater slope will increase the potential of atrazine runoff. Tillage practices have a marginal ability to increase or decrease atrazine runoff, although atrazine best management practices are still essential to minimize atrazine runoff (Baker and Mickelson, 1994). Rainfall duration, intensity and timing of precipitation events will affect the amount of atrazine in runoff. A light precipitation event over an extended period will cause less atrazine to appear in the runoff as opposed to a storm with a greater intensity over a shorter period of time (Regehr *et al.*, 1992). In general, the longer the time period between atrazine application and the first runoff event leads to less atrazine present in the runoff.

Little Arkansas Watershed Restoration and Protection Strategy Project

The Little Arkansas Watershed Restoration and Protection Strategy Project was established in response to the significant levels of atrazine present within the Little Arkansas watershed. The atrazine levels present within the watershed from 1996-2003 are shown in Table 1-1. The average concentration detected is well above the KDHE standard of 3 µg/L (Table 1.1).

Table 1-1. Average concentration of atrazine detected from 1996-2003. (Devlin *et al.*, 2006)

Location	# of Atrazine Detections/Samples Collected	Average Concentration When Atrazine Detected (µg/L)
Alta Mills	6/44	4.8
Halstead	37/68	10.0
Sedgwick	104/212	8.6
Valley Center	7/44	4.6

The Little Arkansas Watershed Restoration and Protection Strategy Project was established in 2004 and implementation began immediately. Watershed Restoration and Protection Strategy (WRAPS) is a program to facilitate planning and a management framework intended to engage anyone of interest within the watershed to first identify the water restoration and protection needs, establish management goals, create a cost effective action plan to achieve goals, and finally to implement the action plan (Kansas, 2007). The stakeholders or interested parties identified one of their implementation goals as the reduction of atrazine herbicide in water to reach a goal of 3 µg/L, with no seasonal spikes (Devlin *et al.*, 2006).

In order to demonstrate this implementation goal, three sub-watersheds within the Little Arkansas Watershed were selected to research water quality improvements. The three sub-watersheds are: Dry Turkey Creek, Upper West Emma Creek, and Black Kettle Creek. During 2006, an incentive program for best management practice (BMP) implementation was developed and presented to the three sub-watersheds and a surface water monitoring plan was installed to measure the effectiveness of these practices. Funding for the BMP implementation incentive program was provided by the city of Wichita, Kansas Department of Health and Environment and the State Conservation Commission. Farmers within the three sub-watersheds received incentive payments for implementing best management practices on grain sorghum fields. The incentive payments were based on the amount of best management practices a farmer was willing to implement with a maximum cost share of $6/acre (Table 1-2) (Devlin *et al.*, 2006).

Table 1-2. Percent reduction associated with each BMP. (Devlin *et al.*, 2006)

Atrazine BMPs Utilized	Reduction per acre
Incorporate atrazine into the first 2" of soil prior to planting	0.70
Apply atrazine in fall or prior to April 15	0.50
Apply atrazine as part of a postemergence premix	0.60
Reduce soil-applied atrazine rates to 1 lb ai/acre or less	0.33
Use split applications of atrazine, e.g. 2/3 prior to April 15 and 1/3 at planting	0.25
Band apply atrazine at planting	0.50
Use no atrazine	1.00

Total Maximum Daily Loads (TMDL) are established separately by each state. For instance, the Kansas Department of Health and Environment (KDHE) will collect samples and set a TMDL for a given pollutant, such as atrazine. During the next five years a partnership of interested parties will be developed and will attempt to demonstrate a reduction in the specified impairment. After the five year period KDHE will establish a set of regulations for this particular situation. In the next five years, KDHE will monitor the progress and, if no reduction in the impairment is experienced, KDHE will set a "no use" regulation. If the impairment averages below the set standard, the watershed will be removed from the TMDL list. If there is marked improvement, but the impairment does not average below the standard, KDHE can establish a 4B Alternative.

The 4B Alternative was created in 2006 for the pollutant atrazine in the Little Arkansas Watershed. The 4B Alternative was chosen by the TMDL coordinator due to improvements and planning accomplished by the Little Arkansas WRAPS partnership. In 2011, KDHE will collect samples and analyze the samples for the presence of atrazine. If the samples average below the standard of 3 μg/L the watershed will be removed from the TMDL list.

Atrazine Herbicide Best Management Practices

Best management practices are defined as a (Tollner, 2002) "management strategy proven to reduce pollution impacts." In the 1980's, Kansas State University started to research atrazine best management practices (BMPs). Atrazine BMPs are designed to meet the following objectives (Devlin, *et al.*, 2000):

1. Reduce the availability of atrazine for loss after application.
2. Reduce the rate of atrazine used in a field and/or watershed.
3. Reduce the impact of the first runoff event on atrazine loss.
4. Provide a mechanism for deposition of the atrazine before it leaves the field.

Many BMPs were developed including the following: soil incorporation, application timing, split application, reduced soil applied rates, postemergence applications of atrazine, combine surface application with postemergence, alternative herbicides, vegetative filter strips, band application and buffer zones (Devlin and Regehr, 1996). Atrazine BMPs have the ability to reduce atrazine losses in runoff to 1 to 3 percent of the total atrazine applied. The greatest reduction in atrazine loss is experienced when a combination of BMPs are used (Devlin *et al.*, 2007b).

The majority of the atrazine BMPs used within the three sub-watershed of the Little Arkansas Watershed are listed in Table 1-2. In the following sections the atrazine BMPs will be discussed in detail.

Incorporation of Atrazine into the top 2" of soil

Incorporating the atrazine application into the top 5.08 cm of soil is an effective BMP. Incorporation should only be used when tillage is already planned on the field site (Devlin *et al.*, 2007b). By incorporating herbicide into the top 5.08 cm of soil, the herbicide is removed from the surface mixing zone of the soil profile. The mixing zone of the soil profile is considered to be the top 0.6-1.3 cm where rainfall and runoff interact (Mickelson *et al.*, 2001). Incorporation will also provide protection from volitization and will increase the residence time of the herbicide in the soil profile (Mickelson *et al.*, 2001). The degree of incorporation is related to weed control. Deep incorporation should be avoided due to the reduced concentration in the weed germination zone (Devlin *et al.*, 2007b). The time period between the first storm event and the herbicide application can affect the amount lost. Baker and Laflen (1979) used a rainfall simulation study to show how incorporation reduced herbicide losses shortly after the application period. Incorporating atrazine into has the potential for reducing atrazine runoff by 60-75% (Devlin *et al.*, 2000).

Apply Atrazine in the Fall or prior to April 15

The State of Kansas generally experiences a continental type climate. The rainy season occurres during late April, May and June and during these months high intensity storm events can be experienced. As opposed to the time period between November through mid-April where rainfall intensity, duration, and depth is typically lower (Devlin *et al.*, 2000). Precipitation events occurring in the late fall, winter and even early spring allow the herbicide to infiltrate into the mixing zone (Devlin *et al.*, 2007b). The time period between the first storm event and the herbicide application can affect the amount lost. By removing the herbicide application from time periods where high rainfall is historically experienced the amount of herbicide runoff loss can be reduced. Research has shown that by applying atrazine in the fall through April 15 can reduce atrazine runoff by 50% (Devlin *et al.*, 2007b).

Apply Atrazine as part of a postemergence premix

A significant reduction in herbicide losses in surface runoff can be expected when applying the herbicide as a part of a postemergence premix. The reduction of herbicide loss is due to the developed foliage of the plant. The foliage intercepts part of the application and precipitation reducing the impact of a storm event (Devlin *et al.*, 2007b). A postemergence premix should contain a low application rate of atrazine mixed with other herbicides. A typical atrazine rate in a postemergence premix is approximately 60-70% less than normal soil-applied atrazine rates (Devlin *et al.*, 2000). Postemergence herbicide applications can provide an effective weed control while maintaining crop yields (Parker *et al.*, 2006).

Many studies have been conducted comparing herbicide losses between postemergence and pre-emergence applications. Gorneau *et al.* (2001) studied herbicide losses between postemergence and pre-emergence application on various tillage practices using a rainfall simulator. Postemergence broadcast applications demonstrated a reduction of 69% compared to a pre-emergent broadcast plus postemergence application on a disk tillage system. Postemergence broadcast applications demonstrated the greatest reduction in herbicide losses on all tillage practices studied. In general, postemergence applications have the potential to provide a 50-67% reduction in atrazine runoff compared to preemergence applications (Devlin *et al.*, 2007b).

Reduce soil-applied Atrazine rate

The outputs of a system are directly related to the inputs. Intuitively, if the inputs are reduced consequently the outputs will be reduced. By using a reduced rate of herbicide application, the amount of herbicide available for runoff will be reduced (Devlin *et al.*, 2007b). Many studies have looked at the effect of reduced application rate on runoff losses. Hall *et al.* (1972) measured the runoff losses of atrazine at various application rates. The application rates ranged from one-fourth to four times the normal application rate. The losses measured were generally proportional to the application rate and were approximately 2.5% of the application. Similar results were demonstrated in each individual study, showing that reducing the soil-applied atrazine rate will decrease the amount of atrazine present in the surface runoff (Hanson *et al.*, 1997). Reducing the soil-applied atrazine rate will not reduce weed control and can potentially reduce runoff by 33% (Devlin *et al.*, 2000).

Use split application of atrazine

Applying herbicide in a split application will reduce the amount of herbicide available to runoff at any one given time. A split application can be comprised of an application of one-half to two-thirds of the total before April 15 and another application of one-third to one-half of the total before or immediately following planting (Devlin *et al.*, 2007b). An advantage to a split application is the early application is made at a time where there is less potential for herbicide runoff. Rector *et al.* (2003) was able to model atrazine loss based on previously completed field experiments. A split application with a fall and a pre-emergence application were compared to an early preplant and pre-emergence application and a pre-emergence only application. The studied showed a greater reduction using a fall and pre-emergence application as opposed to the other two types of applications. Gorneau *et al.* (2001) was able to show that a split application has the potential for a reduction in herbicide loss in various tillage practices, such as disk tillage, ridge till and no-till. In general, the use of a split application has the potential to reduce herbicide losses by approximately 25% (Devlin *et al.*, 2000).

Band apply Atrazine at planting

Band application is the process by which herbicide is applied is a narrow band varying in width. In area in-between the treated bands weed control is maintained through mechanical cultivation (Hansen *et al.*, 2000). Broadcast application is the process by which herbicide is applied over the entire field area. By definition, a farmer will apply less atrazine in a band application than with a broadcast application, as much as one-half to two-thirds less (Franti *et al.*, 1997). A reduction in the amount of herbicide applied will reduce input costs and decreases the amount of herbicide available to runoff. Band application works well in ridge-till and mulch-till systems where cultivation is already planned (Devlin *et al.*, 2007b).

The specific band widths have been researched to determine the width with the best weed control. Gaynor and Van Wesenbeeck (1995) reported a band width of 50-cm was the optimum width for reducing herbicide losses. The 50-cm band was able to reduce herbicide loss 70%, from broadcast applications. Other studies report 25.4- to 38.1-cm bands are able to reduce losses by 50-67% compared to broadcast applications (Devlin *et al.*, 2000).

A primary concern to all farmers is the influence on yield. Will a reduction in applied herbicide result in more weed competition for essential water and nutrients resulting in decreased yield? Hansen *et al.* (2000) studied the influence of band application on yield. The conclusion of the study was that there were no negative influences on yield from band application. Meaning the same yields were experienced with both broadcast and band applications.

Use no Atrazine

Today, new herbicides are emerging that do not contain atrazine and provide weed control in crops specifically corn and grain sorghum. Using alternative herbicides will essentially eliminate atrazine runoff (Devlin *et al.*, 2007b). Table 1-3 (Devlin *et al.*, 2000) gives examples of a few non-atrazine herbicides and the types of weeds controlled. Another non-atrazine herbicide is mesotrione. Mesotrione is a selective herbicide for broadleaf weed control, primarily used is pre-emergence and postemergence applications (Armel *et al.*, 2003). Mesotrione alone provided some weed control while it was more efficient when used in a combination with another herbicide (Bollman *et al.*, 2006).

Table 1-3. Types of weeds controlled with the use of non-atrazine herbicides.

Non-atrazine Herbicide	Types of Weeds Controlled
Lightning	Broadleaf, Many grasses
Hornet	Broadleaf
Exceed	Broadleaf, Shattercane, Johnsongrass
Balance	Broadleaf, Many grasses
Roundup Ultra	Broad spectrum
Liberty	Broad spectrum

CHAPTER 2 - Watershed Scale Monitoring

Objectives

The primary objective of this study was to determine the origin of the pollutants of concern, atrazine, sediment, total nitrogen and phosphorus, and E. coli. The secondary objective was to recognize any possible watershed scale patterns that emerge through the analysis of the pollutants.

Watershed Scale Monitoring

While it is important to understand how herbicides and other pollutants react in a field scale experiment, it is equally important to understand the trends and/or patterns that occur on a watershed scale. Watershed scale monitoring is now becoming an area of interest in research. If the patterns and trends of pollutants can be identified, it will help individuals assess impaired watersheds and apply practices to improve conditions.

In recent years there have been a few studies to investigate the patterns and trends of the concentration of atrazine within a watershed. Naturally, within a system the maximum concentration of atrazine will coincide with spring runoff and application periods (Rawn *et al.*, 1999). In this particular study there are two application periods, one application on corn and the other on grain sorghum. Elevated concentrations are usually experienced during the rainy season, in the Midwestern proportion of the United States that typically begins in May and will extend into July (Richards and Baker, 1998). Atrazine concentrations will typically follow a generalized curve. Concentrations peak directly following the application period, the concentrations will remain elevated for a time period and decrease quickly. After the reduction, concentrations will level off for the rest of the year (Donald *et al.*, 1999). Atrazine concentrations in surface waters tend to be highly seasonal and variable between years; the variability is due in part to the intensity and timing of the rainfall (Rawn *et al.*, 1999; Richards and Baker, 1998). Richards and Baker (1998) determined that atrazine levels tended to increase or decrease almost in parallel with the stream flow. When high flow rates occur, atrazine levels will increase accordingly.

Another pattern that emerged in two different watershed scale monitoring studies was how the size of the river or stream affected the concentration levels within the system. The smaller the stream, the wider the extremes. Smaller streams are more volatile, meaning during a storm event the flow rate will dramatically increase and then decrease within a shorter time span than a larger stream.

In a larger river atrazine, concentrations are more variable upstream than at midstream or the outlet (Donald *et al.*, 1998). In a larger river other events are integrated through smaller tributaries. As the outlet is reached, the river has built up a buffering capacity resulting in slower, minimal changes in concentration and a lower peak concentration. This integration emerged as a pattern on a smaller scale in watersheds (Donald *et al.*, 1998).

The drinking water standard for atrazine in surface waters used as a water supply is an annual average concentration of 3µg/L. For the most part, in the Midwest, the rivers frequently exceed the standard for short periods of time. Although, on an annual basis the drinking water standard is rarely exceeded (Richards and Baker, 1998). In general, Harmon-Fetcho *et al.* (1999) determined that atrazine concentration found in surface waters was an adequate reflection of the agricultural activity within a watershed.

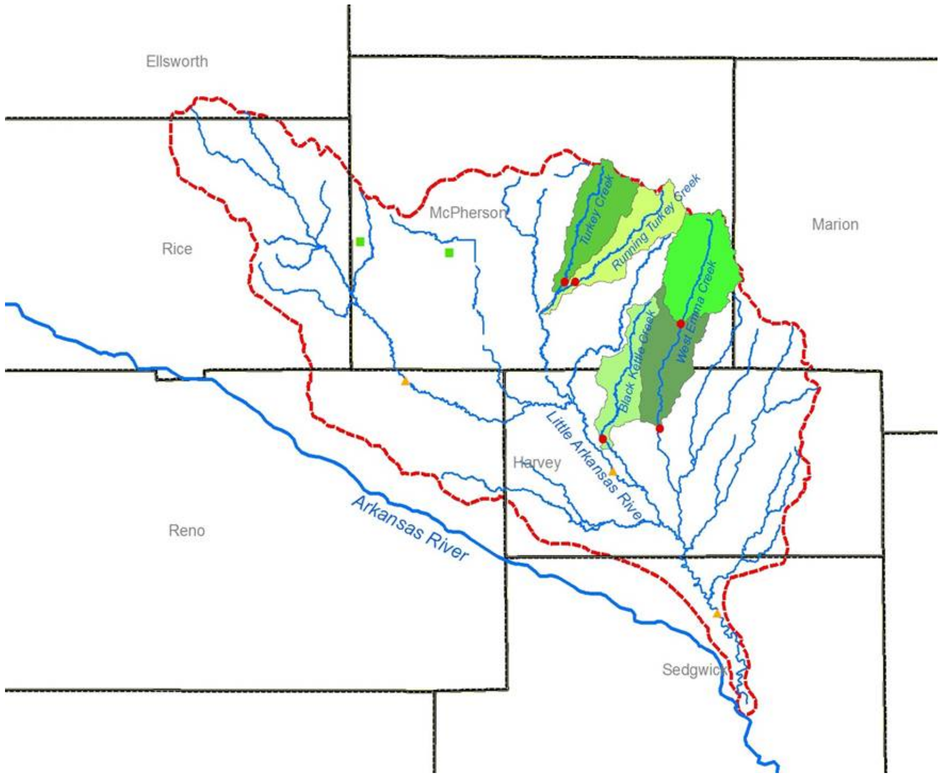
Watershed Monitoring

Sampling was conducted at various points along the Little Arkansas River and also at the outflows of five sub-watersheds in the northeast portion of the watershed. Figure 2-1 is a detailed map of the Little Arkansas River Watershed. The five sub-watershed outflows are depicted with a red circle while the main stream sites sampled are depicted with an orange triangle. The main stream sites are located in Valley Center, HWY 50 near Halstead and HWY 61. Table 2-1 indicates the coordinates of the sampling sites.

Table 2-1. Main stem sampling site coordinates.

Sampling Site	Longitude	Latitude
Valley Center	W 97°38.870'	N 37°83.220'
Hwy 50	W 97°32.432'	N 38°01.715'
Hwy 61	W 97°50.524'	N 38°09.181'

Figure 2-1 Map of Little Arkansas River sampling sites.



Water samples were obtained once a month during winter months when flow is minimal. In order to determine herbicide concentration patterns throughout a watershed sampling at a high frequency over the period around the application times is necessary (Rawn *et al.*, 1999). To address this, water samples were taken at least once a week or following a storm event during the months from April to September for an annual total of 30 samples. Samples were obtained with the use of the sampler shown in Figure 2-2.

The sampling device allows for a representative sample to be taken. A representative sample is a water sample with the same characteristics found in the water column. As the sampler is lowered into centroid of the stream, water is pulled into the bottle within the sampler and becomes an integrated sample. The centroid represents the point in the stream with the maximum potential to carry suspended material. ISCO samplers (Teledyne, 2005), shown in Figure 2-3, provide a total composite sample of a storm event, are also maintained on site to obtain samples at various points on the stream hydrograph. Water samples were contained in clear and amber bottles, which had been washed with soapy water, rinsed with methanol and the baked 100° for approximately twenty-four hours. The samples were stored at 4° C to preserve the samples. Amber bottles were used to protect the atrazine within the sample from degradation from ultraviolet light. In previous studies, duplicate testing was conducted to provide an allowable consistency of analysis.

Figure 2-2. Water sampling device.

Figure 2-3. ISCO sampler maintained on stream sites.

Water Quality Analysis

Water Quality Parameters

The water quality parameters of concern are atrazine concentration, total suspended solids (TSS), total nitrogen and total phosphorus. E. coli was monitored as a general indicator of water quality.

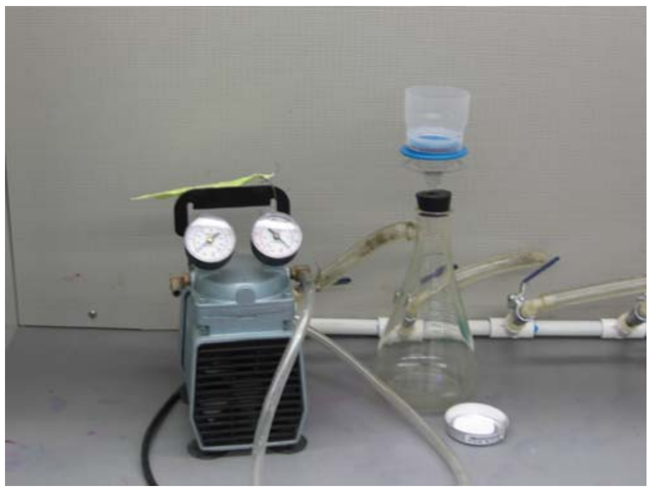
Laboratory Anaylsis

Analysis of atrazine concentration, TSS and E. coli was performed by the Water Quality Laboratory in the Biological and Agricultural Department at Kansas State University. Nutrient analysis was performed by the Soil Testing Laboratory in the Department of Agronomy at Kansas State University.

The analysis of atrazine concentration was determined by Enzyme-Linked Immunoassay (ELISA) by using a Rapid Assay Kit manufactured by Abraxis LLC. In a test tube provided, antibody-coated magnetic particles were mixed with the water sample and the enzyme conjugate, Horseradish peroxidase. The solution was allowed to incubate, during which the atrazine and enzyme conjugate were bound to the antibody sites on the magnetic particles. After the incubation period, the test tube containing the solution was placed in a magnetic separator. The magnetic separator holds the particles to the sides of the test tube allowing excess solution to be removed. The test tubes were removed from the magnetic separator; a solution was then added to dissolve the particles and bind the enzyme conjugate. This process produced a blue color. The solution was allowed to incubate for a second time. A stopping solution, a diluted acid solution, was then added producing a yellow color. The color intensity was measured using a spectrophotometer at 450 nm. The spectrometer is calibrated using a set of calibration standards provided by the manufacturer (Adams *et al.*, 2004). The accuracy of ELISA methods have been analyzed and compared to other analytical methods such as gas chromatography. When compared to gas chromatography, ELISA in general tended to over estimate the concentration of atrazine in the water samples (Gruessner *et al.*, 1995). The over estimation was possibly due to the presence of atrazine metabolites and other triazine herbicides, which are structurally similar to atrazine. The antibody used in ELIZA lacked an exact specificity for atrazine, which allows for the other compounds to increase level of atrazine measured (Gruessner *et al.*, 1995).

The TSS analysis was performed by vacuum filtering a 25 mL sample through a 47mm glass fiber filter the setup, shown in Figure 2-4. The filters were ProWeigh preweighed filters for gravimetric analysis. The filters were dried for 12 hours at 70ºC and then a final weight of the filter and canister together and the canister alone were recorded. The initial weight of the filter was provided by the manufacturer.

Figure 2-4. Vacuum filter system used in analysis of TSS.



The water samples were analyzed for E. coli using a serial dilution method. A 1 mL water sample was placed in 9 mL of a phosphorus buffer solution. The resulting solution was placed on a vortex for 20 seconds to thoroughly mix the solution suspending the bacteria. A 1 mL sample of the solution was then placed on an Eosin Methylene Blue Agar plate, and another 1 mL sample of solution was placed in 9 mL of a phosphorus buffer solution. This process was repeated to obtain the desired dilutions. An illustration of the serial dilution method was shown in Figure 2-5. The plated sample was then incubated at 35°C for 48 hours. Colonies were counted and recorded every twenty-four hours. Dilutions were used as a means of replication to ensure an accurate measure of the E. coli population.

Eosin Methylene Blue Agar is a selective medium used for the isolation of gram negative bacteria such as E. coli. The Eosin Methylene Blue Agar contains eosin Y and methylene blue dyes both pH indicator dyes which inhibit the growth of gram positive bacteria (Becton, Dickinson and Company, 2007). E. coli will ferment lactose or sucrose, which gives the bacteria a green metallic color (Figure 2-6), which allows one to distinguish E. coli from other bacteria which appear colorless on the Eosin Methylene Blue Agar (Becton Dickinson and Company, 2007).

Figure 2-5 Diagram of the serial dilution method.

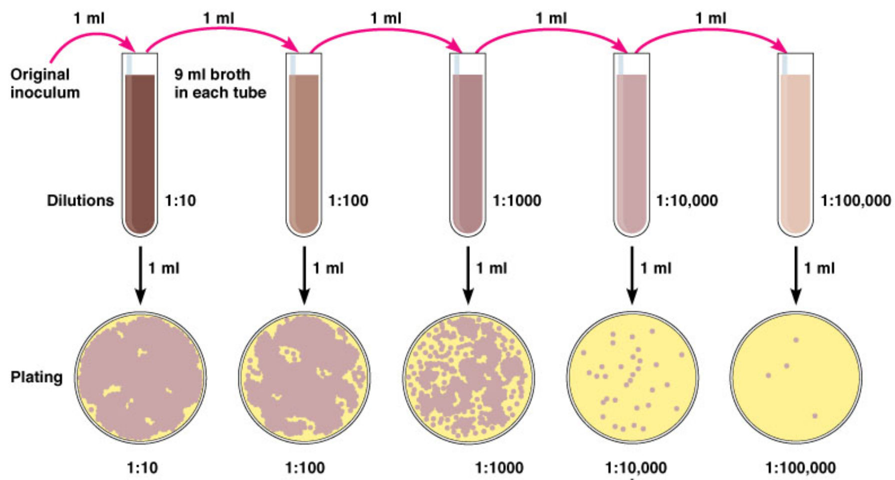


Figure 2-6. EColi grown on Eosin Methylene Blue Agar.

The nutrient analysis involved the analysis of total nitrogen and total phosphorus. Total N and P were determined using a Potassium Persulfate digestion proves. The samples were analyzed using a Technicon Analyzer II for phosphorus and an Alpkem RFA for nitrate nitrogen (KSU, 2005; Hosomi *et al.*, 1986).

Watershed Analysis

The objectives were accomplished by dividing the Little Arkansas Watershed into three distinct subunits, upstream, midstream, and the outflow of the watershed. Each of the subunits were sampled at the outflow. The outflows were located at HWY 61, HWY 50 and Valley Center. These outflows were located with orange triangles on Figure 2-1. By analyzing the water samples and using the flow rates for each outflow, contaminant loading can be calculated for each pollutant. Using agriculture statistics, a comparison was made between how much atrazine and and nutrients were applied to how much was lost throughout the year. This allows trouble spots to be pin pointed so that practices can be implemented to reduce these sources.

Kansas Agricultural Statistics

An estimation of the number of acres of corn, grain sorghum, and row crops were obtained through the United States Department of Agriculture's statistical database, which is updated every year by state and county. In order to obtain the necessary acreage within the watershed, a ratio of each county within the watershed was estimated (Table 2-1). The analysis of the study work under the assumption that the crop acreage provided by USDA was uniformly distributed throughout each county. It is important to note that the number of agriculture acres within the watershed is an estimation.

Table 2-2. Crop acreage estimation for the Little Arkansas River Watershed.

Stream Site	Crop	Ellsworth	Harvey	Marion	McPherson	Reno	Rice	Sedgwick	TOTAL
HWY 61	**% W/in Zone**	**100%**	**0%**	**0%**	**17%**	**13%**	**100%**	**0%**	
	Corn	13	0	0	2370	506	6650	0	9539
	Grain Sorghum	255	0	0	4694	953	10425	0	16327
	Corn + GS	268	0	0	7063	1459	17075	0	25866
	Total Row Crops	319	0	0	10921	2139	27725	0	41104
HWY 50	***% W/in Zone***	**0%**	**17%**	**0%**	**58%**	**54%**	**0%**	**0%**	
	Corn	0	5264	0	8273	2195	0	0	15732
	Grain Sorghum	0	5838	0	16385	4133	0	0	26356
	Corn + GS	0	11102	0	24658	6328	0	0	42088
	Total Row Crops	0	17755	0	38125	9275	0	0	65156
VC	***% W/in Zone***	**0%**	**83%**	**100%**	**25%**	**33%**	**0%**	**100%**	
	Corn	0	26256	1390	3548	1349	0	1530	34072
	Grain Sorghum	0	29122	2510	7026	2539	0	2545	43742
	Corn + GS	0	55378	3900	10574	3888	0	4075	77814
	Total Row Crops	0	88565	6350	16349	5698	0	6475	123437

In the Little Arkansas River Watershed, over half of the agricultural acreage is located in the southern most portion of the watershed. In Figure 2-7, a pie graph shows how the acreage is distributed throughout the watershed. The figure indicates the upstream third of the watershed has the least amount of crop acres, the crop acres increase in the midstream third and are highest in the outflow portion of the watershed.

The crops of the utmost concern are corn and grain sorghum. Within the watershed, grain sorghum is the predominant crop planted. When the acreage of grain sorghum and corn are combined; 41% of the acres are corn and 59% are grain sorghum. A pattern similar to the total acreage exists when analyzing the total amount of grain sorghum and corn planted within the watershed. The most acreage is planted in the lower third of the watershed and the least planted in the upper third as shown in Figures 2-8 and 2-9.

Figure 2-7 Distribution of crop acreage.

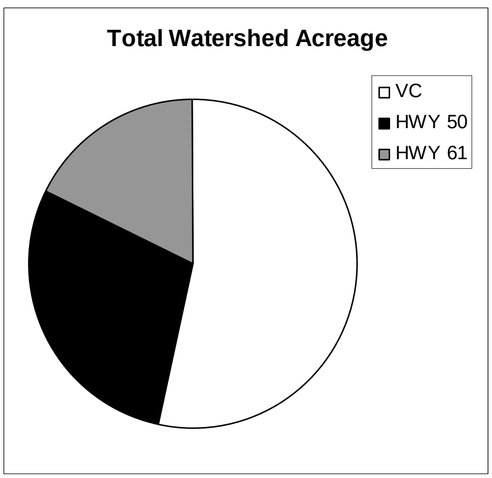


Figure 2-8 Distribution of Corn Acreage

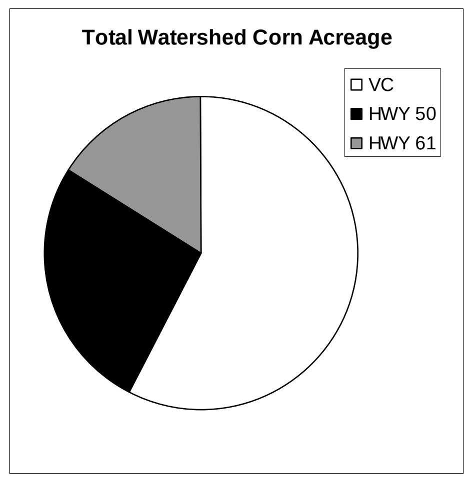
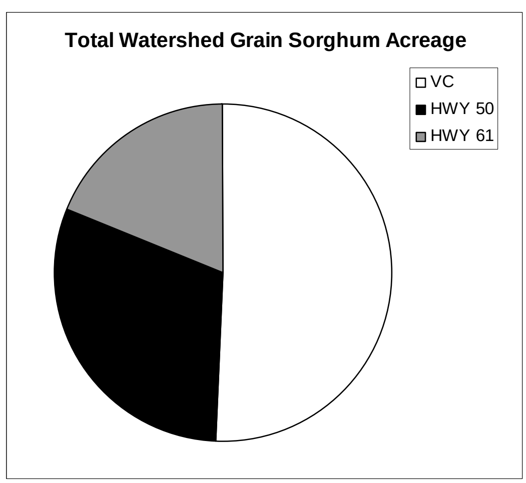


Figure 2-9 Distribution of Grain Sorghum Acreage



Precipitation Differences in 2006 and 2007

Research has shown that atrazine concentrations in surface waters tend to be highly seasonal and variable between years, the variability is due in part to the intensity and timing of the rainfall (Rawn, 1999, Richards, 1998). During the two years of the study 2006 and 2007, there were significant differences in the precipitation. Figure 2-10 shows a comparison between 2006, 2007, and the expected 30 year monthly averages. The graph shows that on average, 2007 received more precipitation than the previous year, with differences occurring during the months of March, April and May. It is important to note the rainfall experienced in 2007 roughly follows the pattern of the monthly averages. During 2007, the rainfall occurred early in the season and, with the rainfall from December 2006, this caused the soil to become saturated early in the season. Due to the presence of a saturated soil, very little rainfall was required to produce runoff during these months. This phenomenon can be seen in the discharge rates of 2007. Figure 2-11 shows a comparison of the discharge rates at Valley Center, the outflow of the watershed on a monthly average, while Figure 2-12 shows the flows rates throughout the year. Figure 2-12 distinctly shows the numerous peak flows experienced in 2007 as opposed to 2006.

Figure 2-10. Precipitation comparison at Valley Center between 2006 and 2007.

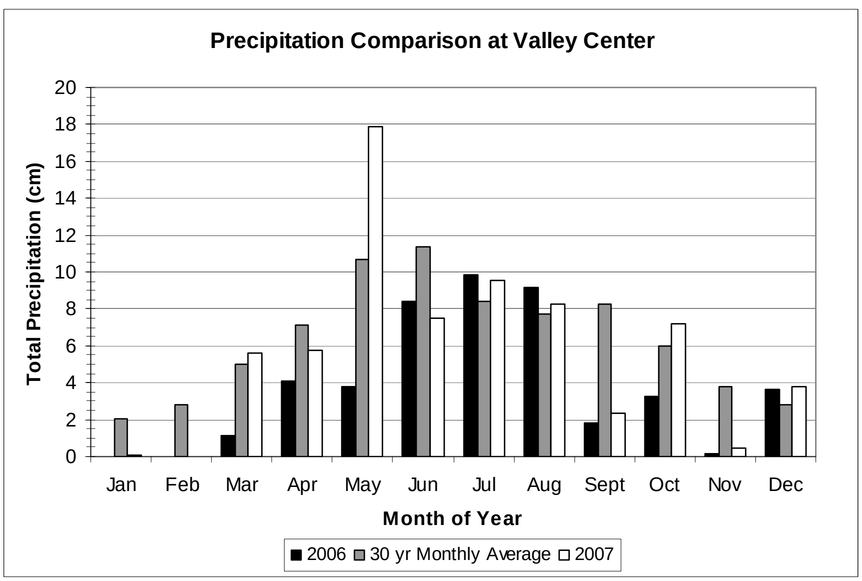


Figure 2-11. Discharge Comparison at Valley Center for 2006 and 2007.

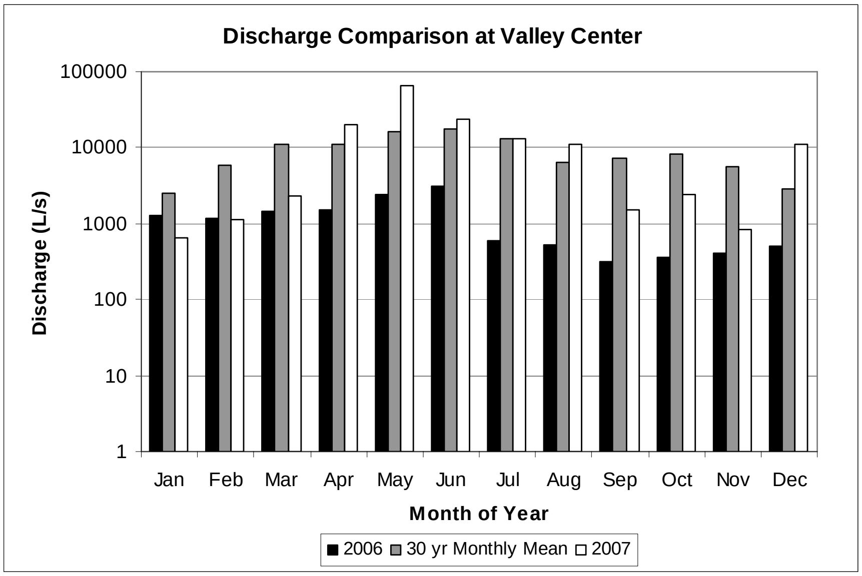
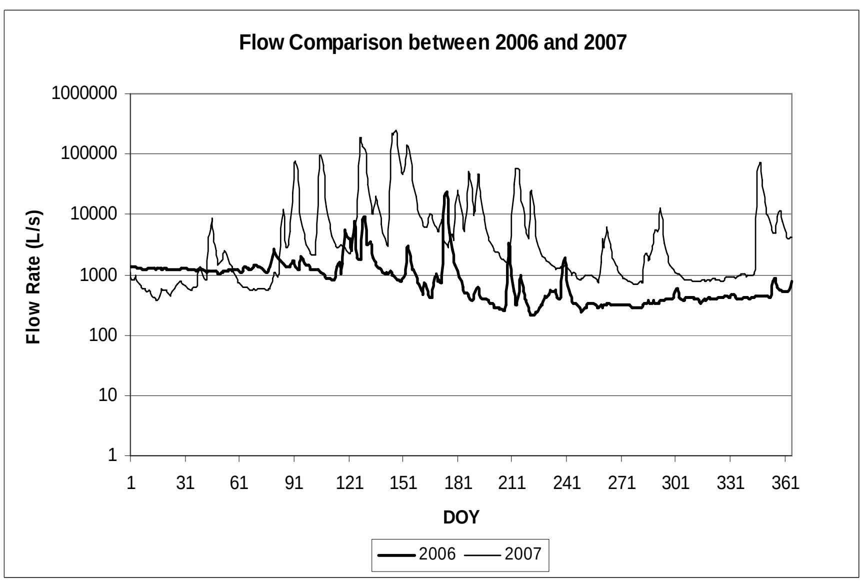


Figure 2-12. Flow comparison between 2006 and 2007 at Valley Center.

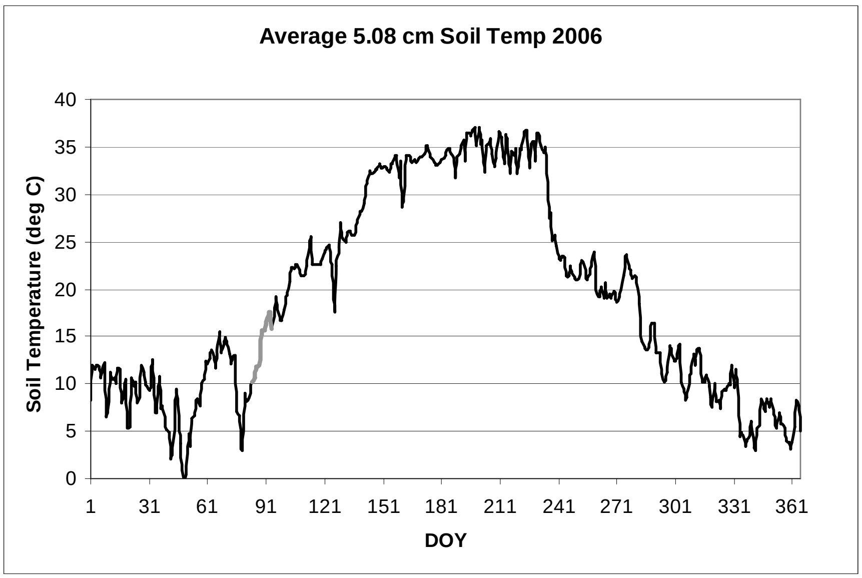


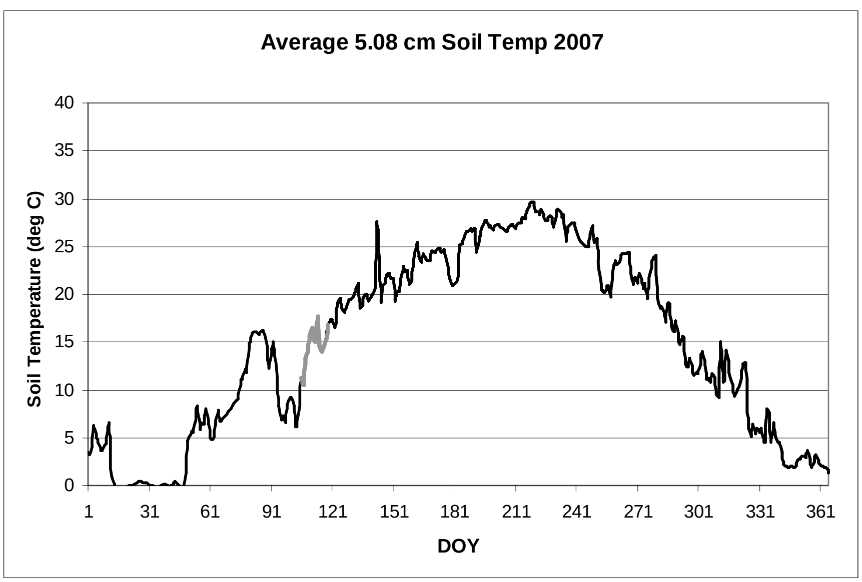
On average 2007 experienced higher flow rates at the outflow of the watershed when compared to 2006. Even though the months of June, July, and August produced more precipitation during 2006, 2007 had higher flow rates. The most extreme flow comparison between 2006 and 2007 was where 2007 exceed the 2006 flow rate by 100 times. This occurred because of the high amount of rainfall occurring earlier in the season creating a saturated soil. The runoff patterns showed the results of the rainfall distribution during each month..

Analysis of Atrazine

Atrazine is a herbicide applied to both grain sorghum and corn. Corn is planted after the soil temperature is consistently above 10°C, and grain sorghum is planted after the soil temperature is consistently above 16°C. Atrazine is typically applied just prior to planting or more commonly at planting time. Figure 2-13, diagrams the average soil temperatures 2 inches below the surface throughout 2006 and 2007.

Figure 2-13. Diagram of average soil temperatures for 2006 and 2007.





The water samples collected over the study were analyzed to determine the atrazine concentration using an Enzyme-Linked Immunoassay analysis. Daily loadings were calculated by the following equations.

Equation #1: Loading (kg/d) = Flow rate (L/s) x Concentration (μg/L) x (0.00864)

Equation #2: Loading (kg/d) = Flow rate (L/s) x Concentration (mg/L) X (0.0864)

The regulations regarding atrazine are unique with the respect to reporting concentrations and loadings. A loading must be calculated using half of the detectable limit, 0.30 μg/L, if the water sample did not show a detectable atrazine concentration.

The question now, is how to differentiate between the loading due to corn and to grain sorghum. The study was conducted under the assumption that the loading due to corn primarily occurs before atrazine was applied to grain sorghum. In other words, the atrazine lost during the period of time when the average soil temperature is consistently above 10°C and below 16°C is lost from the atrazine applied to corn. The rest of the atrazine lost throughout the rest of the year is from the atrazine applied to the grain sorghum acres. The assumption is made because the atrazine applied to corn has been lost or been draw into the soil before the grain sorghum application. The assumption allows for no interaction of the corn and grain sorghum applications. Analyzing Figure 2-12, shows that during 2006 average soil temperatures where consistently above 10°C from March 25 to April 4, in 2007, the average soil temperatures where consistently above 10°C from April 16 to April 29 and consistenly above 16°C the rest of the growing seasons. In order to obtain a ratio of how much atrazine was lost from the watershed, the assumption was made that all acreage of grain sorghum was applied with the labeled rate of 2.8 kg/ha. The assumption allows for an estimation of the total loading of atrazine present within the watershed. Table 2-3 shows the calculated loadings for the assumption of an application rate of 2.8 kg/ha. Using the loading calculated, the percentage lost can be determined for the total watershed and the main stream sites for both 2006 and 2007 (Table 2-4).

Table 2-4 indicates the amount of atrazine lost from the fields if all of the grain sorghum acres were treated with the normal accepted application rate of 2.8 kg/ha. The percentage given in the table is the percent lost of the total weight that was applied. Within the watershed there is a significant amount of atrazine applied with the highest proportion being applied to grain sorghum. In 2007, a higher percentage was lost from grain sorghum than in 2006. The middle third of the watershed, Hwy 50, lost the most, accounting for approximately half of the atrazine that was lost in the watershed.

Table 2-3. Atrazine loadings for assumed application rates.

Crop	Corn	Grain Sorghum
Application Rate	**1.12 kg/ha**	**2.8 kg/ha**
Total Watershed	26911	187246
Main Stream Sites		
HWY 61	4325	18510
HWY 50	7134	29880
Valley Center	15451	138856

Table 2-4. Atrazine lost from grain sorghum as weight and percent of applied.

Atrazine lost from grain sorghum after application of 2.8 kg/ha.				
Location	**2006**		**2007**	
	Atrazine (kg)	**% of Applied**	**Atrazine (kg)**	**% of Applied**
Total Watershed	78	0.04%	2708	1.45%
Main Stream Sites				
HWY 61	11	0.06%	336	1.81%
HWY 50	20	0.07%	1319	4.41%
Valley Center	46	0.03%	1054	0.76%

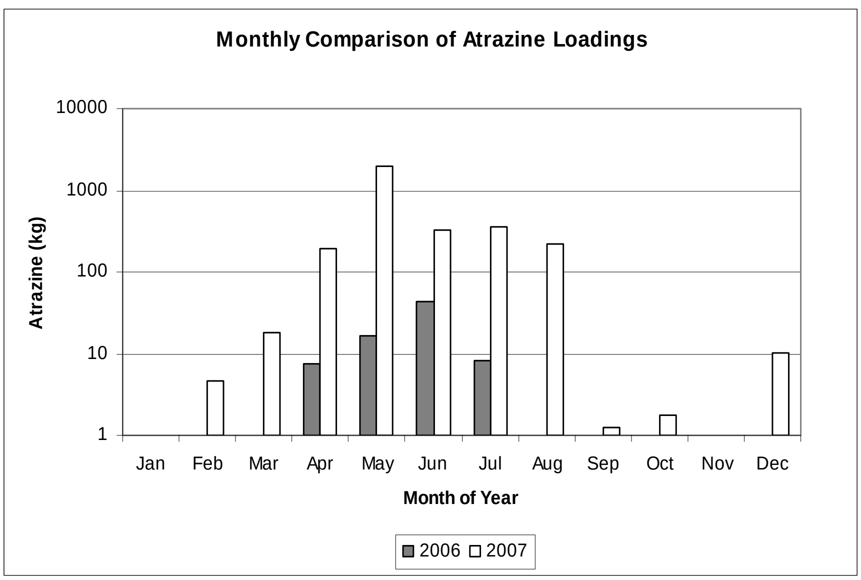
In reality, it is recognized that not all of the corn acres will be treated with atrazine or at the application rate of 2.8 kg/ha. In the last few years producers have changed to planting a RoundUp Ready variety. Even with the use of a RoundUp Ready variety the producers still apply a reduced application of atrazine as an insurance policy against weeds until the canopy is established. Table 2-4, shows percentage of atrazine lost if the corn acreage was treated with a 1.12 kg/ha application rate instead of the higher rate of 2.8 kg/ha. Table 2-4 indicates that in a real world scenario the amount lost from corn fields is higher but does not significantly contribute to the over all loss of atrazine into surface waters.

Table 2-5. Atrazine lost from corn as weight and percent of applied.

Atrazine lost from corn after application of 1.12 kg/ha.		
Location	2007	
	Atrazine (lb)	% of Applied
Total Watershed	74	0.27%
Main Stream Sites		
HWY 61	8	0.19%
HWY 50	26	0.36%
Valley Center	40	0.26%

Atrazine does not follow that pattern of the other water quality parameters. In the other parameters, the lower portion of the watershed contributes the most pollutants into the system. Where as with atrazine, the most atrazine lost occurs in the midstream portion of the watershed. The upstream portion has a smaller corn and grain sorghum acreage and thus a small amount of atrazine in total were applied. The midstream portion of the watershed contains the 5 sub-watersheds to be discussed in the following chapter. These sub-watersheds have a high proportion of grain sorghum acreage with applied atrazine. The outflow portion of the watershed has a lower application of atrazine and the contribution of the tributaries tend to dilute concentrations and reduce the load.

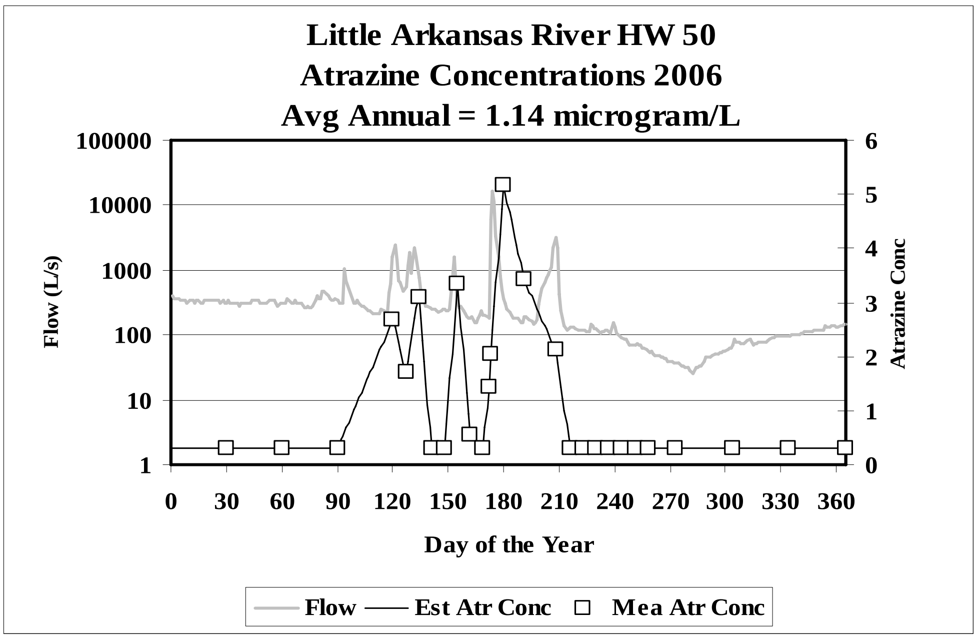
Figure 2-14 Monthly comparison of atrazine loadings for 2006 and 2007.

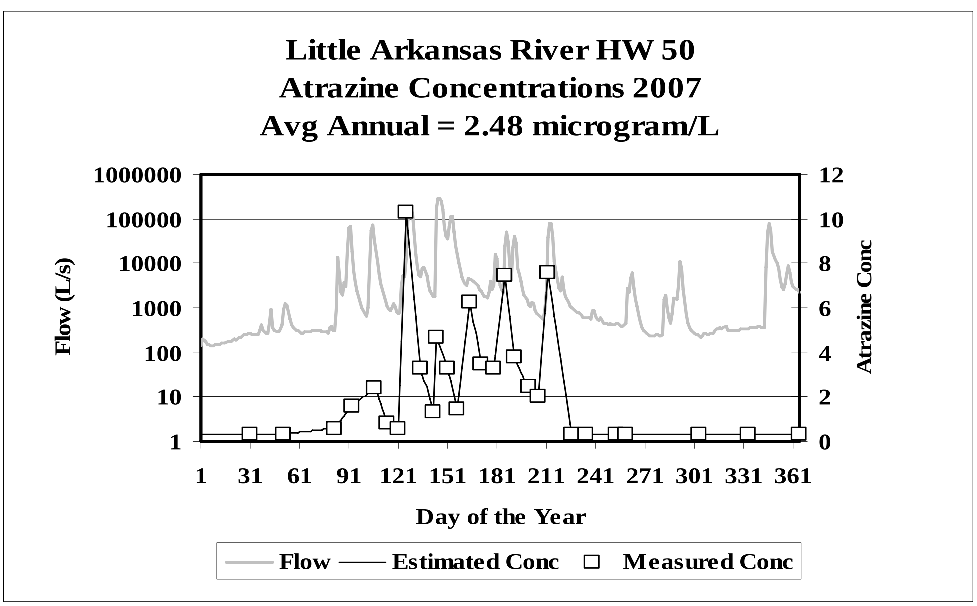


A temporal pattern of atrazine loss is shown in Figure 2-14. The highest atrazine loading within the Little Arkansas River was experienced during the months of April, May and June. These losses would be in runoff from atrazine applied to grain sorghum.

In 2007, March experienced above average rainfall which led to the soil saturation. The saturated soil resulted in surface runoff occurring earlier in the rainy season than normal. These saturated soils caused atrazine losses earlier in 2007 than in 2006 when the soil was fairly dry until the peak runoff, shown in Figure 2-15. The high rainfall in 2007 caused higher, more frequent concentration peaks within the subsequent months. During 2007, these concentration peaks showed losses both in the corn and grain sorghum application periods.

Figure 2-15. Atrazine concentration at HWY 50 for 2006 and 2007.

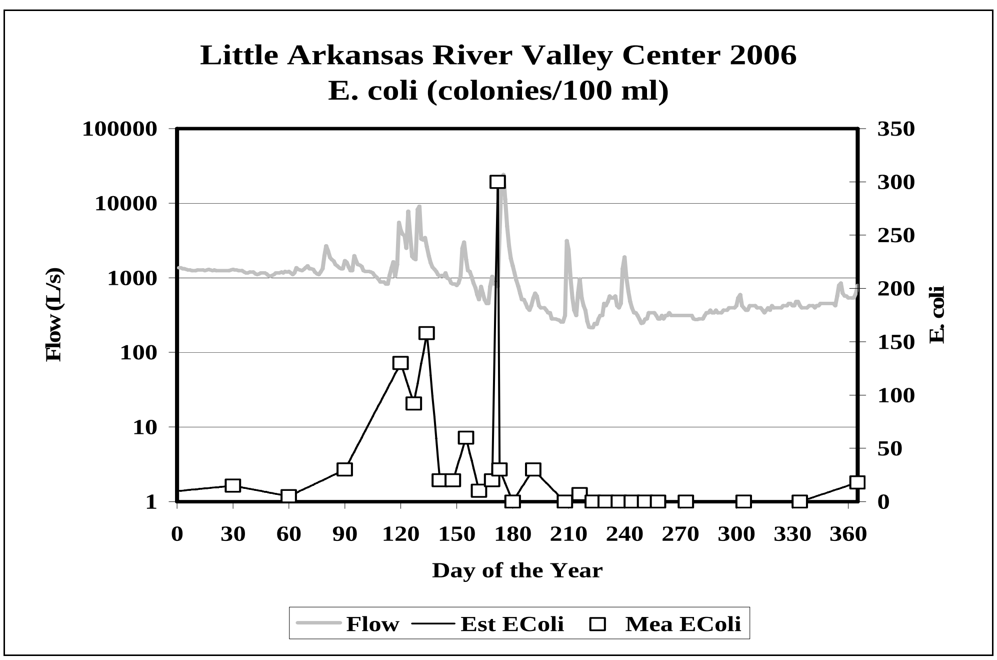


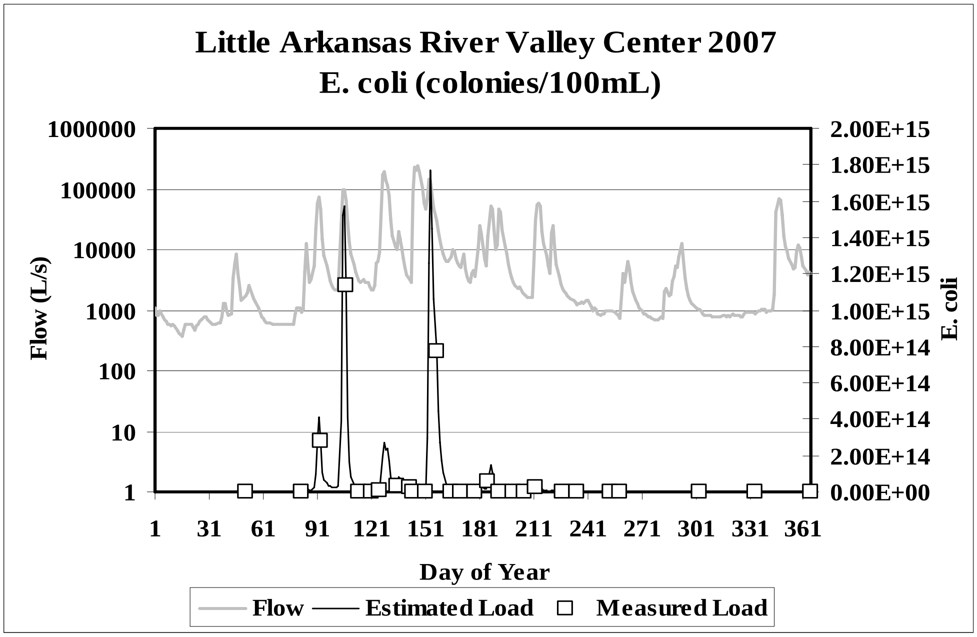


Analysis of E. coli

E. coli was analyzed as a general indicator of water quality, an overabundance of E. coli colonies could indicate a degradation of water quality. The laboratory analysis of E. coli gave a concentration of colonies per 100 mL, the concentration is used to calculate a loading of colonies per day. Figure 2-16 shows the E. coli loading with respect to the flow. The graph indicates there is higher E. coli loadings in the beginning of the year and then decreases to a very small loading from the middle of the year to the end. This pattern is shown in both 2006 and 2007, and can be seen in the other two main stem sites, Hwy 50 and Hwy 61.

Figure 2-16 E. coli loadings with respect to flow rate.



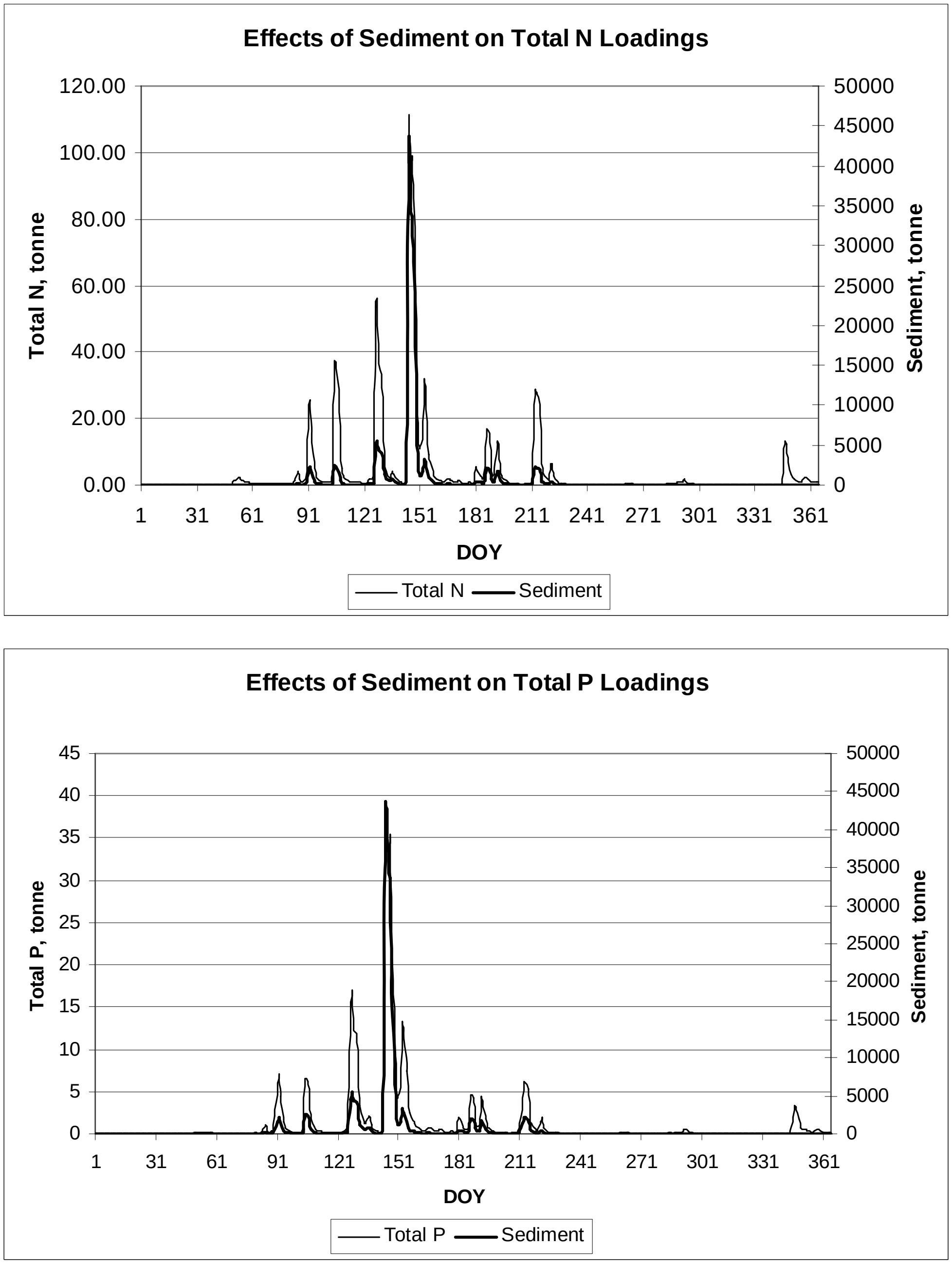


These patterns could be explained by the temperatures slowly increasing in the first few months of the year causing the E. coli to emerge from dormancy and multiply. When the first major storm events occurred the E. coli present in the system were transported in the surface runoff and high flow rates. So even though, later in the rainy season when major storm events occurred, the E. coli had already been removed from the system causing the loadings to decrease substantially. Potential E. coli sources are livestock, wildlife and municipal lagoons.

Analysis of Sediment

Sediment is a common non-point source pollutant. High amounts of sediment in surface waters can cause turbidity problems. Sediment also carries other absorbed or adsorbed pollutants including nitrogen and phosphorus. Figure 2-17, shows the relationship between sediment and total nitrogen and phosphorus losses. These figures show that when a peaks were experienced in sediment loading, there a peak in both the nitrogen and phosphorus loadings. These figures would suggest that if one were to decrease sediment loadings within watershed, the nutrient loadings would in turn decrease.

Figure 2-17 Relationship between sediment and Total N and Total P.



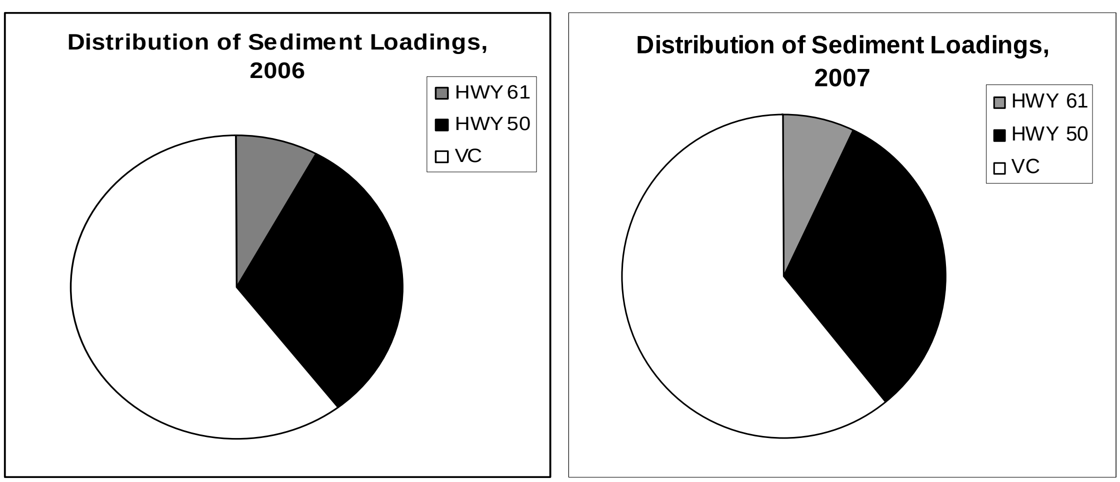
The question could be asked "where in the Little Arkansas River Watershed is the sediment coming from?" When analyzing the sediment loading the total acreage of row crops will be used. The watershed has a total row crop area of 93,005 ha. This can be broken down into the upstream, midstream, and outflow portions of the watershed (Table 2-6).

Table 2-6. Distribution of row crops throughout watershed.

Location	Row Crop (hectacre)	Acreage as Percent of Total
HWY 61, upstream	16643	18%
HWY 50, midstream	26382	28%
Valley Center, outflow	49980	54%

The crop distribution would lead to the conclusion that higher sediment loadings will occur in the lower portion of the watershed. Figure 2-18 shows the distribution of sediment throughout the watershed. The figure shows the largest sediment loading is found in the outflow of the watershed, which can be associated with the large acreage of row crops present in the area. Also, as the water flows through the watershed the sediment will compound. As long as the stream velocities are high enough they can carry the sediments and there will be limited deposition. Even though, the added surface water from the tributaries decrease the sediment concentration as the water travels through the watershed the high amount of row crops counteract this effect.

Figure 2-18. Distribution of Sediment Loadings through the watershed for 2006 and 2007.



There was a substantial difference in the amount of sediment lost from the watershed between 2006 and 2007. 2006 showed only a fraction of the sediment lost as in 2007 because of the reduced rainfall

When evaluating the total suspended solids within the watershed, a pattern emerged. The pattern is that as the year progresses the amount of sediment lost to surface runoff decreases. This is especially true when comparing the middle of the year, April to July, to the end of the year, August to December, shown in Figure 2-19. The pattern is due to the presence or absence of established vegetation. In the early portion of the year the ground is typically bare because crops, specifically row crops, have not emerged. Later in the year, the row crops have established vegetative cover to provide protection to the ground surface through interception of rainfall. Interception decreases the impact of rainfall minimizing the amount of sediment particles that are separated from the ground surface. This can also be seen in Figure 2-20 comparing TSS concentration versus the flow rates.

Figure 2-19. Monthly comparison of sediment loadings for 2006 and 2007.

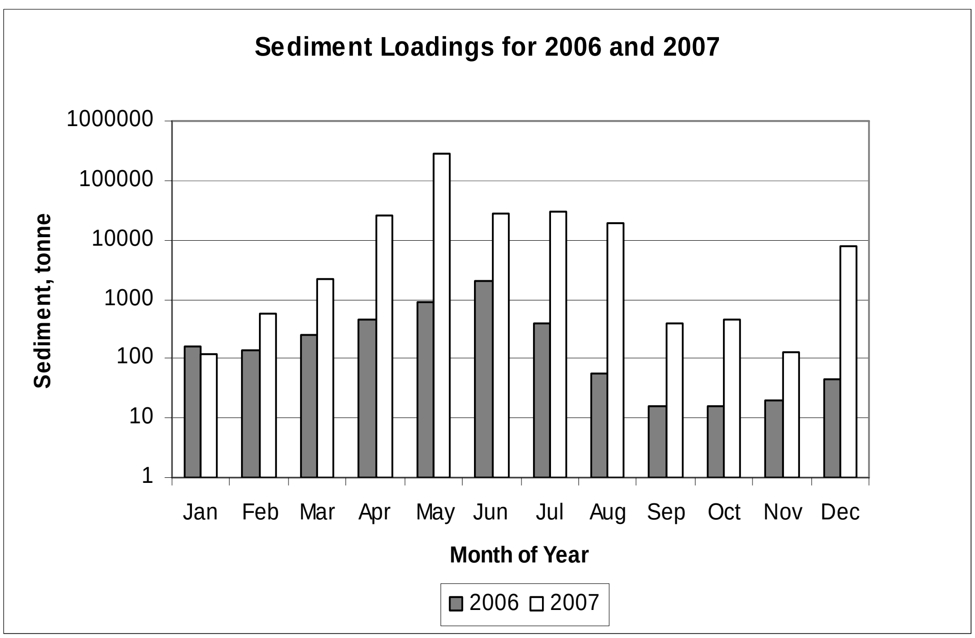
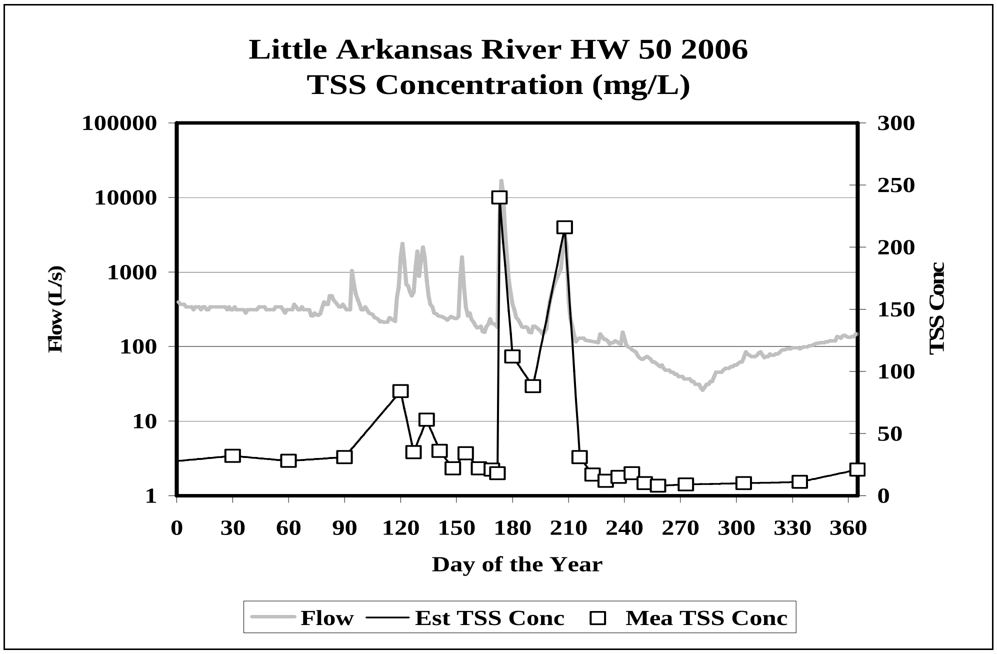


Figure 2-20. TSS concentration with respect to flow rates at HWY 50 in 2006.



Analysis of Nutrients

The nutrients of concern in surface water are nitrogen and phosphorous. Nitrogen and phosphorus have the ability to produce eutrophication in surface water systems. These nutrients were measured as total nitrogen and phosphorus (TN and TP). The total acreage of row crops was used to determine the amount of fertilizers applied to the system. The row crops are soybean, corn and grain sorghum. Typically the amount of nitrogen and phosphorus fertilizers applied is determined through soil testing. This study used the assumption that all of the soil had similar tilth. The Corn Production Handbook through Kansas State Extension suggested an application of 151 kg/ha of nitrogen fertilizer and 56 kg/ha of phosphorus (KSU, 2007). The Sorghum Production Handbook through Kansas State Extension suggested an application of 84 kg/ha of nitrogen and 34 kg/ha of phosphorus (KSU, 1998). The Soybean Production Handbook through Kansas State Extension suggests a application of 34 kg/ha of nitrogen and 11 kg/ha of phosphorus (KSU, 1997). Using these suggestions of application rates, an estimate can be made of the total nutrients applied throughout the watershed. This is an estimation because throughout the watershed pasturelands are commonly fertilized adding to the amount applied and this contribution is very difficult to estimate. Table 2-7 indicates the amount of nitrogen and phosphorus fertilizers applied throughout the watershed.

Table 2-7. Distribution of applied nitrogen and phosphorus fertilizers.

Location	Total Applied Nitrogen (tonne)	Total Applied Phosphorus (tonne)
Total Watershed	8652	3254
Main Stream Site		
HWY 61	1509	569
HWY 50	2435	918
Valley Center	4708	1767

Table 2-8 shows the amount and percent of TN and TP lost from each third and the total watershed in both 2006 and 2007. Like the other water quality parameters, the outflow, Valley Center had the most fertilizers applied. In 2006, roughly the same percentage of total nitrogen and phosphorus was lost throughout the watershed. During 2007, a greater percentage of nutrients were lost throughout the watershed due to the greater precipitation and daily flow rates. When separating the watershed into components, the middle portion lost more nutrients than the other portions even though more was estimated to be applied in the lower portion of the watershed. The difference is possibly due to the difference in farming practices within the watershed. Figure 2-21 and Figure 2-22 shows that both years follow the pattern of sediment losses.

Table 2-8. Amount and percent of Total N and Total P lost throughout the watershed.

Location	2006				2007			
	Total N (tonne)	% Applied	Total P (tonne)	% Applied	Total N (tonne)	% Applied	Total P (tonne)	% Applied
Total Watershed	51	0.6%	22	0.7%	1421	16%	453	14%
Main Stream Site								
HWY 61	11	0.7%	4	0.7%	407	27%	92	16%
HWY 50	5	0.2%	4	0.4%	584	24%	218	24%
Valley Center	35	0.7%	14	0.8%	430	9%	142	8%

Figure 2-21. Monthly comparison of Total N lost during 2006 and 2007.

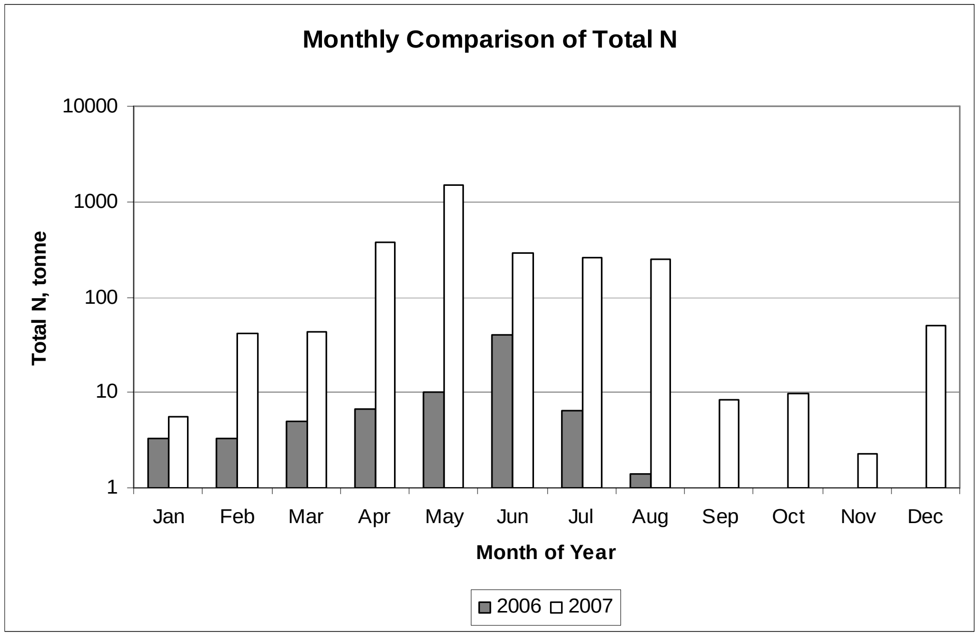
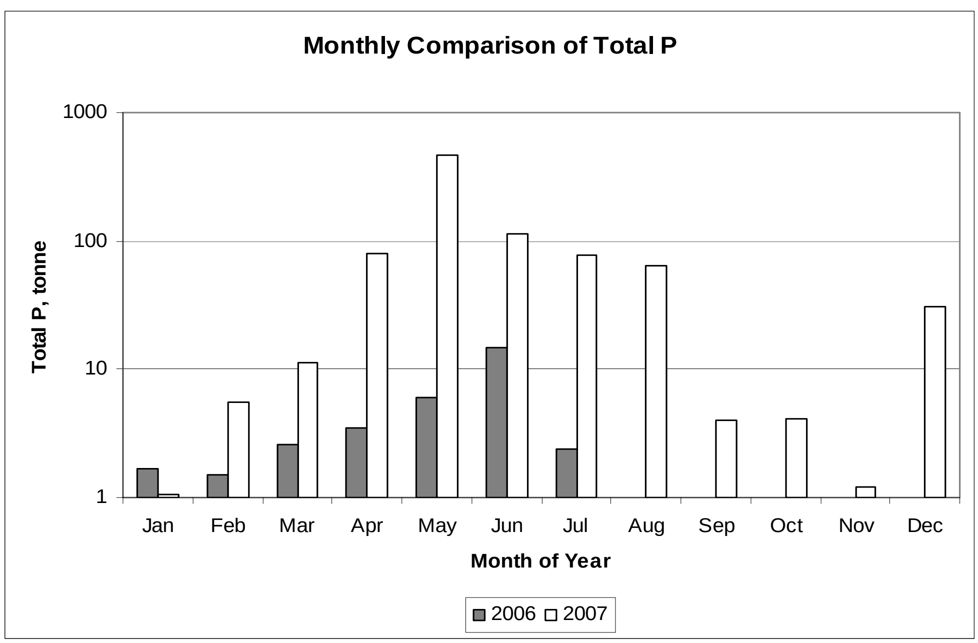


Figure 2-22. Monthly comparison of Total P lost during 2006 and 2007.



Conclusions

Watershed scale monitoring is necessary to fully understand the sources and transport of various pollutants. A watershed scale monitoring study was completed for the Little Arkansas River Watershed. The study was conducted during 2006 and 2007, a dry year and a wet year. The precipitation differences in the years allowed for patterns to emerge with respect to various pollutants.

In summary, the factor most influencing all of the water quality parameters except E. coli was the rainfall intensity and timing. When analyzing the atrazine lost from grain sorghum and corn, it was determined that atrazine lost from corn is not a significant contributor to the total atrazine loading when compared to grain sorghum. Most of the atrazine was lost during the rainy season, in the months of May through June, and from the midstream portion of the watershed.

The analysis of E. coli loadings revealed only one pattern. The highest concentrations of E. coli were experienced early in the year. The concentrations then significantly decrease after the first major storm events and the concentrations remain low throughout the rest of year even though substantial storm events occurred causing runoff.

There was a large amount of sediment lost throughout the watershed. Most of the sediment was lost from the lower portion of the watershed. When the individual years were analyzed most of the sediment was lost earlier in the season than later in the season because of protection provided by the crop cover. This pattern also emerges in the nutrient analysis. The nutrient loadings follow the sediment loadings due to their sorbtive nature. The watershed scale monitoring study allowed for the pollutant sources to be identified and thus practices can be implemented to decrease the pollutant loadings throughout the watershed.

Watershed scale monitoring made it evident that although atrazine best management practices were effective in reducing atrazine concentrations within surface water there was no impact on the other water quality parameters. In order to increase water quality primarily with respect to sediment and nutrients other best management practices should be considered.

CHAPTER 3 - Paired Sub-Watershed Montioring

Objectives

The primary objective of the study is to determine the effectiveness of the various atrazine best management practices. The secondary objective of the study is to determine the impact of the atrazine best management practices on other water quality parameters.

Introduction

The purpose of the study is to determine the effectiveness of atrazine best management practices on a sub-watershed scale. Atrazine BMPs are designed to meet the following objectives (Devlin *et al.*, 2000):

1. Reduce the availability of atrazine for loss after application.
2. Reduce the rate of atrazine used in a field and/or watershed.
3. Reduce the impact of the first runoff event on atrazine loss.
4. Provide a mechanism for deposition of the atrazine before it leaves the field.

The atrazine Best Management Practices (BMPs) that were investigated were the following: incorporation into the first 2" of soil prior to planting, application in the fall or prior to April 15, application as part of a postemergence premix, reduced soil application, split applications, band applications at planting and the use of no atrazine. These BMPs were discussed in detail in Chapter 1.

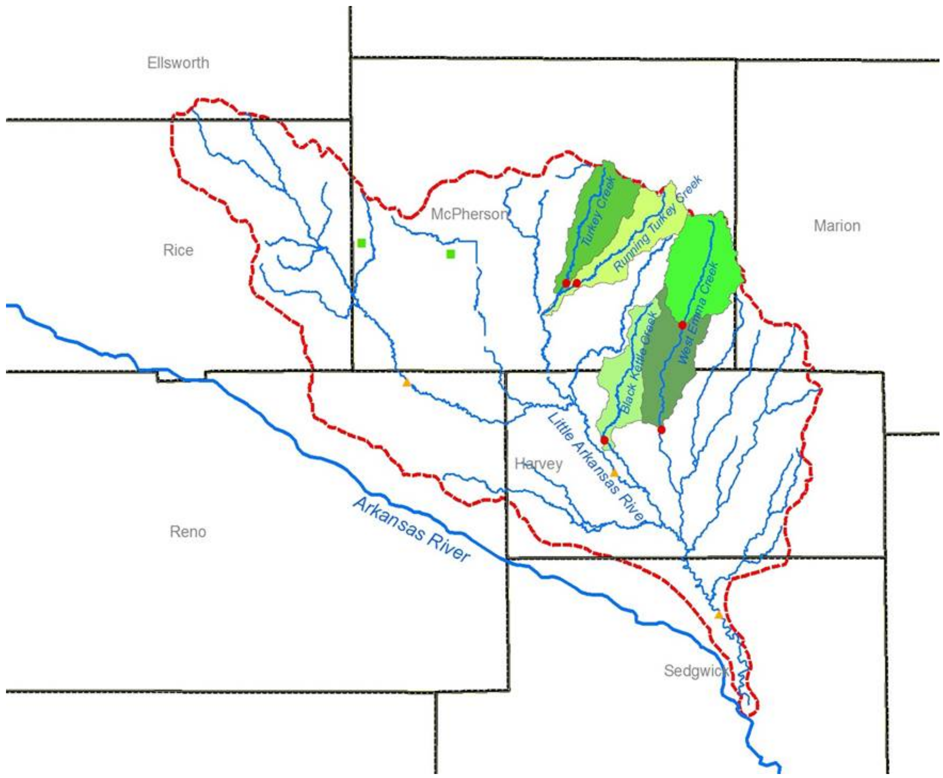
The study was in response to an implementation goal established by the Little Arkansas Watershed Restoration and Protection Strategy Project (WRAPS). The WRAPS implementation goal was to reduce atrazine herbicide in water to reach a goal of 3 μg/L, with no seasonal spikes (Devlin *et al.*, 2006). Further information on the Little Arkansas Watershed Restoration and Protection Strategy Project can be found in Chapter 1.

Paired Sub-Watershed Monitoring

Five sub-watersheds within the Little Arkansas Watershed were selected for the study. The sub-watersheds were selected with respect to the acreage of grain sorghum within each sub-watershed. A large grain sorghum acreage was desirable in order to implement multiple atrazine

BMPs within given area. The five sub-watersheds are located in the northeast corner of the watershed, shown in various shades of green Figure 3-1. The sub-watersheds are Dry Turkey, Running Turkey, Upper West Emma, Lower West Emma and Black Kettle Creek. Table 3-1 gives the sampling site coordinates.

Figure 3-1. Map of the five sub-watersheds within the Little Arkansas Watershed.



The sub-watersheds of Dry Turkey, Upper West Emma, and Black Kettle Creek had atrazine BMPs implemented throughout while the remaining two sub-watersheds, Running Turkey and Lower West Emma, remained the same to provide a comparison. Table 3-1(Devlin *et al.*, 2007a) specifies the different atrazine BMPs used in 2006 and 2007.

Table 3-1. Atrazine BMPs used in 2006 and 2007 within the Little Arkansas River Watershed.

Atrazine BMP	2006	2007
Incorporate atrazine into the first 2" of soil prior to planting	X	X
Apply atrazine in the fall or prior to April 15	X	X
Apply atrazine as part of a postemergence premix	X	X
Reduce soil-applied atrazine rates to 1 lb ai/acre or less	X	X
Use split applications of atrazine, e.g. 2/3 prior to April 15 and 1/3 at planting	X	X
Band apply atrazine at planting	X	X
Use no atrazine	X	X
Establish buffer strip		X
Incorporate atrazine with 1/2" sprinkler irrigation		X

Table 3-2 (Devlin *et al.*, 2007a), indicates the distribution of the BMPs through the three sub-watersheds for 2006 and 2007. During 2006, the BMPs were only applied to grain sorghum then in 2007 BMPs were added to corn. As shown in Table 3-1, two atrazine BMPs were added in 2007, the establishment of buffer strips and incorporation of atrazine with ½" sprinkler irrigation, although it is shown in Table 3-2, that these BMPs where not implemented within the three sub-watersheds. When comparing 2006 and 2007 in Table 3-2, it is shown that in 2007 significantly more acreage, approximately 54% more acres, implemented BMPs in 2007 than in 2006.

Table 3-2. Atrazine BMPs implemented in 2006 and 2007 by BMP and acres utilized.

Atrazine BMP Implemented	2006		2007	
	No. of Acres BMP Implemented	Percent of Total Acres with BMPs	No. of Acres BMP Implemented	Percent of Total Acres with BMPs
Preplant Incorporation	705	15	1880	18
Early Application	817	17	1544	15
Postemergence Application	146	3	796	8
Reduce soil-applied rates	455	10	4570	43
Alternative Crop	1807	38	0	0
Combination of early application and reduced soil applied rate	852	18	157	1
Combination of reduced soil-applied rates and postemergence application	0	0	270	2
No atrazine applied	6	0.1	1294	12

Sub-watershed Sampling

Sampling was conducted at the outflows of each of the five sub-watersheds, depicted in Figure 3-1 as red circles; the coordinates are given in Table 3-3. Water samples were obtained once a month during winter months when flow is minimal. During the months from April through September samples were taken at least once a week or directly following runoff events. Sampling procedure is further discussed in Chapter 2.

Table 3-3. Paired sub-watershed sampling site coordinates.

Sampling Site	Longitude	Latitude
Black Kettle Creek	W 97°33.305'	N 38°04.337'
Upper West Emma	W 97°26.500'	N 38°13.917'
Dry Turkey	W 97°36.607'	N 38°17.376'
Lower West Emma	W 97°28.302'	N 38°05.206'
Running Turkey	W 97°35.584'	N 38°17.442'

Water Quality Analysis

The same water quality parameters from the watershed-scale monitoring study were analyzed in the paired sub-watershed scale study. The water quality parameters of concern are atrazine concentration, total suspended solids (TSS), total nitrogen and phosphorus (TN and TP concentrations. The analysis of atrazine concentration, and TSS was performed by the Water Quality Laboratory in the Biological and Agricultural Department at Kansas State University. The nutrient analysis was performed by the Soil Testing Laboratory in the Department of Agronomy at Kansas State University. The laboratory analysis procedure is detailed in Chapter 2.

Statistical analysis was conducted to determine the significance of the following results. The statistical analysis performed was a pairwise T-test.

Analysis of Atrazine

The objective of the paired sub-watershed study was to determine the effectiveness of atrazine BMPs in their ability to limit the amount of atrazine lost to surface runoff. As shown in the previous chapter, the precipitation differences between 2006 and 2007 impacted the amount of atrazine in the surface runoff. In general, there is a trend toward a reduction in atrazine concentration. Statistically there is no significance between the sub-watersheds with practices and sub-watersheds without practices in 2007 while in 2006 there was a statistically significant difference between the annual average concentrations of treated and untreated sub-watershed. In 2006 there was a 53% reduction in atrazine concentration in the sub-watersheds with the atrazine BMPs implemented. In 2007, there was a 5% reduction in the sub-watershed with the atrazine BMPs. The difference in reduction between the years is primarily due to precipitation differences.

The timing and intensity of a rainfall event have a large impact on the amount of atrazine lost to surface runoff. The atrazine BMPs were able to have an impact on the amount of atrazine lost in surface runoff during the rainy season. In both 2006 and 2007, during the months of May and June when the most precipitation occurs, the sub-watersheds with BMPs contributed less atrazine to the runoff than the sub-watersheds without BMPs, shown in Figure 3-3 and Figure 3-4. In 2007, the months of May, June, July and August showed a reduction in atrazine loading in sub-watersheds with BMPs. With respect to atrazine loading, the sub-watersheds with BMPs contributed less than the sub-watershed without practices. The sub-watersheds without practices contributed over half of total atrazine loading from the entire year in both 2006 and 2007.

Figure 3-2. Annual average atrazine concentration of treated and untreated sub-watersheds

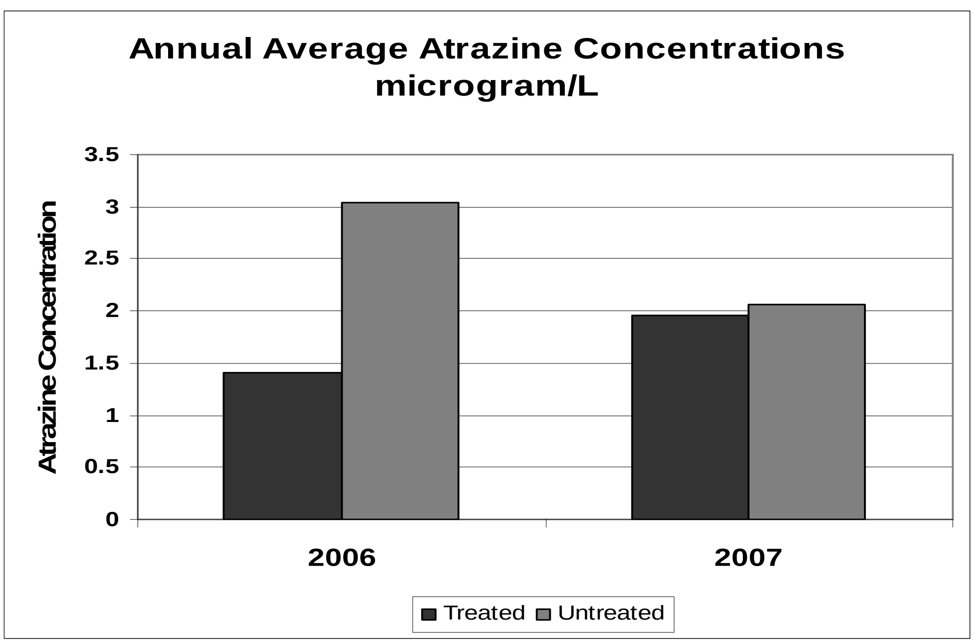


Figure 3-3. Monthly comparison of atrazine loading in treated and untreated sub-watersheds in 2006.

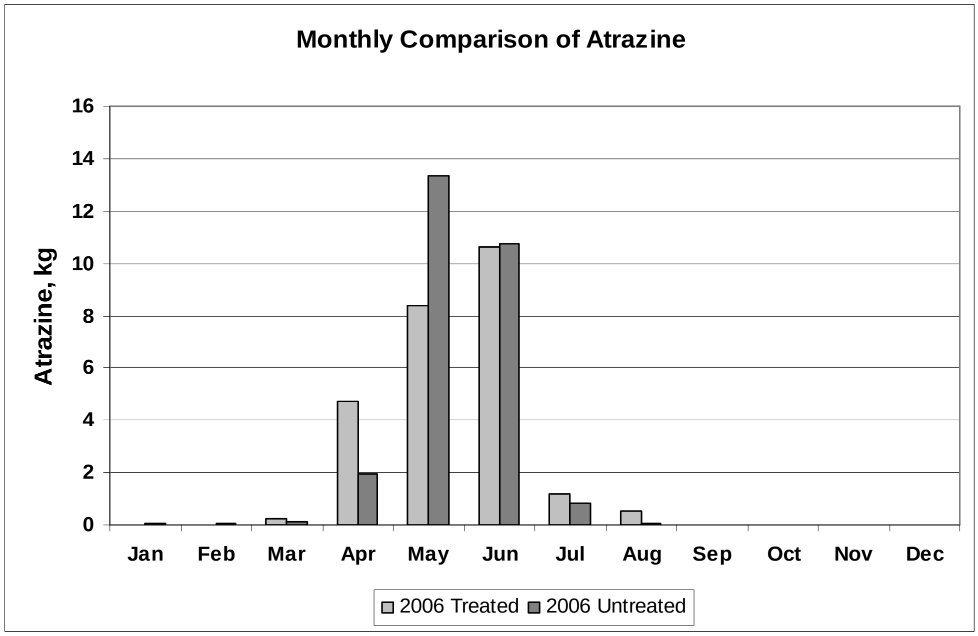
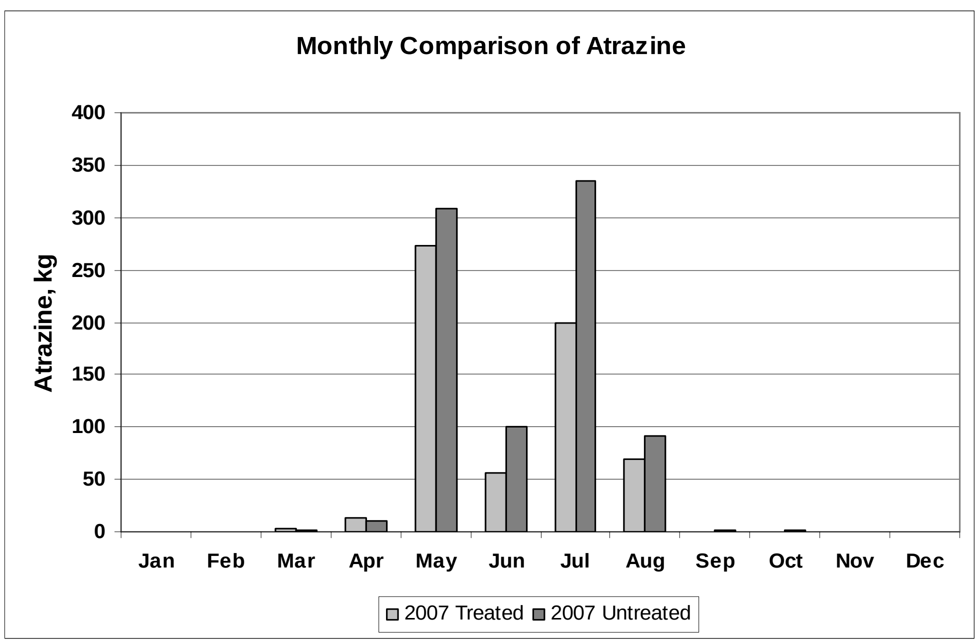


Figure 3-4 Monthly comparison of atrazine loading in treated and untreated sub-watersheds in 2007.



More specifically, in 2006, the BMPs were able to minimize the concentration found during peak flow rates. Figure 3-5, shows the sub-watershed Upper West Emma which had BMPs implement and Figure 3-6 shows the sub-watershed Lower West Emma which kept the existing farming practices. Both sub-watersheds experienced similar flow rates at approximately the same time period but there is a definite decrease in atrazine concentration between sub-watersheds.

Figure 3-5. Atrazine concentration with respect to flow rate for Upper West Emma subwatershed in 2006.

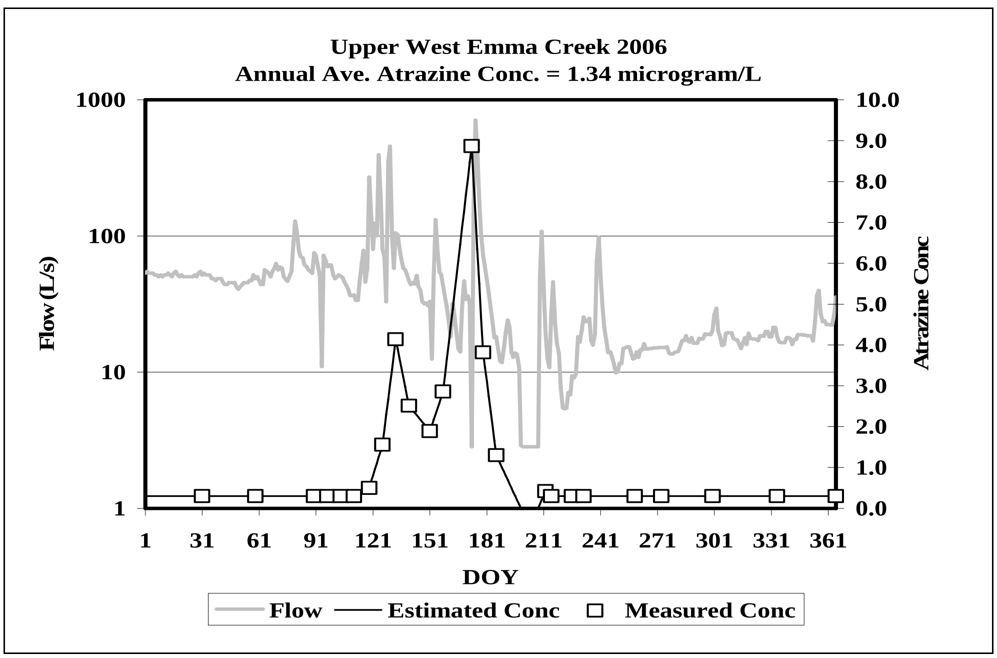
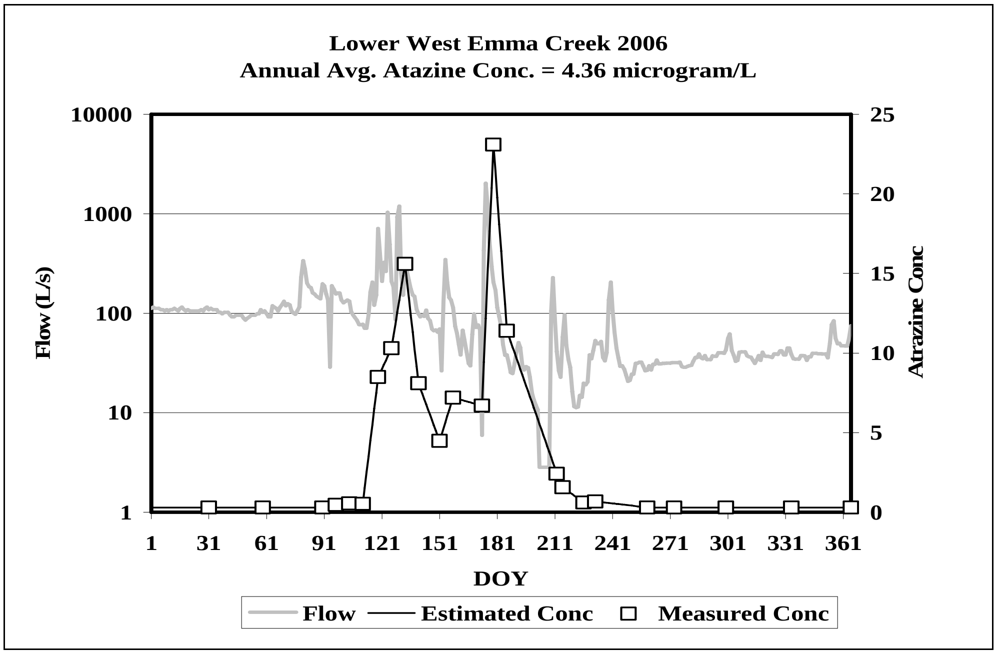


Figure 3-6 Atrazine concentration with respect to flow rate for Lower West Emma subwatershed in 2006.



In general, the atrazine BMPs were effective in decreasing the atrazine loading experienced during the year, in both a dry year and a wet year. This finding indicates atrazine BMPs are an effective tool in decreasing the amount of atrazine lost in spite of the weather extremes experienced in Kansas.

Analysis of Sediment

When comparing TSS for 2006 and 2007 the atrazine trend was not repeated between the years. Table 3-4 indicates the sediment loading for the sub-watersheds in 2006 and 2007.

Table 3-4. TSS loading (tonne) comparison of sub-watersheds in 2006 and 2007.

Site		2006	2007
Treated	Black Kettle	489	8382
	U W Emma	44	10638
	Dry Turkey	199	4035
	Total	**732**	**23055**
Untreated	L W Emma	181	15681
	Running Turkey	151	19024
	Total	**377**	**45343**

In 2006, the treated sub-watershed lost twice as much sediment as the untreated sub-watersheds. In contrast, 2007 the untreated sub-watersheds lost twice as much as the treated sub-watersheds. The only consistent trend presented with the data is that more sediment was lost from all the sub-watersheds in 2007 than 2006 which can be contributed to the above average precipitation in 2007. The annual sediment loading is shown in Figure 3-7. There was a statistically significant difference in 2007 between the treated and untreated sub-watersheds, although not in 2006.

The one trend that was consistent was that in both years sediment loss decreased substantially after the rainy season ended in late June and early July. This trend is due to the emergence of crops which act as protection against rainfall and provide a means to slow the velocity of runoff allowing for deposition to occur. Figure 3-8 and Figure 3-9 depict this trend, by comparing the sediment loading on a monthly basis. This trend can also be seen in Figure 3-10 which shows the TSS loading with respect to the flow rates throughout the year.

Figure 3-7. Annual sediment loading for treated and untreated sub-watersheds.

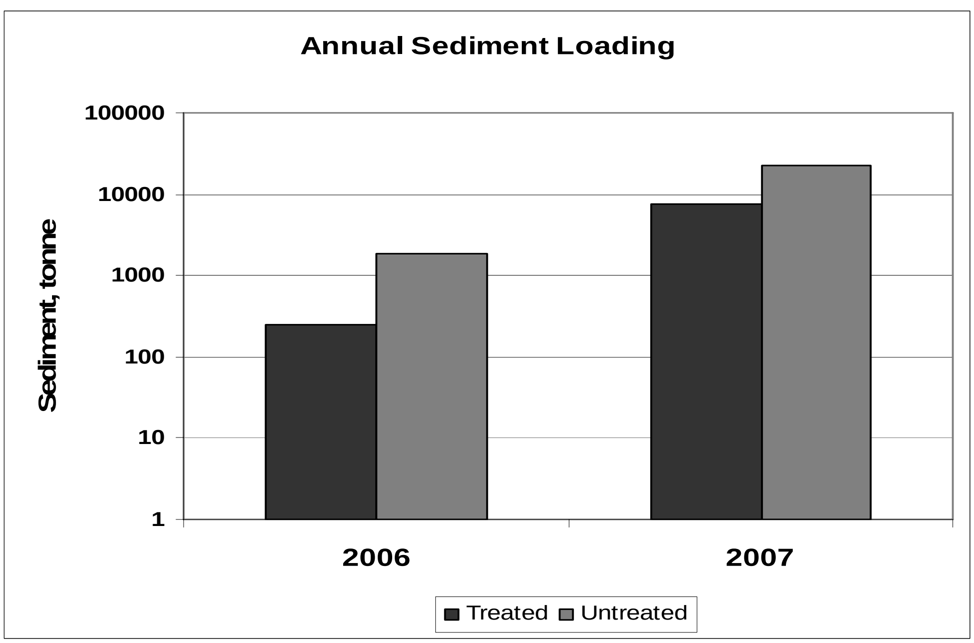


Figure 3-8. Monthly comparison of sediment loadings in 2006.

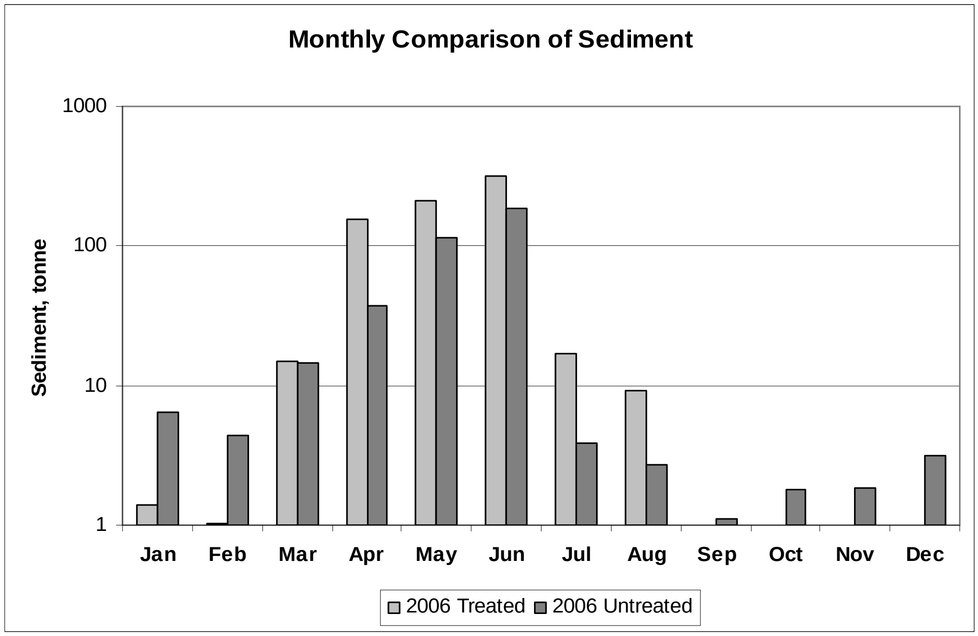


Figure 3-9. Monthly comparison of sediment loading in 2007.

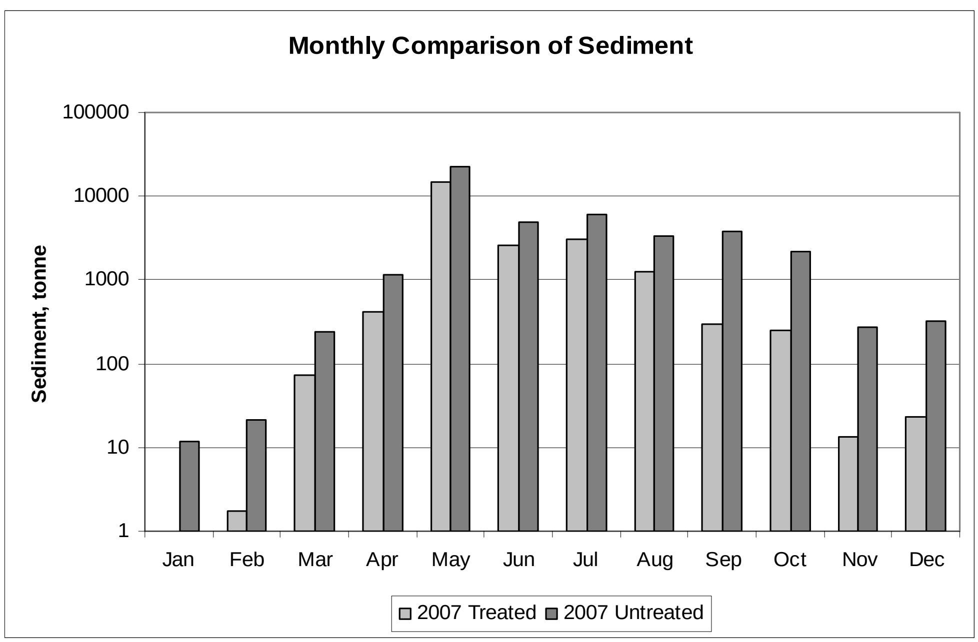
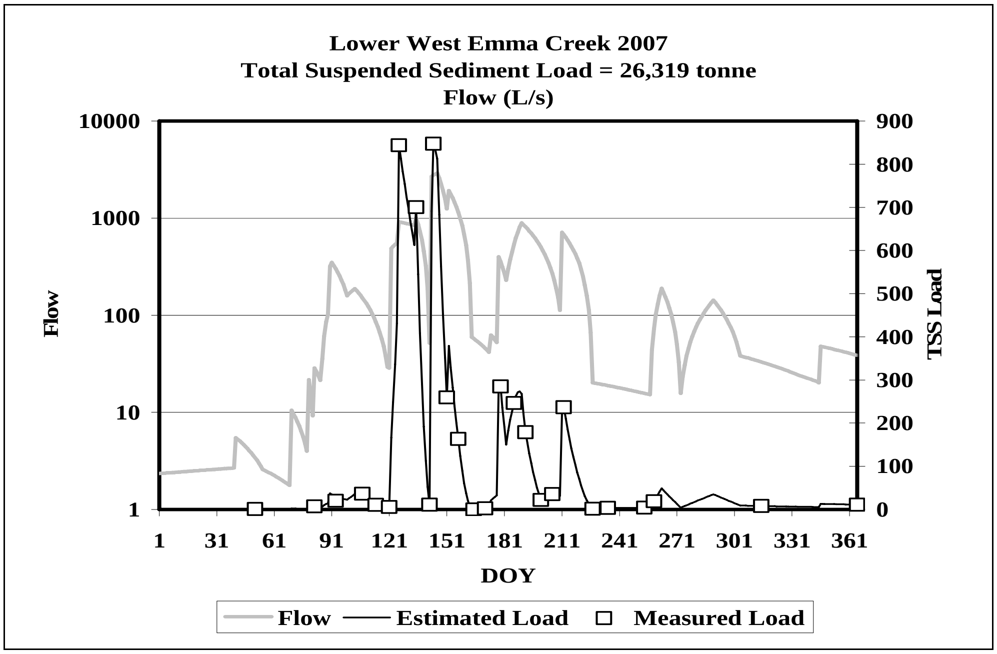


Figure 3-10. TSS loading with respect to flow rates at Lower West Emma Creek in 2007.



Analysis of Nutrients

Between the years there is a substantial difference in amount of nutrients lost from the sub-watersheds due to precipitation differences. TN in the treated sub-watersheds in 2006 is approximately 3 times higher that in the untreated sub-watersheds, shown in Figure 3-11. While in 2007, TN lost in the treated sub-watersheds was a little more than half of TN that was lost in the untreated sub-watersheds. In 2006, the TP loadings for the treated and untreated sub-watersheds were approximately the same. While in 2007, the TP lost from the treated sub-watersheds is just over half of the TP lost from the untreated sub-watersheds, shown in Figure 3-12. There is a statistically significant difference for both TN and TP during 2007, although not in 2006. This is consistent with the finding of sediment loadings in 2007, to be significantly different because the amount of sediment within a system can be related to the amount of nutrients within the same system.

Figure 3-11 Annual TN loading from treated and untreated sub-watersheds.

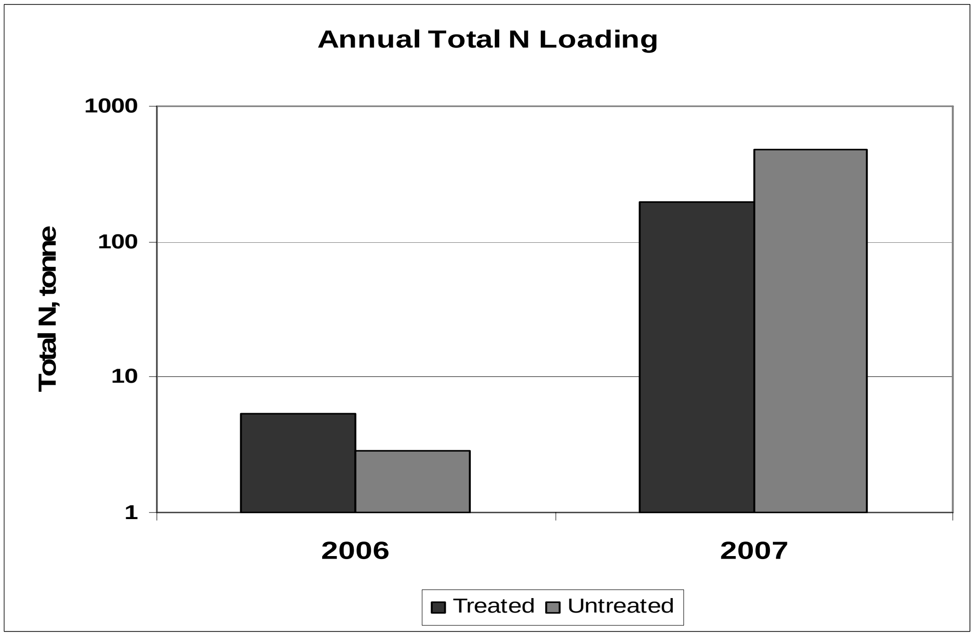
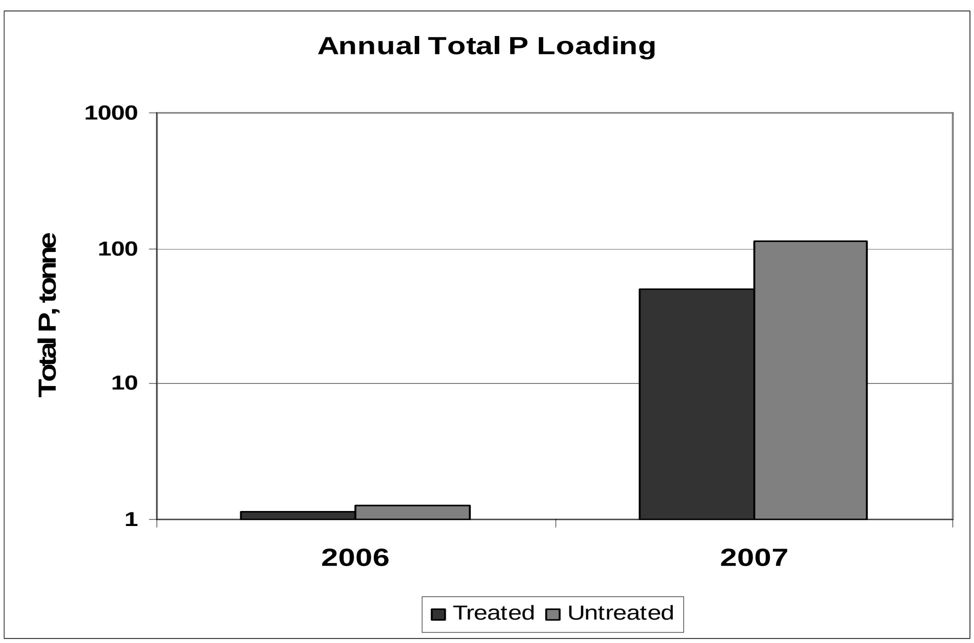


Figure 3-12 Annual TP loading from treated and untreated sub-watersheds.



Similar to sediment, the nutrient loadings reach their peaks during the rainy season and then decrease throughout the rest of the year. This is due to the decrease of sediment in the runoff. Nutrients such as TN and TP are adsorped onto the surface of the soil particle and are transported if erosion occurs. The emergence of crops and the related increase in land cover reduces the amount of sediment lost consequently reducing the nutrient loading. Figure 3-13 and 3-14 show a monthly comparison between the treated and untreated sub-watershed, both demonstrating the trend. Figure 3-15 depicts this trend with nutrient concentrations with respect to flow rates through the year.

Figure 3-13 Monthly comparison of Total N between the sub-watersheds in 2007.

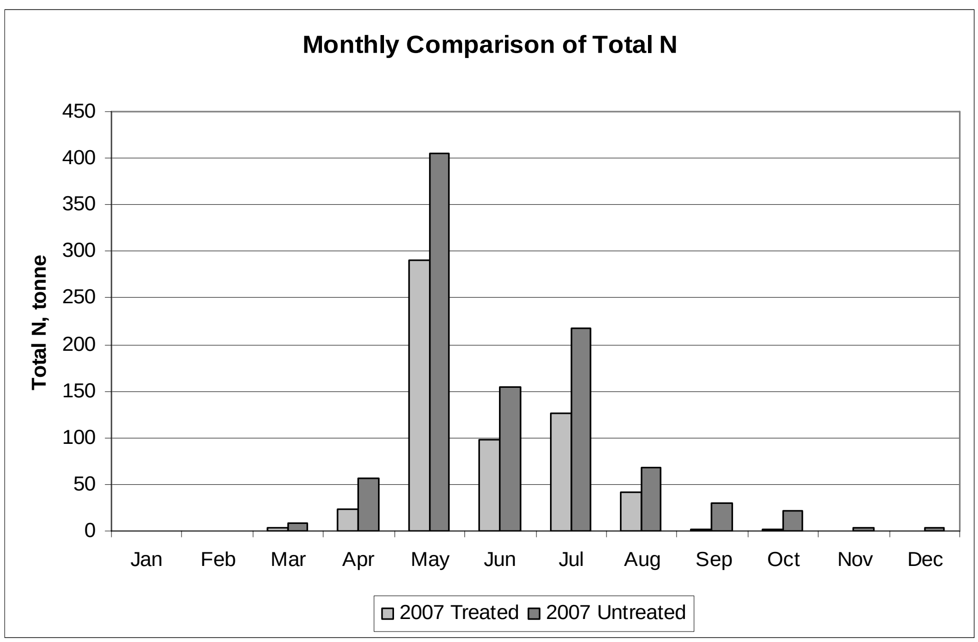


Figure 3-14 Monthly comparison of Total P between sub-watershed in 2007.

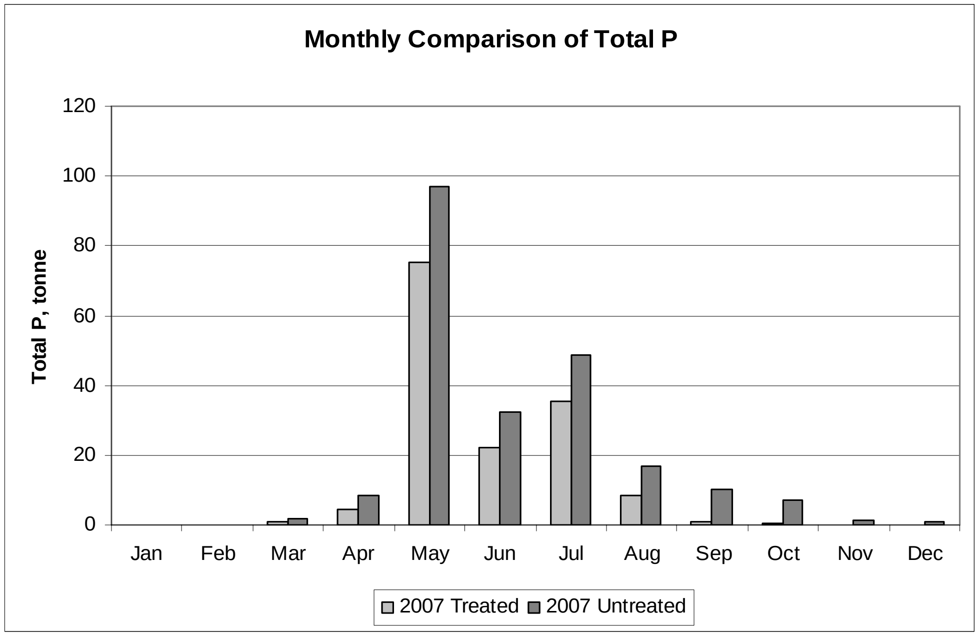
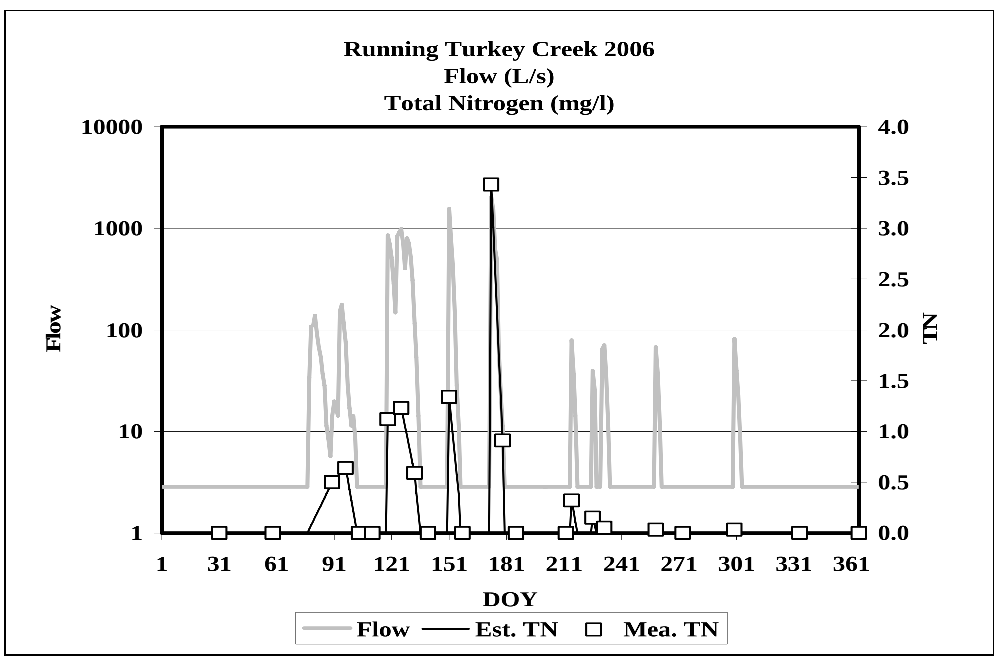


Figure 3-15 Total N concentrations with respect to flow rate in Running Turkey during 2006.



Conclusions

In summary the objectives of the study were to determine the effectiveness of atrazine BMPs and also determine the effectives of atrazine BMPs in reducing other pollutants attached to sediment such as TN and TP. Five sub-watersheds were selected, three sub-watersheds implemented the atrazine BMPs while the remaining two kept the existing farming practices.

There was a significant difference in atrazine concentration, showing a reduction in atrazine in treated sub-watersheds versus the untreated sub-watersheds in 2006. Although there is not a significant difference in 2007 between treated and untreated sub-watersheds. The other water quality parameters of concern only exhibited a statistically significant difference in 2007.

Atrazine BMPs are an effective means to reduce atrazine concentration within surface runoff during normal and dry years. Although, there was a significant difference in the other water quality parameters, there is still a substantial loading of the pollutants within the surface runoff. This indicates that there is a need for addition BMPs which focus more on reducing sediment loadings. A reduction in sediment would consequently lead to a reduction in other pollutants such as total nitrogen and phosphorus..

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Appendix A - 2006 Main Stem Data

Table A-1 Discrete atrazine concentrations (µg/L) for sites in the Little Arkansas River main stem study for 2006

Date	Site		
	Valley Center	HW 50	HW 61
01-30	0.30	0.30	0.30
03-01	0.30	0.30	0.30
03-31	0.30	0.30	0.30
04-30	2.30	2.67	1.88
05-07	1.80	1.32	0.30
05-14	2.210	3.40	2.56
05-21	0.30	0.30	0.30
05-28	0.30	0.30	0.30
06-04	3.10	3.34	4.12
06-11	1.70	0.54	0.30
06-18	1.30	0.30	0.30
06-21	1.71	1.44	1.84
06-22	2.65	2.04	4.32
06-28	5.44	5.16	2.78
07-10	2.06	3.42	1.37
07-27	0.42	2.12	2.19
08-04	0.30	0.30	0.30
08-11	0.30	0.30	0.30
08-18	0.30	0.30	0.30
08-25	0.30	0.30	0.30
09-01	0.30	0.30	0.30
09-08	0.30	0.30	0.30
09-15	0.30	0.30	0.30
09-30	0.30	0.30	0.30
10-31	0.30	0.30	0.30
11-30	0.30	0.30	0.30
12-31	0.30	0.30	0.30

Table A-2 Discrete total suspended solids concentrations (mg/L) for sites in the Little Arkansas River main stem study for 2006.

Date	Site		
	Valley Center	HW 50	HW 61
01-30	32	32	20
03-01	36	28	16
03-31	58	31	18
04-30	112	84	51
05-07	124	35	34
05-14	110	61	44
05-21	52	36	22
05-28	32	22	20
06-04	61	34	36
06-11	26	22	18
06-18	38	21	17
06-21	45	18	35
06-22	111	240	152
06-28	154	112	4
07-10	31	80	8
07-27	18	216	44
08-04	522	31	32
08-11	16	17	15
08-18	18	12	12
08-25	17	15	14
09-01	45	18	15
09-08	10	10	10
09-15	11	8	9
09-30	9	9	5
10-31	16	10	12
11-30	12	11	10
12-31	34	21	14

Table A-3 Discrete total nitrogen concentrations (mg/L) for sites in the Little Arkansas River main stem study for 2006.

Date	Site		
	Valley Center	HW 50	HW 61
01-30	0.82	0.48	0.29
03-01	0.94	0.44	0.31
03-31	1.07	0.51	0.37
04-30	1.39	1.19	0.48
05-07	1.06	0.84	0.31
05-14	1.15	0.79	0.36
05-21	0.76	0.51	0.26
05-28	0.74	0.43	0.24
06-04	1.12	1.08	0.32
06-11	0.75	0.51	0.25
06-18	1.00	0.48	0.20
06-21	2.11	1.33	0.21
06-22	3.06	2.07	4.89
06-28	2.55	2.72	2.22
07-10	1.25	1.22	2.06
07-27	0.73	1.58	1.91
08-04	0.75	0.62	0.62
08-11	0.68	0.58	0.46
08-18	0.70	0.57	0.32
08-25	0.72	0.52	0.22
09-01	0.62	0.43	0.15
09-08	0.58	0.40	0.18
09-15	0.56	0.36	0.16
09-30	0.59	0.28	0.09
10-31	0.46	0.22	0.06
11-30	0.33	0.18	0.03
12-31	0.44	0.12	0.04

Table A-4 Discrete total phosphorus concentrations (mg/L) for sites in the Little Arkansas River main stem study for 2006.

Date	Site		
	Valley Center	HW 50	HW 61
01-30	0.36	0.28	0.08
03-01	0.42	0.29	0.12
03-31	0.588	0.37	0.18
04-30	0.68	0.78	0.28
05-07	0.61	0.64	0.21
05-14	0.60	0.82	0.26
05-21	0.54	0.33	0.14
05-28	0.41	0.31	0.11
06-04	0.56	0.58	0.16
06-11	0.41	0.38	0.11
06-18	0.43	0.39	0.13
06-21	1.22	0.68	0.21
06-22	1.22	0.97	1.56
06-28	0.67	0.62	0.40
07-10	0.31	0.59	0.85
07-27	0.24	0.76	0.58
08-04	0.39	0.39	0.32
08-11	0.26	0.26	0.16
08-18	0.24	0.24	0.14
08-25	0.24	0.24	0.11
09-01	0.25	0.25	0.09
09-08	0.19	0.19	0.07
09-15	0.18	0.18	0.08
09-30	0.16	0.16	0.06
10-31	0.17	0.17	0.05
11-30	0.16	0.16	0.06
12-31	0.22	0.22	0.03

Table A-5 Discrete E. coli populations (colonies/100mL) for sites in the Little Arkansas River main stem study for 2006.

Date	Site		
	Valley Center	HW 50	HW 61
01-30	15	0	0
03-01	5	0	0
03-31	30	0	0
04-30	130	132	5
05-07	92	10	0
05-14	158	112	15
05-21	20	0	0
05-28	20	0	0
06-04	60	42	5
06-11	10	0	0
06-18	20	0	0
06-21	300	0	0
06-22	30	35	20
06-28	0	15	10
07-10	30	10	10
07-27	0	28	10
08-04	7	5	0
08-11	0	0	0
08-18	0	0	0
08-25	0	0	0
09-01	0	0	0
09-08	0	0	0
09-15	0	0	0
09-30	0	0	0
10-31	0	0	0
11-30	0	0	0
12-31	18	18	0

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006.

Date	Site		
	Valley Center	HW 50	HW 61
1/1/2006	48	14.0	7.0
1/2/2006	48	13.0	6.5
1/3/2006	47	13.0	6.5
1/4/2006	47	13.0	6.5
1/5/2006	46	12.0	6.0
1/6/2006	45	12.0	6.0
1/7/2006	45	12.0	6.0
1/8/2006	44	12.0	6.0
1/9/2006	44	11.0	5.5
1/10/2006	44	12.0	6.0
1/11/2006	45	12.0	6.0
1/12/2006	45	12.0	6.0
1/13/2006	45	11.0	5.5
1/14/2006	45	12.0	6.0
1/15/2006	44	12.0	6.0
1/16/2006	45	11.0	5.5
1/17/2006	46	11.0	5.5
1/18/2006	45	12.0	6.0
1/19/2006	44	12.0	6.0
1/20/2006	45	12.0	6.0
1/21/2006	44	12.0	6.0
1/22/2006	44	12.0	6.0
1/23/2006	44	12.0	6.0
1/24/2006	44	12.0	6.0
1/25/2006	44	12.0	6.0
1/26/2006	44	12.0	6.0
1/27/2006	44	11.0	5.5
1/28/2006	44	12.0	6.0
1/29/2006	45	11.0	5.5
1/30/2006	46	11.0	5.5
1/31/2006	45	12.0	6.0

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
2/1/2006	45	11.0	5.5
2/2/2006	44	11.0	5.5
2/3/2006	44	11.0	5.5
2/4/2006	44	11.0	5.5
2/5/2006	42	11.0	5.5
2/6/2006	41	10.0	5.0
2/7/2006	41	11.0	5.5
2/8/2006	42	11.0	5.5
2/9/2006	42	11.0	5.5
2/10/2006	42	11.0	5.5
2/11/2006	40	11.0	5.5
2/12/2006	39	11.0	5.5
2/13/2006	40	12.0	6.0
2/14/2006	41	12.0	6.0
2/15/2006	41	12.0	6.0
2/16/2006	41	12.0	6.0
2/17/2006	40	11.0	5.5
2/18/2006	38	11.0	5.5
2/19/2006	37	11.0	5.5
2/20/2006	38	11.0	5.5
2/21/2006	39	11.0	5.5
2/22/2006	41	12.0	6.0
2/23/2006	41	12.0	6.0
2/24/2006	41	12.0	6.0
2/25/2006	42	12.0	6.0
2/26/2006	41	11.0	5.5
2/27/2006	43	10.0	5.0
2/28/2006	42	11.0	5.5

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
3/1/2006	43	11.0	5.5
3/2/2006	41	11.0	5.5
3/3/2006	39	11.0	5.5
3/4/2006	41	13.0	6.5
3/5/2006	48	12.0	6.0
3/6/2006	46	11.0	5.5
3/7/2006	45	11.0	5.5
3/8/2006	44	12.0	6.0
3/9/2006	46	11.0	5.5
3/10/2006	48	11.0	5.5
3/11/2006	51	11.0	5.5
3/12/2006	47	11.0	5.5
3/13/2006	47	9.2	4.6
3/14/2006	46	9.1	4.6
3/15/2006	42	10.0	5.0
3/16/2006	40	9.4	4.7
3/17/2006	39	9.3	4.7
3/18/2006	42	9.7	4.9
3/19/2006	47	12.0	6.0
3/20/2006	70	14.0	7.0
3/21/2006	95	13.0	6.5
3/22/2006	81	13.0	6.5
3/23/2006	66	17.0	8.5
3/24/2006	62	17.0	8.5
3/25/2006	59	15.0	7.5
3/26/2006	53	14.0	7.0
3/27/2006	51	13.0	6.5
3/28/2006	48	12.0	6.0
3/29/2006	47	12.0	6.0
3/30/2006	47	13.0	6.5
3/31/2006	60	12.0	6.0

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
4/1/2006	57	11.0	5.5
4/2/2006	49	11.0	5.5
4/3/2006	44	11.0	5.5
4/4/2006	44	37.0	18.5
4/5/2006	70	24.0	12.0
4/6/2006	60	18.0	9.0
4/7/2006	53	15.0	7.5
4/8/2006	52	13.0	6.5
4/9/2006	50	11.0	5.5
4/10/2006	44	11.0	5.5
4/11/2006	43	12.0	6.0
4/12/2006	43	11.0	5.5
4/13/2006	43	10.0	5.0
4/14/2006	42	9.7	4.9
4/15/2006	41	9.5	4.8
4/16/2006	38	8.7	4.4
4/17/2006	36	8.5	4.3
4/18/2006	34	8.2	4.1
4/19/2006	31	7.6	3.8
4/20/2006	31	7.7	3.9
4/21/2006	31	7.5	3.8
4/22/2006	29	7.5	3.8
4/23/2006	29	7.5	3.8
4/24/2006	38	8.6	4.3
4/25/2006	48	8.3	4.2
4/26/2006	58	8.0	4.0
4/27/2006	37	7.7	3.9
4/28/2006	53	16.0	8.0
4/29/2006	195	22.0	11.0
4/30/2006	154	57.0	28.5

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
5/1/2006	136	85.0	42.5
5/2/2006	129	50.0	25.0
5/3/2006	88	24.0	12.0
5/4/2006	275	23.0	11.5
5/5/2006	139	19.0	9.5
5/6/2006	68	17.0	8.5
5/7/2006	64	19.0	9.5
5/8/2006	62	41.0	20.5
5/9/2006	292	67.0	33.5
5/10/2006	322	31.0	15.5
5/11/2006	116	54.0	27.0
5/12/2006	113	76.0	38.0
5/13/2006	122	55.0	27.5
5/14/2006	92	27.0	13.5
5/15/2006	69	17.0	8.5
5/16/2006	56	13.0	6.5
5/17/2006	49	12.0	6.0
5/18/2006	46	10.0	5.0
5/19/2006	43	9.7	4.9
5/20/2006	39	9.2	4.6
5/21/2006	37	9.0	4.5
5/22/2006	38	8.9	4.5
5/23/2006	37	8.7	4.4
5/24/2006	41	8.4	4.2
5/25/2006	35	8.0	4.0
5/26/2006	34	8.4	4.2
5/27/2006	30	8.9	4.5
5/28/2006	29	8.7	4.4
5/29/2006	29	8.4	4.2
5/30/2006	28	8.4	4.2
5/31/2006	30	8.9	4.5

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
6/1/2006	37	29.0	14.5
6/2/2006	88	56.0	28.0
6/3/2006	106	22.0	11.0
6/4/2006	62	12.0	6.0
6/5/2006	44	9.1	4.6
6/6/2006	43	10.0	5.0
6/7/2006	36	8.2	4.1
6/8/2006	30	7.5	3.8
6/9/2006	26	6.8	3.4
6/10/2006	21	6.3	3.2
6/11/2006	18	6.4	3.2
6/12/2006	27	6.6	3.3
6/13/2006	22	5.6	2.8
6/14/2006	18	5.5	2.8
6/15/2006	16	6.5	3.3
6/16/2006	16	7.0	3.5
6/17/2006	27	8.3	4.2
6/18/2006	37	7.2	3.6
6/19/2006	29	7.1	3.6
6/20/2006	30	6.9	3.5
6/21/2006	27	6.4	3.2
6/22/2006	141	208.0	104.0
6/23/2006	692	596.0	298.0
6/24/2006	851	398.0	199.0
6/25/2006	399	119.0	59.5
6/26/2006	173	57.0	28.5
6/27/2006	94	28.0	14.0
6/28/2006	64	18.0	9.0
6/29/2006	51	13.0	6.5
6/30/2006	41	11.0	5.5

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
7/1/2006	33	8.7	4.4
7/2/2006	27	8.1	4.1
7/3/2006	22	7.3	3.7
7/4/2006	18	6.5	3.3
7/5/2006	18	6.4	3.2
7/6/2006	16	6.5	3.3
7/7/2006	14	6.3	3.2
7/8/2006	13	5.5	2.8
7/9/2006	15	5.4	2.7
7/10/2006	19	6.6	3.3
7/11/2006	22	6.6	3.3
7/12/2006	20	6.3	3.2
7/13/2006	15	6.0	3.0
7/14/2006	14	5.8	2.9
7/15/2006	14	5.2	2.6
7/16/2006	14	5.4	2.7
7/17/2006	13	6.1	3.1
7/18/2006	12	10.2	2.9
7/19/2006	12	14.2	2.2
7/20/2006	10	18.3	8.9
7/21/2006	10	22.3	15.7
7/22/2006	9.9	26.4	22.5
7/23/2006	9.7	30.4	29.3
7/24/2006	9.6	34.5	36.1
7/25/2006	9	38.5	42.9
7/26/2006	9	75.8	49.7
7/27/2006	11	113.0	56.5
7/28/2006	111	79.0	39.5
7/29/2006	84	15.0	7.5
7/30/2006	34	8.5	4.3
7/31/2006	19	6.5	3.3

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
8/1/2006	13	5.0	2.5
8/2/2006	11	4.1	2.1
8/3/2006	22	4.5	2.3
8/4/2006	34	4.6	2.3
8/5/2006	19	4.6	2.3
8/6/2006	15	4.6	2.3
8/7/2006	13	4.3	2.2
8/8/2006	9.2	4.3	2.2
8/9/2006	7.7	4.2	2.3
8/10/2006	7.6	4.2	2.3
8/11/2006	7.6	4.1	2.4
8/12/2006	8.6	4.1	2.4
8/13/2006	8.4	4.0	2.5
8/14/2006	10	4.0	2.5
8/15/2006	11	5.2	2.6
8/16/2006	11	4.8	2.4
8/17/2006	16	4.4	2.2
8/18/2006	15	4.4	2.2
8/19/2006	17	4.2	2.1
8/20/2006	20	3.8	1.9
8/21/2006	19	4.0	2.0
8/22/2006	19	4.0	2.0
8/23/2006	20	4.2	2.1
8/24/2006	15	4.1	2.1
8/25/2006	14	3.9	2.0
8/26/2006	16	3.8	1.9
8/27/2006	47	5.5	2.8
8/28/2006	67	4.6	2.3
8/29/2006	36	3.7	1.9
8/30/2006	23	3.5	1.8
8/31/2006	17	3.4	1.7

Table A-6 Average stream flowrate per day (cfs) for sites int eh Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
9/1/2006	14	3.2	1.6
9/2/2006	12	3.1	1.6
9/3/2006	12	3.0	1.5
9/4/2006	11	2.7	1.4
9/5/2006	9.8	2.5	1.3
9/6/2006	8.7	2.4	1.2
9/7/2006	8.8	2.4	1.2
9/8/2006	9.9	2.5	1.3
9/9/2006	10	2.6	1.3
9/10/2006	12	2.5	1.3
9/11/2006	12	2.4	1.2
9/12/2006	12	2.2	1.1
9/13/2006	12	2.2	1.1
9/14/2006	11	2.1	1.1
9/15/2006	10	2.0	1.0
9/16/2006	10	1.9	1.0
9/17/2006	11	2.0	1.0
9/18/2006	10	1.8	0.9
9/19/2006	11	1.7	0.9
9/20/2006	11	1.7	0.9
9/21/2006	12	1.7	0.9
9/22/2006	11	1.6	0.8
9/23/2006	11	1.6	0.8
9/24/2006	11	1.5	0.8
9/25/2006	11	1.5	0.8
9/26/2006	11	1.4	0.7
9/27/2006	11	1.4	0.7
9/28/2006	11	1.4	0.7
9/29/2006	11	1.3	0.7
9/30/2006	11	1.3	0.7

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
10/1/2006	11	1.3	0.7
10/2/2006	11	1.3	0.7
10/3/2006	11	1.2	0.6
10/4/2006	10	1.2	0.6
10/5/2006	9.8	1.1	0.6
10/6/2006	9.8	1.1	0.6
10/7/2006	10	1.1	0.6
10/8/2006	10	1.0	0.5
10/9/2006	10	0.9	0.5
10/10/2006	11	1.0	0.5
10/11/2006	12	1.1	0.6
10/12/2006	12	1.1	0.6
10/13/2006	13	1.2	0.6
10/14/2006	12	1.2	0.6
10/15/2006	12	1.4	0.7
10/16/2006	13	1.6	0.8
10/17/2006	12	1.6	0.8
10/18/2006	12	1.6	0.8
10/19/2006	12	1.6	0.8
10/20/2006	13	1.7	0.9
10/21/2006	13	1.8	0.9
10/22/2006	13	1.8	0.9
10/23/2006	14	1.8	0.9
10/24/2006	14	1.9	1.0
10/25/2006	14	1.9	1.0
10/26/2006	14	2.0	1.0
10/27/2006	15	2.0	1.0
10/28/2006	19	2.1	1.1
10/29/2006	21	2.2	1.1
10/30/2006	15	2.2	1.1
10/31/2006	14	2.5	1.3

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
11/1/2006	13	3.0	1.5
11/2/2006	13	2.8	1.4
11/3/2006	15	2.7	1.4
11/4/2006	15	2.6	1.3
11/5/2006	15	2.6	1.3
11/6/2006	15	2.6	1.3
11/7/2006	14	2.7	1.4
11/8/2006	14	2.9	1.5
11/9/2006	14	3.0	1.5
11/10/2006	13	2.7	1.4
11/11/2006	12	2.5	1.3
11/12/2006	13	2.6	1.3
11/13/2006	14	2.6	1.3
11/14/2006	13	2.8	1.4
11/15/2006	15	2.7	1.4
11/16/2006	14	2.7	1.4
11/17/2006	14	2.8	1.4
11/18/2006	14	2.8	1.4
11/19/2006	14	2.9	1.5
11/20/2006	14	3.1	1.6
11/21/2006	15	3.2	1.6
11/22/2006	15	3.2	1.6
11/23/2006	15	3.3	1.7
11/24/2006	16	3.3	1.7
11/25/2006	16	3.3	1.7
11/26/2006	15	3.4	1.7
11/27/2006	15	3.4	1.7
11/28/2006	17	3.4	1.7
11/29/2006	17	3.4	1.7
11/30/2006	15	3.3	1.7

Table A-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2006 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
12/1/2006	14	3.4	1.7
12/2/2006	14	3.5	1.8
12/3/2006	14	3.5	1.8
12/4/2006	14	3.5	1.8
12/5/2006	15	3.6	1.8
12/6/2006	15	3.6	1.8
12/7/2006	15	3.7	1.9
12/8/2006	14	3.8	1.9
12/9/2006	15	3.9	2.0
12/10/2006	15	3.9	2.0
12/11/2006	16	4.0	2.0
12/12/2006	16	4.0	2.0
12/13/2006	16	4.0	2.0
12/14/2006	16	4.1	2.1
12/15/2006	16	4.1	2.1
12/16/2006	16	4.2	2.1
12/17/2006	16	4.2	2.1
12/18/2006	16	4.2	2.1
12/19/2006	15	4.2	2.1
12/20/2006	20	4.8	2.4
12/21/2006	28	4.7	2.4
12/22/2006	30	4.6	2.3
12/23/2006	22	4.9	2.5
12/24/2006	20	5.0	2.5
12/25/2006	20	4.8	2.4
12/26/2006	19	4.7	2.4
12/27/2006	19	4.7	2.4
12/28/2006	19	4.8	2.4
12/29/2006	19	4.8	2.4
12/30/2006	22	5.2	2.6
12/31/2006	28	5.2	2.6

Appendix B - 2007 Main Stem Data

Table B- 1 Discrete atrazine concentrations (μg/l) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
01-31	0.30	0.30	0.30
02-20	3.12	0.33	0.57
03-24	0.85	0.59	0.47
04-03	1.66	1.60	4.60
04-17	2.12	2.38	1.31
04-24	0.80	0.79	0.92
05-01	1.57	0.58	0.71
05-07	4.80	10.28	8.24
05-15	3.48	3.22	1.93
05-22	2.88	1.35	1.56
05-25	3.52	4.70	4.16
05-31	3.16	3.30	0.84
06-06	2.50	1.47	1.09
06-14	1.66	6.27	0.45
06-20	2.60	3.50	6.66
06-28	5.10	3.28	5.78
07-05	5.22	7.43	5.12
07-11	5.49	3.77	3.89
07-19	0.30	2.45	1.91
07-25	0.93	2.05	1.45
07-31	3.58	7.59	3.78
08-15	0.30	0.30	0.30
08-23	0.30	0.30	0.30
09-11	0.30	0.30	0.30
09-16	0.30	0.30	0.30
10-31	0.30	0.30	0.30
11-30	0.30	0.30	0.30
12-31	0.30	0.30	0.30

Table B-2 Discrete total suspended solids concentrations (mg/l) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
01-31	76	14	51
02-20	108	4	76
03-24	92	128	48
04-03	324	156	148
04-17	252	288	196
04-24	92	100	84
05-01	80	100	116
05-07	240	812	130
05-15	512	316	148
05-22	609	100	168
05-25	2292	364	156
05-31	264	284	132
06-06	168	208	76
06-14	132	164	0
06-20	28	44	68
06-28	100	128	860
07-05	416	700	376
07-11	388	246	312
07-19	194	96	52
07-25	43	8	64
07-31	440	444	172
08-15	24	72	40
08-23	92	64	8
09-11	48	88	100
09-16	8	56	64
10-31	11	56	83
11-30	15	4	136
12-31	158	126	215

Table B-3 Discrete total nitrogen concentrations (mg/l) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
01-31	5.34	1.15	0.63
02-20	8.76	1.83	1.02
03-24	3.66	1.21	1.14
04-03	3.62	3.03	2.77
04-17	4.04	3.17	3.42
04-24	3.10	2.01	2.18
05-01	2.83	3.12	2.36
05-07	3.32	4.08	2.27
05-15	2.19	2.31	2.19
05-22	2.03	1.84	1.80
05-25	5.51	2.92	2.11
05-31	2.42	2.26	1.87
06-06	1.77	1.88	1.73
06-14	1.75	2.46	1.36
06-20	1.79	2.57	3.30
06-28	1.70	2.68	5.23
07-05	3.36	4.10	2.84
07-11	2.78	2.61	3.41
07-19	1.72	1.58	1.49
07-25	0.92	1.11	1.04
07-31	5.53	4.60	3.73
08-15	1.24	0.87	1.20
08-23	1.03	0.70	2.34
09-11	1.06	0.76	1.07
09-16	0.95	0.84	1.23
10-31	0.84	0.38	0.52
11-30	0.72	0.15	0.42
12-31	1.24	0.42	0.88

Table B-4 Discrete total phosphorus concentrations (mg/l) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
01-31	0.71	0.37	0.17
02-20	1.04	0.47	0.23
03-24	0.94	0.42	0.52
04-03	0.98	0.78	0.57
04-17	0.64	0.71	0.56
04-24	0.74	0.47	0.31
05-01	0.51	0.42	0.34
05-07	0.84	1.18	0.42
05-15	1.24	1.03	0.52
05-22	0.68	0.64	0.43
05-25	1.90	0.70	0.50
05-31	0.96	0.93	0.36
06-06	0.88	0.90	0.37
06-14	0.67	0.79	0.39
06-20	0.70	0.68	0.81
06-28	0.72	0.56	1.09
07-05	0.92	1.14	0.78
07-11	0.94	0.89	0.84
07-19	0.67	0.48	0.33
07-25	0.47	0.50	0.41
07-31	1.16	1.19	0.99
08-15	0.60	0.45	0.38
08-23	0.49	0.43	0.39
09-11	0.44	0.43	0.41
09-16	0.40	0.41	0.39
10-31	0.42	0.15	0.16
11-30	0.38	0.24	0.18
12-31	0.62	0.44	0.39

Table B-5 Discrete E. coli populations (colonies/100 ml) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
01-31	0	0	0
02-20	0	0	0
03-24	200	1000	0
04-03	7000	30000	20000
04-17	20000	5000	14000
04-24	0	200	200
05-01	200	0	100
05-07	1000	10000	486
05-15	4000	1000	1000
05-22	10000	1000	10000
05-25	0	0	0
05-31	100	0	0
06-06	30000	0	100
06-14	100	500	2000
06-20	0	100	300
06-28	0	0	0
07-05	4000	10000	0
07-11	0	5000	3000
07-19	0	300	0
07-25	0	100	0
07-31	1000	5000	500
08-15	200	2000	0
08-23	0	300	1000
09-11	300	900	1300
09-16	0	0	1000
10-31	0	0	196
11-30	0	0	0
12-31	0	0	0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007.

Date	Site		
	Valley Center	HW 50	HW 61
1/1/2006	38	5.1	2.6
1/2/2006	29	7.1	3.6
1/3/2006	29	6.7	3.4
1/4/2006	34	6.1	3.1
1/5/2006	28	5.5	2.8
1/6/2006	25	5.2	2.6
1/7/2006	23	5.1	2.6
1/8/2006	21	5.1	2.6
1/9/2006	21	5.1	2.6
1/10/2006	19	5.3	2.7
1/11/2006	20	5.4	2.7
1/12/2006	19	5.4	2.7
1/13/2006	16	5.5	2.8
1/14/2006	15	5.6	2.8
1/15/2006	14	5.7	2.9
1/16/2006	13	5.8	2.9
1/17/2006	16	6	3.0
1/18/2006	21	6.2	3.1
1/19/2006	20	6.2	3.1
1/20/2006	20	6.6	3.3
1/21/2006	20	6.9	3.5
1/22/2006	18	6.8	3.4
1/23/2006	16	7.1	3.6
1/24/2006	19	7.4	3.7
1/25/2006	21	7.7	3.9
1/26/2006	23	8.1	4.1
1/27/2006	25	8.7	4.4
1/28/2006	28	8.7	4.4
1/29/2006	27	9	4.5
1/30/2006	25	9.4	4.7
1/31/2006	23	9.2	4.6

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
2/1/2006	22	9	4.5
2/2/2006	21	8.9	4.5
2/3/2006	20	8.9	4.5
2/4/2006	20	9	4.5
2/5/2006	22	8.7	4.4
2/6/2006	22	11	5.5
2/7/2006	28	15	7.5
2/8/2006	45	11	5.5
2/9/2006	45	10	5.0
2/10/2006	35	9.8	4.9
2/11/2006	29	9.8	4.9
2/12/2006	30	16	8.0
2/13/2006	121	32	16.0
2/14/2006	205	13	6.5
2/15/2006	304	11	5.5
2/16/2006	141	10	5.0
2/17/2006	88	10	5.0
2/18/2006	52	12	6.0
2/19/2006	53	15	7.5
2/20/2006	59	32	16.0
2/21/2006	66	45	22.5
2/22/2006	90	40	20.0
2/23/2006	76	28	14.0
2/24/2006	63	20	10.0
2/25/2006	54	15	7.5
2/26/2006	47	13	6.5
2/27/2006	38	12	6.0
2/28/2006	32	11	5.5

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
3/1/2006	28	11	5.5
3/2/2006	26	9.9	5.0
3/3/2006	23	9.3	4.7
3/4/2006	22	9.8	4.9
3/5/2006	22	10	5.0
3/6/2006	22	10	5.0
3/7/2006	21	10	5.0
3/8/2006	20	10	5.0
3/9/2006	20	10	5.0
3/10/2006	21	11	5.5
3/11/2006	20	11	5.5
3/12/2006	21	11	5.5
3/13/2006	21	11	5.5
3/14/2006	21	11	5.5
3/15/2006	21	11	5.5
3/16/2006	21	10	5.0
3/17/2006	20	10	5.0
3/18/2006	21	10	5.0
3/19/2006	21	9.7	4.9
3/20/2006	30	13	6.5
3/21/2006	39	14	7.0
3/22/2006	38	11	5.5
3/23/2006	32	11	5.5
3/24/2006	37	33	16.5
3/25/2006	148	481	240.5
3/26/2006	436	203	101.5
3/27/2006	195	76	38.0
3/28/2006	100	66	33.0
3/29/2006	111	132	66.0
3/30/2006	188	106	53.0
3/31/2006	773	652	326.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
4/1/2006	2010	2300	1150.0
4/2/2006	2640	2370	1185.0
4/3/2006	1620	661	330.5
4/4/2006	531	239	119.5
4/5/2006	285	128	64.0
4/6/2006	191	85	42.5
4/7/2006	140	62	31.0
4/8/2006	109	46	23.0
4/9/2006	92	36	18.0
4/10/2006	82	30	15.0
4/11/2006	77	26	13.0
4/12/2006	75	23	11.5
4/13/2006	77	36	18.0
4/14/2006	924	296	148.0
4/15/2006	3430	1880	940.0
4/16/2006	3370	2560	1280.0
4/17/2006	2320	1120	560.0
4/18/2006	974	400	200.0
4/19/2006	477	203	101.5
4/20/2006	292	126	63.0
4/21/2006	202	89	44.5
4/22/2006	154	67	33.5
4/23/2006	125	51	25.5
4/24/2006	107	39	19.5
4/25/2006	99	34	17.0
4/26/2006	108	30	15.0
4/27/2006	113	35	17.5
4/28/2006	103	45	22.5
4/29/2006	100	38	19.0
4/30/2006	87	29	14.5

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
5/1/2006	78	26	13.0
5/2/2006	78	28	14.0
5/3/2006	90	116	58.0
5/4/2006	216	191	95.5
5/5/2006	230	177	88.5
5/6/2006	316	438	219.0
5/7/2006	6100	3100	1550.0
5/8/2006	6700	5100	2550.0
5/9/2006	4740	5860	2930.0
5/10/2006	4110	4740	2370.0
5/11/2006	2710	1550	775.0
5/12/2006	1100	546	273.0
5/13/2006	599	294	147.0
5/14/2006	395	192	96.0
5/15/2006	353	175	87.5
5/16/2006	694	275	137.5
5/17/2006	532	299	149.5
5/18/2006	378	193	96.5
5/19/2006	245	117	58.5
5/20/2006	174	86	43.0
5/21/2006	138	71	35.5
5/22/2006	115	61	30.5
5/23/2006	104	62	31.0
5/24/2006	2850	6200	3100.0
5/25/2006	7870	10200	5100.0
5/26/2006	7390	10400	5200.0
5/27/2006	8610	9140	4570.0
5/28/2006	6700	5910	2955.0
5/29/2006	3560	2230	1115.0
5/30/2006	2030	1490	745.0
5/31/2006	1620	1240	620.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
6/1/2006	2410	2370	1185.0
6/2/2006	5110	3900	1950.0
6/3/2006	4810	3940	1970.0
6/4/2006	2950	1770	885.0
6/5/2006	1740	865	432.5
6/6/2006	1050	540	270.0
6/7/2006	689	357	178.5
6/8/2006	495	250	125.0
6/9/2006	369	180	90.0
6/10/2006	300	144	72.0
6/11/2006	257	120	60.0
6/12/2006	218	113	56.5
6/13/2006	218	162	81.0
6/14/2006	262	154	77.0
6/15/2006	362	156	78.0
6/16/2006	333	138	69.0
6/17/2006	251	124	62.0
6/18/2006	216	117	58.5
6/19/2006	185	93	46.5
6/20/2006	182	82	41.0
6/21/2006	294	71	35.5
6/22/2006	169	63	31.5
6/23/2006	125	61	30.5
6/24/2006	110	60	30.0
6/25/2006	101	81	40.5
6/26/2006	144	143	71.5
6/27/2006	162	88	44.0
6/28/2006	128	114	57.0
6/29/2006	373	541	270.5
6/30/2006	886	452	226.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
7/1/2006	618	193	96.5
7/2/2006	392	112	56.0
7/3/2006	257	88	44.0
7/4/2006	191	78	39.0
7/5/2006	583	840	420.0
7/6/2006	1830	1810	905.0
7/7/2006	1670	1080	540.0
7/8/2006	751	343	171.5
7/9/2006	346	155	77.5
7/10/2006	409	824	412.0
7/11/2006	1670	1410	705.0
7/12/2006	1460	971	485.5
7/13/2006	721	274	137.0
7/14/2006	391	200	100.0
7/15/2006	291	138	69.0
7/16/2006	203	92	46.0
7/17/2006	148	69	34.5
7/18/2006	121	56	28.0
7/19/2006	104	42	21.0
7/20/2006	91	37	18.5
7/21/2006	82	46	23.0
7/22/2006	84	45	22.5
7/23/2006	78	31	15.5
7/24/2006	68	26	13.0
7/25/2006	63	25	12.5
7/26/2006	61	23	11.5
7/27/2006	57	22	11.0
7/28/2006	56	20	10.0
7/29/2006	56	30	15.0
7/30/2006	227	76	38.0
7/31/2006	1130	1310	655.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
8/1/2006	1990	2740	1370.0
8/2/2006	2030	2860	1430.0
8/3/2006	1880	1340	670.0
8/4/2006	690	390	195.0
8/5/2006	454	229	114.5
8/6/2006	278	146	73.0
8/7/2006	190	101	50.5
8/8/2006	144	82	41.0
8/9/2006	661	173	86.5
8/10/2006	882	88	44.0
8/11/2006	385	63	31.5
8/12/2006	201	55	27.5
8/13/2006	125	48	24.0
8/14/2006	96	38	19.0
8/15/2006	80	35	17.5
8/16/2006	73	32	16.0
8/17/2006	66	28	14.0
8/18/2006	60	28	14.0
8/19/2006	57	27	13.5
8/20/2006	55	24	12.0
8/21/2006	51	22	11.0
8/22/2006	47	22	11.0
8/23/2006	44	22	11.0
8/24/2006	45	22	11.0
8/25/2006	46	22	11.0
8/26/2006	47	20	10.0
8/27/2006	45	31	15.5
8/28/2006	52	31	15.5
8/29/2006	52	23	11.5
8/30/2006	46	20	10.0
8/31/2006	40	18	9.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
9/1/2006	35	21	10.5
9/2/2006	38	18	9.0
9/3/2006	37	16	8.0
9/4/2006	31	16	8.0
9/5/2006	29	16	8.0
9/6/2006	30	15	7.5
9/7/2006	31	16	8.0
9/8/2006	35	15	7.5
9/9/2006	34	15	7.5
9/10/2006	34	15	7.5
9/11/2006	35	16	8.0
9/12/2006	35	16	8.0
9/13/2006	33	15	7.5
9/14/2006	31	14	7.0
9/15/2006	29	14	7.0
9/16/2006	26	16	8.0
9/17/2006	58	101	50.5
9/18/2006	140	80	40.0
9/19/2006	101	168	84.0
9/20/2006	223	210	105.0
9/21/2006	171	96	48.0
9/22/2006	100	54	27.0
9/23/2006	72	39	19.5
9/24/2006	62	24	12.0
9/25/2006	52	17	8.5
9/26/2006	45	13	6.5
9/27/2006	39	11	5.5
9/28/2006	34	10	5.0
9/29/2006	31	9.6	4.8
9/30/2006	30	8.8	4.4

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
10/1/2006	29	8.1	4.1
10/2/2006	28	8.2	4.1
10/3/2006	28	8.3	4.2
10/4/2006	26	8.3	4.2
10/5/2006	25	8.7	4.4
10/6/2006	25	8.8	4.4
10/7/2006	25	8.3	4.2
10/8/2006	26	8.5	4.3
10/9/2006	27	8.9	4.5
10/10/2006	26	53	26.5
10/11/2006	73	69	34.5
10/12/2006	79	34	17.0
10/13/2006	59	21	10.5
10/14/2006	63	16	8.0
10/15/2006	106	26	13.0
10/16/2006	129	57	28.5
10/17/2006	190	54	27.0
10/18/2006	180	108	54.0
10/19/2006	261	382	191.0
10/20/2006	454	273	136.5
10/21/2006	230	93	46.5
10/22/2006	119	46	23.0
10/23/2006	79	25	12.5
10/24/2006	62	16	8.0
10/25/2006	52	13	6.5
10/26/2006	46	11	5.5
10/27/2006	43	10	5.0
10/28/2006	39	9.4	4.7
10/29/2006	37	8.9	4.5
10/30/2006	36	8.8	4.4
10/31/2006	34	8.1	4.1

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
11/1/2006	31	7.7	3.9
11/2/2006	29	8.1	4.1
11/3/2006	29	9.2	4.6
11/4/2006	29	9.2	4.6
11/5/2006	29	8.9	4.5
11/6/2006	27	8.7	4.4
11/7/2006	27	9.2	4.6
11/8/2006	27	9.3	4.7
11/9/2006	28	9.8	4.9
11/10/2006	27	11	5.5
11/11/2006	28	12	6.0
11/12/2006	29	12	6.0
11/13/2006	29	13	6.5
11/14/2006	28	12	6.0
11/15/2006	29	13	6.5
11/16/2006	28	14	7.0
11/17/2006	29	11	5.5
11/18/2006	30	11	5.5
11/19/2006	29	11	5.5
11/20/2006	29	11	5.5
11/21/2006	29	11	5.5
11/22/2006	28	11	5.5
11/23/2006	28	11	5.5
11/24/2006	31	11	5.5
11/25/2006	32	12	6.0
11/26/2006	32	12	6.0
11/27/2006	32	12	6.0
11/28/2006	33	12	6.0
11/29/2006	32	12	6.0
11/30/2006	31	12	6.0

Table B-6 Average stream flowrate per day (cfs) for sites in the Little Arkansas River main stem study for 2007 (Continued).

Date	Site		
	Valley Center	HW 50	HW 61
12/1/2006	33	13	6.5
12/2/2006	35	13	6.5
12/3/2006	35	13	6.5
12/4/2006	36	13	6.5
12/5/2006	37	13	6.5
12/6/2006	33	14	7.0
12/7/2006	34	14	7.0
12/8/2006	34	13	6.5
12/9/2006	34	13	6.5
12/10/2006	36	13	6.5
12/11/2006	63	294	147.0
12/12/2006	1490	1740	870.0
12/13/2006	2480	2830	1415.0
12/14/2006	2310	1950	975.0
12/15/2006	1310	665	332.5
12/16/2006	577	405	202.5
12/17/2006	396	373	186.5
12/18/2006	340	270	135.0
12/19/2006	256	146	73.0
12/20/2006	198	106	53.0
12/21/2006	172	91	45.5
12/22/2006	176	123	61.5
12/23/2006	328	208	104.0
12/24/2006	412	306	153.0
12/25/2006	383	223	111.5
12/26/2006	267	132	66.0
12/27/2006	192	103	51.5
12/28/2006	162	98	49.0
12/29/2006	137	93	46.5
12/30/2006	148	88	44.0
12/31/2006	144	77	38.5

Appendix C - 2006 Paired Data

Table C-1 Discrete atrazine concentrations (μg/l) for sites in the Little Arkansas River paired watershed study for 2006

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
01-31	0.00	0.00	0.30	0.30	0.00
02-28	0.00	0.00	0.30	0.30	0.00
03-31	0.30	0.30	0.30	0.30	0.30
04-07	0.39	0.56	0.30	0.46	2.39
04-14	0.00	0.00	0.30	0.56	4.42
04-21	0.00	0.00	0.30	0.52	3.67
04-29	4.50	2.34	0.50	8.50	7.25
05-06	8.26	3.89	1.56	10.30	4.26
05-13	1.01	6.89	4.14	15.60	3.01
05-20	0.00	0.00	2.51	8.10	0.00
05-31	16.48	0.00	1.89	4.48	2.48
06-07	0.00	0.00	2.86	7.20	0.00
06-22	4.59	0.00	8.87	6.70	5.51
06-28	4.23	0.30	3.82	23.10	0.00
07-05	0.00	0.00	1.30	11.40	0.00
07-31	0.00	0.30	0.42	2.42	4.22
08-03	0.30	0.00	0.30	1.56	2.10
08-14	0.30	0.00	0.30	0.61	0.30
08-20	0.30	0.00	0.30	0.68	0.00
09-16	0.00	0.00	0.30	0.30	0.00
09-30	0.30	0.00	0.30	0.30	0.00
10-27	0.00	0.00	0.30	0.30	0.00
11-30	0.00	0.00	0.30	0.30	0.00
12-31	0.00	0.30	0.30	0.30	0.00

Table C-2 Discrete total suspended solids (mg/l) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
01-31	0.0	0.0	0.0	0.0	0.0
02-28	0.0	0.0	0.0	0.0	0.0
03-31	21.0	18.0	18.0	18.0	46.0
04-07	34.0	29.0	29.0	29.0	129.0
04-14	0.0	0.0	0.0	0.0	42.3
04-21	0.0	0.0	0.0	0.0	15.6
04-29	54.3	79.2	79.2	79.2	169.5
05-06	79.2	101.5	101.5	101.5	131.5
05-13	24.8	18.4	18.4	18.4	58.3
05-20	0.0	0.0	0.0	0.0	0.0
05-31	101.0	128.0	128.0	128.0	257.4
06-07	0.0	0.0	0.0	0.0	0.0
06-22	169.0	169.0	169.0	169.0	116.0
06-28	51.0	51.0	51.0	51.0	0.0
07-05	0.0	0.0	0.0	0.0	0.0
07-31	0.0	0.0	0.0	0.0	55.1
08-03	15.3	18.4	18.4	18.4	38.4
08-14	10.4	11.6	11.6	11.6	21.9
08-20	15.9	21.2	21.2	21.2	0.0
09-16	10.4	11.8	11.8	11.8	0.0
09-30	0.0	0.0	0.0	0.0	0.0
10-27	15.8	27.2	27.2	27.2	0.0
11-30	0.0	0.0	0.0	0.0	0.0
12-31	0.0	0.0	0.0	0.0	0.0

Table C-3 Discrete nitrogen concentrations (mg/l) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
01-31	0.00	0.00	0.00	0.43	0.00
02-28	0.00	0.00	0.00	0.32	0.00
03-31	0.50	0.42	0.50	0.43	0.36
04-07	0.64	0.58	0.64	0.32	2.87
04-14	0.00	0.00	0.00	0.22	1.45
04-21	0.00	0.00	0.00	0.14	0.64
04-29	1.12	0.82	1.12	1.15	3.56
05-06	1.23	0.96	1.23	1.46	2.38
05-13	0.59	0.38	0.59	0.43	1.01
05-20	0.00	0.00	0.00	0.65	0.00
05-31	1.34	1.34	1.34	0.48	1.56
06-07	0.00	0.00	0.00	0.67	0.00
06-22	3.43	5.95	1.36	2.74	3.88
06-28	0.91	0.81	0.51	1.97	0.00
07-05	0.00	0.00	0.00	0.65	0.00
07-31	0.00	0.00	0.00	1.68	2.41
08-03	0.32	0.32	0.32	1.01	0.82
08-14	0.15	0.15	0.15	0.38	0.35
08-20	0.05	0.05	0.05	0.20	0.00
09-16	0.03	0.03	0.03	0.14	0.00
09-30	0.00	0.00	0.00	0.18	0.00
10-27	0.03	0.03	0.03	0.32	0.00
11-30	0.00	0.00	0.00	0.20	0.00
12-31	0.00	0.00	0.00	0.32	0.00

Table C-4 Discrete phosphorus concentrations (mg/l) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
01-31	0.00	0.00	0.00	0.00	0.00
02-28	0.00	0.00	0.00	0.00	0.00
03-31	0.10	0.10	0.10	0.10	0.10
04-07	0.18	0.18	0.18	0.18	0.18
04-14	0.00	0.00	0.00	0.00	0.00
04-21	0.00	0.00	0.00	0.00	0.00
04-29	0.48	0.48	0.48	0.48	0.48
05-06	0.61	0.61	0.61	0.61	0.61
05-13	0.08	0.08	0.08	0.08	0.08
05-20	0.00	0.00	0.00	0.00	0.00
05-31	1.24	0.87	0.87	0.87	0.87
06-07	0.00	0.00	0.00	0.00	0.00
06-22	1.21	0.60	0.91	0.91	0.91
06-28	0.07	0.05	0.07	0.07	0.07
07-05	0.00	0.00	0.00	0.00	0.00
07-31	0.00	0.00	0.00	0.00	0.00
08-03	0.04	0.04	0.04	0.04	0.04
08-14	0.02	0.02	0.02	0.02	0.02
08-20	0.02	0.02	0.02	0.02	0.02
09-16	0.01	0.01	0.01	0.01	0.01
09-30	0.00	0.00	0.00	0.00	0.00
10-27	0.01	0.01	0.01	0.01	0.01
11-30	0.00	0.00	0.00	0.00	0.00
12-31	0.00	0.00	0.00	0.00	0.00

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
1/1/2006	0.1	0.1	1.9	4.0	0.1
1/2/2006	0.1	0.1	1.9	4.1	0.1
1/3/2006	0.1	0.1	1.9	4.0	0.1
1/4/2006	0.1	0.1	1.9	4.0	0.1
1/5/2006	0.1	0.1	1.9	4.0	0.1
1/6/2006	0.1	0.1	1.8	3.8	0.1
1/7/2006	0.1	0.1	1.8	3.8	0.1
1/8/2006	0.1	0.1	1.8	3.6	0.1
1/9/2006	0.1	0.1	1.8	3.8	0.1
1/10/2006	0.1	0.1	1.8	3.6	0.1
1/11/2006	0.1	0.1	1.8	3.8	0.1
1/12/2006	0.1	0.1	1.8	3.8	0.1
1/13/2006	0.1	0.1	1.9	4.0	0.1
1/14/2006	0.1	0.1	1.8	3.8	0.1
1/15/2006	0.1	0.1	1.8	3.6	0.1
1/16/2006	0.1	0.1	1.9	4.0	0.1
1/17/2006	0.1	0.1	1.9	4.1	0.1
1/18/2006	0.1	0.1	1.8	3.8	0.1
1/19/2006	0.1	0.1	1.8	3.6	0.1
1/20/2006	0.1	0.1	1.8	3.8	0.1
1/21/2006	0.1	0.1	1.8	3.6	0.1
1/22/2006	0.1	0.1	1.8	3.6	0.1
1/23/2006	0.1	0.1	1.8	3.6	0.1
1/24/2006	0.1	0.1	1.8	3.6	0.1
1/25/2006	0.1	0.1	1.8	3.6	0.1
1/26/2006	0.1	0.1	1.8	3.6	0.1
1/27/2006	0.1	0.1	1.8	3.8	0.1
1/28/2006	0.1	0.1	1.8	3.6	0.1
1/29/2006	0.1	0.1	1.9	4.0	0.1
1/30/2006	0.1	0.1	1.9	4.1	0.1
1/31/2006	0.1	0.1	1.8	3.8	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
2/1/2006	0.1	0.1	1.9	4.0	0.1
2/2/2006	0.1	0.1	1.8	3.8	0.1
2/3/2006	0.1	0.1	1.8	3.8	0.1
2/4/2006	0.1	0.1	1.8	3.8	0.1
2/5/2006	0.1	0.1	1.7	3.6	0.1
2/6/2006	0.1	0.1	1.7	3.6	0.1
2/7/2006	0.1	0.1	1.7	3.5	0.1
2/8/2006	0.1	0.1	1.7	3.6	0.1
2/9/2006	0.1	0.1	1.7	3.6	0.1
2/10/2006	0.1	0.1	1.7	3.6	0.1
2/11/2006	0.1	0.1	1.6	3.4	0.1
2/12/2006	0.1	0.1	1.6	3.3	0.1
2/13/2006	0.1	0.1	1.6	3.3	0.1
2/14/2006	0.1	0.1	1.6	3.4	0.1
2/15/2006	0.1	0.1	1.6	3.4	0.1
2/16/2006	0.1	0.1	1.6	3.4	0.1
2/17/2006	0.1	0.1	1.6	3.4	0.1
2/18/2006	0.1	0.1	1.5	3.1	0.1
2/19/2006	0.1	0.1	1.4	3.0	0.1
2/20/2006	0.1	0.1	1.5	3.1	0.1
2/21/2006	0.1	0.1	1.6	3.3	0.1
2/22/2006	0.1	0.1	1.6	3.4	0.1
2/23/2006	0.1	0.1	1.6	3.4	0.1
2/24/2006	0.1	0.1	1.6	3.4	0.1
2/25/2006	0.1	0.1	1.7	3.5	0.1
2/26/2006	0.1	0.1	1.7	3.5	0.1
2/27/2006	0.1	0.1	1.8	3.8	0.1
2/28/2006	0.1	0.1	1.7	3.6	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
3/1/2006	0.1	0.1	1.8	3.7	0.1
3/2/2006	0.1	0.1	1.7	3.5	0.1
3/3/2006	0.1	0.1	1.6	3.3	0.1
3/4/2006	0.1	0.1	1.6	3.3	0.1
3/5/2006	0.1	0.1	2.0	4.2	0.1
3/6/2006	0.1	0.1	1.9	4.1	0.1
3/7/2006	0.1	0.1	1.9	4.0	0.1
3/8/2006	0.1	0.1	1.8	3.7	0.1
3/9/2006	0.1	0.1	1.9	4.1	0.1
3/10/2006	0.1	0.1	2.0	4.3	0.1
3/11/2006	0.1	0.1	2.2	4.7	0.1
3/12/2006	0.1	0.1	2.0	4.2	0.1
3/13/2006	0.1	0.1	2.1	4.4	0.1
3/14/2006	0.1	0.1	2.0	4.3	0.1
3/15/2006	0.1	0.1	1.8	3.7	0.1
3/16/2006	0.1	0.1	1.7	3.6	0.1
3/17/2006	0.1	0.1	1.6	3.5	0.1
3/18/2006	0.1	0.1	1.8	3.8	0.1
3/19/2006	1.2	0.7	1.9	4.1	10.4
3/20/2006	3.8	2.3	3.1	8.1	32.9
3/21/2006	3.9	2.3	4.5	11.9	30.4
3/22/2006	4.9	2.9	3.8	9.9	27.9
3/23/2006	3.2	1.9	2.7	7.1	25.4
3/24/2006	2.4	1.4	2.5	6.5	22.9
3/25/2006	1.9	1.1	2.4	6.4	20.4
3/26/2006	1.3	0.8	2.2	5.7	17.9
3/27/2006	1.0	0.6	2.1	5.5	15.4
3/28/2006	0.4	0.2	2.0	5.2	12.9
3/29/2006	0.3	0.2	1.9	5.1	10.4
3/30/2006	0.2	0.1	1.9	4.9	7.9
3/31/2006	0.5	0.1	2.7	7.0	5.4

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
4/1/2006	0.7	0.3	2.5	6.7	13.1
4/2/2006	0.6	0.4	2.1	5.5	20.8
4/3/2006	0.5	0.4	1.8	4.8	28.5
4/4/2006	5.4	0.3	0.4	1.0	29.7
4/5/2006	6.3	3.2	2.5	6.7	30.8
4/6/2006	4.2	3.8	2.3	6.1	32.0
4/7/2006	2.7	2.5	2.1	5.5	33.1
4/8/2006	1.0	1.6	2.2	5.7	34.3
4/9/2006	0.6	0.6	2.2	5.7	35.4
4/10/2006	0.4	0.4	1.8	4.8	31.1
4/11/2006	0.5	0.2	1.7	4.5	26.8
4/12/2006	0.3	0.3	1.8	4.6	22.5
4/13/2006	0.1	0.2	1.8	4.8	18.3
4/14/2006	0.1	0.1	1.8	4.7	14.0
4/15/2006	0.1	0.1	1.7	3.7	9.7
4/16/2006	0.1	0.1	1.6	3.4	5.4
4/17/2006	0.1	0.1	1.5	3.2	1.1
4/18/2006	0.1	0.1	1.4	3.0	1.0
4/19/2006	0.1	0.1	1.3	2.7	0.9
4/20/2006	0.1	0.1	1.3	2.7	0.8
4/21/2006	0.1	0.1	1.3	2.7	0.8
4/22/2006	0.1	0.1	1.2	2.5	0.7
4/23/2006	0.1	0.1	1.2	2.5	0.6
4/24/2006	0.1	0.1	1.6	3.4	0.5
4/25/2006	0.1	0.1	2.2	5.8	4.3
4/26/2006	0.1	0.1	2.8	7.3	10.2
4/27/2006	0.1	0.1	1.6	4.3	16.1
4/28/2006	0.1	0.1	2.0	5.4	22.1
4/29/2006	30.3	0.1	9.6	25.1	28.0
4/30/2006	24.6	25.8	5.4	14.1	33.9

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
5/1/2006	18.3	15.6	2.8	7.4	31.7
5/2/2006	10.1	8.6	4.4	11.5	29.5
5/3/2006	5.2	4.4	3.5	9.3	27.3
5/4/2006	29.6	25.2	14.0	36.6	25.2
5/5/2006	32.1	27.3	6.6	17.4	25.7
5/6/2006	35.0	29.8	2.8	7.4	26.2
5/7/2006	24.6	20.9	2.5	6.5	26.7
5/8/2006	14.2	12.1	1.2	3.0	27.3
5/9/2006	28.4	24.1	12.5	32.7	27.8
5/10/2006	25.1	21.3	16.1	42.2	23.8
5/11/2006	18.4	15.6	3.4	9.0	19.9
5/12/2006	10.9	9.3	2.0	5.4	15.9
5/13/2006	4.1	3.5	3.7	9.7	12.0
5/14/2006	1.9	1.6	3.6	9.4	8.0
5/15/2006	0.5	0.4	2.9	7.5	4.1
5/16/2006	0.1	0.1	2.4	6.2	0.1
5/17/2006	0.1	0.1	2.0	5.4	0.1
5/18/2006	0.1	0.1	2.0	5.2	0.1
5/19/2006	0.1	0.1	1.8	3.9	0.1
5/20/2006	0.1	0.1	1.7	3.5	0.1
5/21/2006	0.1	0.1	1.6	3.3	0.1
5/22/2006	0.1	0.1	1.6	3.4	0.1
5/23/2006	0.1	0.1	1.6	3.3	0.1
5/24/2006	0.1	0.1	1.8	3.8	0.1
5/25/2006	0.1	0.1	1.5	3.1	0.1
5/26/2006	0.1	0.1	1.4	3.0	0.1
5/27/2006	0.1	0.1	1.2	2.5	0.1
5/28/2006	0.1	0.1	1.1	2.4	0.1
5/29/2006	0.1	0.1	1.1	2.4	0.1
5/30/2006	0.1	0.1	1.1	2.3	0.1
5/31/2006	55.4	66.5	1.2	2.5	37.6

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
6/1/2006	28.6	34.3	0.4	0.9	44.5
6/2/2006	15.1	18.1	1.8	4.6	20.2
6/3/2006	5.3	6.4	4.7	12.2	6.4
6/4/2006	1.0	1.2	2.8	7.3	1.2
6/5/2006	0.4	0.5	1.9	5.1	0.5
6/6/2006	0.1	0.1	1.8	4.8	0.1
6/7/2006	0.1	0.1	1.5	4.0	0.1
6/8/2006	0.1	0.1	1.2	2.6	0.1
6/9/2006	0.1	0.1	1.1	2.2	0.1
6/10/2006	0.1	0.1	0.8	1.7	0.1
6/11/2006	0.1	0.1	0.6	1.3	0.1
6/12/2006	0.1	0.1	1.1	2.4	0.1
6/13/2006	0.1	0.1	0.9	1.9	0.1
6/14/2006	0.1	0.1	0.7	1.5	0.1
6/15/2006	0.1	0.1	0.5	1.1	0.1
6/16/2006	0.1	0.1	0.5	1.0	0.1
6/17/2006	0.1	0.1	1.0	2.2	0.1
6/18/2006	0.1	0.1	1.7	3.5	12.1
6/19/2006	0.1	0.1	1.2	2.5	48.3
6/20/2006	0.1	0.1	1.3	2.7	84.5
6/21/2006	0.1	0.1	1.1	2.4	120.6
6/22/2006	72.4	105.7	0.1	0.2	156.8
6/23/2006	53.4	78.0	5.3	15.2	78.0
6/24/2006	22.1	32.3	25.1	71.5	32.3
6/25/2006	17.3	25.3	15.5	44.2	25.3
6/26/2006	2.3	3.4	6.4	18.3	3.4
6/27/2006	0.8	1.2	3.7	10.4	1.2
6/28/2006	0.4	0.6	2.5	7.3	0.1
6/29/2006	0.1	0.1	2.1	6.0	0.1
6/30/2006	0.1	0.1	1.7	4.0	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
7/1/2006	0.1	0.1	1.3	3.3	0.1
7/2/2006	0.1	0.1	1.0	2.5	0.1
7/3/2006	0.1	0.1	0.8	1.7	0.1
7/4/2006	0.1	0.1	0.6	1.3	0.1
7/5/2006	0.1	0.1	0.6	1.3	0.1
7/6/2006	0.1	0.1	0.5	1.1	0.1
7/7/2006	0.1	0.1	0.4	0.9	0.1
7/8/2006	0.1	0.1	0.4	0.9	0.1
7/9/2006	0.1	0.1	0.5	1.1	0.1
7/10/2006	0.1	0.1	0.7	1.4	5.6
7/11/2006	0.1	0.1	0.9	1.8	3.1
7/12/2006	0.1	0.1	0.8	1.6	1.9
7/13/2006	0.1	0.1	0.5	1.0	0.5
7/14/2006	0.1	0.1	0.5	1.0	0.1
7/15/2006	0.1	0.1	0.5	1.0	0.1
7/16/2006	0.1	0.1	0.5	1.0	0.1
7/17/2006	0.1	0.1	0.4	0.8	0.1
7/18/2006	0.1	0.1	0.1	0.6	0.1
7/19/2006	0.1	0.1	0.1	0.5	0.1
7/20/2006	0.1	0.1	0.1	0.4	0.1
7/21/2006	0.1	0.1	0.1	0.4	0.1
7/22/2006	0.1	0.1	0.1	0.1	0.1
7/23/2006	0.1	0.1	0.1	0.1	0.1
7/24/2006	0.1	0.1	0.1	0.1	0.1
7/25/2006	0.1	0.1	0.1	0.1	0.1
7/26/2006	0.1	0.1	0.1	0.1	0.1
7/27/2006	0.1	0.1	0.1	0.1	48.2
7/28/2006	0.1	0.1	1.8	3.7	43.7
7/29/2006	0.1	0.1	3.8	8.0	39.2
7/30/2006	0.1	0.1	1.4	3.0	34.7
7/31/2006	0.1	0.1	0.7	1.5	30.2

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
8/1/2006	0.1	0.1	0.4	0.9	25.6
8/2/2006	0.1	0.1	0.4	0.8	21.1
8/3/2006	2.8	1.1	1.0	2.0	16.6
8/4/2006	1.3	0.5	1.6	3.4	12.1
8/5/2006	0.5	0.2	0.8	1.7	0.2
8/6/2006	0.1	0.1	0.6	1.2	0.1
8/7/2006	0.1	0.1	0.5	1.0	0.1
8/8/2006	0.1	0.1	0.3	0.6	0.1
8/9/2006	0.1	0.1	0.2	0.4	0.1
8/10/2006	0.1	0.1	0.2	0.4	0.1
8/11/2006	0.1	0.1	0.2	0.4	0.1
8/12/2006	0.1	0.1	0.3	0.5	0.1
8/13/2006	0.1	0.1	0.2	0.5	0.1
8/14/2006	1.4	0.1	0.3	0.7	2.4
8/15/2006	0.9	0.1	0.3	0.7	1.0
8/16/2006	0.1	0.1	0.3	0.7	0.5
8/17/2006	0.1	0.1	0.6	1.3	0.1
8/18/2006	0.1	0.1	0.6	1.2	0.1
8/19/2006	2.3	1.3	0.7	1.5	0.1
8/20/2006	2.5	1.4	0.9	1.9	0.1
8/21/2006	1.3	0.7	0.8	1.7	0.1
8/22/2006	0.4	0.2	0.8	1.7	0.1
8/23/2006	0.1	0.1	0.9	1.8	0.1
8/24/2006	0.1	0.1	0.6	1.3	0.1
8/25/2006	0.1	0.1	0.6	1.2	0.1
8/26/2006	0.1	0.1	0.7	1.4	0.1
8/27/2006	0.1	0.1	2.3	4.8	0.1
8/28/2006	0.1	0.1	3.5	7.3	0.1
8/29/2006	0.1	0.1	1.8	3.8	0.1
8/30/2006	0.1	0.1	1.1	2.3	0.1
8/31/2006	0.1	0.1	0.8	1.6	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
9/1/2006	0.1	0.1	0.6	1.3	0.1
9/2/2006	0.1	0.1	0.5	1.0	0.1
9/3/2006	0.1	0.1	0.5	1.0	0.1
9/4/2006	0.1	0.1	0.5	1.0	0.1
9/5/2006	0.1	0.1	0.4	0.8	0.1
9/6/2006	0.1	0.1	0.3	0.7	0.1
9/7/2006	0.1	0.1	0.4	0.7	0.1
9/8/2006	0.1	0.1	0.4	0.9	0.1
9/9/2006	0.1	0.1	0.4	0.9	0.1
9/10/2006	0.1	0.1	0.5	1.1	0.1
9/11/2006	0.1	0.1	0.5	1.1	0.1
9/12/2006	0.1	0.1	0.5	1.1	0.1
9/13/2006	0.1	0.1	0.5	1.1	0.1
9/14/2006	0.1	0.1	0.5	1.0	0.1
9/15/2006	0.1	0.1	0.4	0.9	0.1
9/16/2006	2.4	0.1	0.4	0.9	0.1
9/17/2006	1.3	0.1	0.5	1.0	0.1
9/18/2006	0.4	0.1	0.5	1.0	0.1
9/19/2006	0.1	0.1	0.5	1.1	0.1
9/20/2006	0.1	0.1	0.5	1.1	0.1
9/21/2006	0.1	0.1	0.6	1.2	0.1
9/22/2006	0.1	0.1	0.5	1.1	0.1
9/23/2006	0.1	0.1	0.5	1.1	0.1
9/24/2006	0.1	0.1	0.5	1.1	0.1
9/25/2006	0.1	0.1	0.5	1.1	0.1
9/26/2006	0.1	0.1	0.5	1.1	0.1
9/27/2006	0.1	0.1	0.5	1.1	0.1
9/28/2006	0.1	0.1	0.5	1.1	0.1
9/29/2006	0.1	0.1	0.5	1.1	0.1
9/30/2006	0.1	0.1	0.5	1.1	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
10/1/2006	0.1	0.1	0.5	1.1	0.1
10/2/2006	0.1	0.1	0.5	1.1	0.1
10/3/2006	0.1	0.1	0.5	1.1	0.1
10/4/2006	0.1	0.1	0.5	1.0	0.1
10/5/2006	0.1	0.1	0.5	1.0	0.1
10/6/2006	0.1	0.1	0.5	1.0	0.1
10/7/2006	0.1	0.1	0.5	1.0	0.1
10/8/2006	0.1	0.1	0.5	1.0	0.1
10/9/2006	0.1	0.1	0.5	1.1	0.1
10/10/2006	0.1	0.1	0.6	1.2	0.1
10/11/2006	0.1	0.1	0.6	1.3	0.1
10/12/2006	0.1	0.1	0.6	1.3	0.1
10/13/2006	0.1	0.1	0.7	1.4	0.1
10/14/2006	0.1	0.1	0.6	1.3	0.1
10/15/2006	0.1	0.1	0.6	1.2	0.1
10/16/2006	0.1	0.1	0.6	1.3	0.1
10/17/2006	0.1	0.1	0.6	1.2	0.1
10/18/2006	0.1	0.1	0.6	1.2	0.1
10/19/2006	0.1	0.1	0.6	1.2	0.1
10/20/2006	0.1	0.1	0.6	1.3	0.1
10/21/2006	0.1	0.1	0.6	1.3	0.1
10/22/2006	0.1	0.1	0.6	1.3	0.1
10/23/2006	0.1	0.1	0.7	1.4	0.1
10/24/2006	0.1	0.1	0.7	1.4	0.1
10/25/2006	0.1	0.1	0.7	1.4	0.1
10/26/2006	0.1	0.1	0.7	1.4	0.1
10/27/2006	2.9	0.1	0.7	1.5	0.1
10/28/2006	1.4	0.1	0.9	2.0	0.1
10/29/2006	0.8	0.1	1.0	2.2	0.1
10/30/2006	0.3	0.1	0.7	1.5	0.1
10/31/2006	0.1	0.1	0.6	1.3	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
11/1/2006	0.1	0.1	0.6	1.2	0.1
11/2/2006	0.1	0.1	0.6	1.2	0.1
11/3/2006	0.1	0.1	0.7	1.4	0.1
11/4/2006	0.1	0.1	0.7	1.4	0.1
11/5/2006	0.1	0.1	0.7	1.4	0.1
11/6/2006	0.1	0.1	0.7	1.4	0.1
11/7/2006	0.1	0.1	0.6	1.3	0.1
11/8/2006	0.1	0.1	0.6	1.3	0.1
11/9/2006	0.1	0.1	0.6	1.3	0.1
11/10/2006	0.1	0.1	0.6	1.2	0.1
11/11/2006	0.1	0.1	0.5	1.1	0.1
11/12/2006	0.1	0.1	0.6	1.2	0.1
11/13/2006	0.1	0.1	0.6	1.3	0.1
11/14/2006	0.1	0.1	0.6	1.2	0.1
11/15/2006	0.1	0.1	0.7	1.4	0.1
11/16/2006	0.1	0.1	0.6	1.3	0.1
11/17/2006	0.1	0.1	0.6	1.3	0.1
11/18/2006	0.1	0.1	0.6	1.3	0.1
11/19/2006	0.1	0.1	0.6	1.3	0.1
11/20/2006	0.1	0.1	0.6	1.3	0.1
11/21/2006	0.1	0.1	0.7	1.4	0.1
11/22/2006	0.1	0.1	0.7	1.4	0.1
11/23/2006	0.1	0.1	0.6	1.4	0.1
11/24/2006	0.1	0.1	0.7	1.5	0.1
11/25/2006	0.1	0.1	0.7	1.5	0.1
11/26/2006	0.1	0.1	0.6	1.3	0.1
11/27/2006	0.1	0.1	0.6	1.3	0.1
11/28/2006	0.1	0.1	0.8	1.6	0.1
11/29/2006	0.1	0.1	0.8	1.6	0.1
11/30/2006	0.1	0.1	0.6	1.4	0.1

Table C-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2006

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
12/1/2006	0.1	0.1	0.6	1.2	0.1
12/2/2006	0.1	0.1	0.6	1.2	0.1
12/3/2006	0.1	0.1	0.6	1.2	0.1
12/4/2006	0.1	0.1	0.6	1.2	0.1
12/5/2006	0.1	0.1	0.6	1.3	0.1
12/6/2006	0.1	0.1	0.6	1.3	0.1
12/7/2006	0.1	0.1	0.6	1.3	0.1
12/8/2006	0.1	0.1	0.6	1.2	0.1
12/9/2006	0.1	0.1	0.6	1.3	0.1
12/10/2006	0.1	0.1	0.6	1.3	0.1
12/11/2006	0.1	0.1	0.7	1.4	0.1
12/12/2006	0.1	0.1	0.7	1.4	0.1
12/13/2006	0.1	0.1	0.7	1.4	0.1
12/14/2006	0.1	0.1	0.7	1.4	0.1
12/15/2006	0.1	0.1	0.7	1.4	0.1
12/16/2006	0.1	0.1	0.7	1.4	0.1
12/17/2006	0.1	0.1	0.7	1.4	0.1
12/18/2006	0.1	0.1	0.7	1.4	0.1
12/19/2006	0.1	0.1	0.6	1.3	0.1
12/20/2006	0.1	0.1	0.8	1.8	0.1
12/21/2006	0.1	0.1	1.3	2.7	0.1
12/22/2006	0.1	0.1	1.4	3.0	0.1
12/23/2006	0.1	0.1	0.9	2.0	0.1
12/24/2006	0.1	0.1	0.8	1.7	0.1
12/25/2006	0.1	0.1	0.8	1.8	0.1
12/26/2006	0.1	0.1	0.8	1.7	0.1
12/27/2006	0.1	0.1	0.8	1.7	0.1
12/28/2006	0.1	0.1	0.8	1.7	0.1
12/29/2006	0.1	0.1	0.8	1.7	0.1
12/30/2006	0.1	0.1	0.9	2.0	0.1
12/31/2006	0.1	0.1	1.3	2.7	0.1

Appendix D - 2007 Paired Data

Table D-1 Discrete atrazine concentrations (µg/l) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
02-20	0.40	0.00	0.55	0.24	1.09
03-23	0.46	0.00	0.30	0.30	0.30
04-03	0.40	4.04	2.75	1.15	2.49
04-17	0.35	1.48	0.56	0.51	0.94
04-24	0.68	0.00	0.30	0.30	0.68
05-01	0.30	0.00	0.30	1.08	0.66
05-06	1.86	2.83	5.76	1.01	3.25
05-15	1.97	5.54	1.05	6.49	1.06
05-22	0.38	0.00	1.43	2.39	1.35
05-31	1.90	2.83	3.54	2.22	4.96
06-06	1.45	1.28	1.57	2.06	2.90
06-14	0.70	0.00	0.52	0.59	0.56
06-20	0.69	0.00	0.30	0.37	10.41
06-28	0.66	0.00	0.30	0.30	0.30
07-05	9.73	0.00	12.88	6.61	6.79
07-11	10.15	4.18	13.01	6.53	6.00
07-19	6.01	1.18	4.80	7.41	3.87
07-25	2.78	0.00	1.35	3.33	0.30
07-31	1.40	0.00	0.48	0.83	0.30
08-15	3.89	7.52	6.85	9.50	7.59
08-29	0.30	0.00	0.30	0.30	0.00
09-11	0.30	0.00	0.30	0.30	0.00
09-16	0.30	0.00	0.30	0.30	0.00
11-11	0.30	0.00	0.30	0.30	0.00
12-31	0.30	0.00	0.30	0.30	0.00

Table D-2 Discrete total suspended solids (mg/l) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
02-20	76	0	76	92	0
03-23	96	0	32	92	0
04-03	104	72	36	24	72
04-17	104	68	60	88	52
04-24	196	0	20	44	52
05-01	180	0	44	72	0
05-06	468	96	344	336	160
05-15	68	92	100	256	164
05-22	60	0	108	76	56
05-31	144	126	120	112	412
06-06	76	32	44	76	96
06-14	68	0	48	52	0
06-20	4	0	144	0	0
06-28	56	0	0	20	0
07-05	56	0	416	292	0
07-11	112	72	108	168	104
07-19	76	16	36	80	96
07-25	116	0	0	16	0
07-31	84	0	36	48	0
08-15	184	136	128	128	92
08-29	308	0	0	28	0
09-11	76	0	0	64	0
09-16	416	0	36	88	0
11-11	400	0	248	95	0
12-31	80	0	28	86	0

Table D-3 Discrete nitrogen concentrations (mg/l) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
02-20	1.00	0.00	0.96	1.65	0.00
03-23	1.25	0.00	1.62	1.70	0.00
04-03	2.62	2.50	3.31	3.22	2.38
04-17	3.31	2.98	3.88	3.71	2.63
04-24	2.52	0.00	3.20	2.63	2.00
05-01	1.78	0.00	2.39	2.55	3.99
05-06	4.74	3.51	5.14	4.55	3.61
05-15	2.59	2.47	2.85	3.79	3.34
05-22	0.91	0.00	3.02	2.04	2.14
05-31	1.93	1.97	2.31	2.80	2.38
06-06	1.91	1.66	2.90	2.24	2.80
06-14	2.00	0.00	3.03	2.07	0.00
06-20	1.76	0.00	3.12	2.12	0.00
06-28	1.62	0.00	4.04	3.72	0.00
07-05	1.48	0.00	4.95	5.32	0.00
07-11	3.77	2.72	3.43	2.87	1.86
07-19	2.6	2.47	1.57	5.74	2.43
07-25	1.44	0.00	3.68	2.16	0.00
07-31	1.05	0.00	3.79	1.79	0.00
08-15	3.12	4.04	3.96	4.57	4.01
08-29	1.68	0.00	0.00	1.40	0.00
09-11	1.04	0.00	0.00	1.21	0.00
09-16	2.1	0.00	0.42	1.31	0.00
11-11	2.32	0.00	0.68	2.28	0.00
12-31	0.54	0.00	0.54	1.14	0.00

Table D-4 Discrete phosphorus concentrations (mg/l) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
02-20	0.47	0.00	0.51	0.31	0.00
03-23	0.15	0.00	0.50	0.53	0.00
04-03	0.39	0.72	0.61	0.62	0.90
04-17	0.21	0.47	0.36	0.43	0.64
04-24	0.22	0.00	0.45	0.43	0.76
05-01	0.14	0.00	0.21	0.38	1.31
05-06	0.98	0.75	1.39	1.52	0.92
05-15	0.60	0.90	0.49	0.97	1.24
05-22	0.11	0.00	0.63	0.59	1.03
05-31	0.47	0.41	0.58	0.56	0.67
06-06	0.23	0.65	0.53	0.55	0.95
06-14	0.32	0.00	0.51	0.54	1.07
06-20	0.28	0.00	0.40	0.53	1.17
06-28	0.29	0.00	0.72	0.79	0.00
07-05	0.29	0.00	1.03	1.05	0.63
07-11	0.57	0.77	0.81	0.82	1.44
07-19	0.65	0.93	0.59	1.19	1.12
07-25	0.28	0.00	0.31	0.51	0.00
07-31	0.30	0.00	0.35	0.55	0.00
08-15	0.85	0.80	0.80	0.86	0.86
08-29	0.53	0.00	0.00	0.55	0.00
09-11	0.29	0.00	0.32	0.52	0.00
09-16	0.56	0.00	0.24	0.48	0.00
11-11	0.74	0.00	0.93	0.98	0.00
12-31	0.48	0.00	0.14	0.35	0.00

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
1/1/2007	0.10	0.10	0.10	2.34	0.10
1/2/2007	0.10	0.10	0.10	2.35	0.10
1/3/2007	0.10	0.10	0.10	2.36	0.10
1/4/2007	0.10	0.10	0.10	2.37	0.10
1/5/2007	0.10	0.10	0.10	2.37	0.10
1/6/2007	0.10	0.10	0.10	2.38	0.10
1/7/2007	0.10	0.10	0.10	2.39	0.10
1/8/2007	0.10	0.10	0.10	2.40	0.10
1/9/2007	0.10	0.10	0.10	2.41	0.10
1/10/2007	0.10	0.10	0.10	2.42	0.10
1/11/2007	0.10	0.10	0.10	2.42	0.10
1/12/2007	0.10	0.10	0.10	2.43	0.10
1/13/2007	0.10	0.10	0.10	2.44	0.10
1/14/2007	0.10	0.10	0.10	2.45	0.10
1/15/2007	0.10	0.10	0.10	2.46	0.10
1/16/2007	0.10	0.10	0.10	2.47	0.10
1/17/2007	0.10	0.10	0.10	2.48	0.10
1/18/2007	0.10	0.10	0.10	2.48	0.10
1/19/2007	0.10	0.10	0.10	2.49	0.10
1/20/2007	0.10	0.10	0.10	2.50	0.10
1/21/2007	0.10	0.10	0.10	2.51	0.10
1/22/2007	0.10	0.10	0.10	2.52	0.10
1/23/2007	0.10	0.10	0.10	2.53	0.10
1/24/2007	0.10	0.10	0.10	2.53	0.10
1/25/2007	0.10	0.10	0.10	2.54	0.10
1/26/2007	0.10	0.10	0.10	2.55	0.10
1/27/2007	0.10	0.10	0.10	2.56	0.10
1/28/2007	0.10	0.10	0.10	2.57	0.10
1/29/2007	0.10	0.10	0.10	2.58	0.10
1/30/2007	0.10	0.10	0.10	2.59	0.10
1/31/2007	0.10	0.10	0.10	2.59	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
2/1/2007	0.10	0.10	0.10	2.60	0.10
2/2/2007	0.10	0.10	0.10	2.61	0.10
2/3/2007	0.10	0.10	0.10	2.62	0.10
2/4/2007	0.10	0.10	0.10	2.63	0.10
2/5/2007	0.10	0.10	0.10	2.64	0.10
2/6/2007	0.10	0.10	0.10	2.64	0.10
2/7/2007	0.10	0.10	0.10	2.65	0.10
2/8/2007	0.10	0.10	0.10	2.66	0.10
2/9/2007	0.10	0.10	0.10	2.67	0.10
2/10/2007	1.90	0.10	1.22	5.47	0.10
2/11/2007	1.79	0.10	1.16	5.26	0.10
2/12/2007	1.68	0.10	1.11	5.06	0.10
2/13/2007	1.58	0.10	1.05	4.85	0.10
2/14/2007	1.47	0.10	0.99	4.64	0.10
2/15/2007	1.36	0.10	0.94	4.44	0.10
2/16/2007	1.25	0.10	0.88	4.23	0.10
2/17/2007	1.15	0.10	0.83	4.03	0.10
2/18/2007	1.04	0.10	0.77	3.82	0.10
2/19/2007	0.93	0.10	0.71	3.61	0.10
2/20/2007	0.82	0.10	0.66	3.41	0.10
2/21/2007	0.72	0.10	0.60	3.20	0.10
2/22/2007	0.61	0.10	0.54	2.99	0.10
2/23/2007	0.50	0.10	0.49	2.79	0.10
2/24/2007	0.30	0.10	0.43	2.58	0.10
2/25/2007	0.10	0.10	0.42	2.52	0.10
2/26/2007	0.10	0.10	0.41	2.46	0.10
2/27/2007	0.10	0.10	0.41	2.41	0.10
2/28/2007	0.10	0.10	0.40	2.35	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
3/1/2007	0.10	0.10	0.39	2.29	0.10
3/2/2007	0.10	0.10	0.38	2.23	0.10
3/3/2007	0.10	0.10	0.38	2.18	0.10
3/4/2007	0.10	0.10	0.37	2.12	0.10
3/5/2007	0.10	0.10	0.36	2.06	0.10
3/6/2007	0.10	0.10	0.35	2.00	0.10
3/7/2007	0.10	0.10	0.34	1.94	0.10
3/8/2007	0.10	0.10	0.34	1.89	0.10
3/9/2007	0.10	0.10	0.33	1.83	0.10
3/10/2007	0.10	0.10	0.32	1.77	0.10
3/11/2007	2.90	0.10	2.78	10.48	0.10
3/12/2007	2.65	0.10	2.61	9.67	0.10
3/13/2007	2.40	0.10	2.44	8.86	0.10
3/14/2007	2.15	0.10	2.27	8.04	0.10
3/15/2007	1.90	0.10	2.10	7.23	0.10
3/16/2007	1.65	0.10	1.92	6.42	0.10
3/17/2007	1.40	0.10	1.75	5.61	0.10
3/18/2007	1.15	0.10	1.58	4.79	0.10
3/19/2007	0.90	0.10	1.41	3.98	0.10
3/20/2007	4.50	0.10	3.44	21.60	0.10
3/21/2007	3.00	0.10	2.64	15.42	0.10
3/22/2007	1.50	0.10	1.83	9.24	0.10
3/23/2007	7.80	0.10	10.44	28.56	0.10
3/24/2007	6.60	18.50	8.76	26.14	11.52
3/25/2007	5.40	22.00	7.08	23.72	13.75
3/26/2007	4.20	25.50	5.40	21.30	15.98
3/27/2007	39.40	29.00	11.42	35.60	18.21
3/28/2007	41.75	33.33	27.51	60.65	20.81
3/29/2007	44.10	37.67	43.60	85.70	23.40
3/30/2007	56.80	42.00	54.71	101.74	38.20
3/31/2007	175.40	58.00	92.60	318.40	52.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
4/1/2007	182.60	56.00	99.40	349.73	56.34
4/2/2007	161.31	54.00	91.80	325.81	52.34
4/3/2007	140.03	52.00	84.20	301.90	48.33
4/4/2007	118.74	50.00	76.60	277.98	44.33
4/5/2007	97.45	48.00	69.00	254.07	40.32
4/6/2007	76.16	46.00	61.40	230.15	36.32
4/7/2007	54.88	44.00	53.80	206.23	32.31
4/8/2007	33.59	42.00	46.20	182.32	28.31
4/9/2007	88.40	40.00	38.60	158.40	24.30
4/10/2007	58.17	38.00	41.20	167.17	25.43
4/11/2007	67.20	36.00	46.76	174.15	28.01
4/12/2007	60.45	34.00	52.33	181.12	30.58
4/13/2007	53.70	32.00	57.89	188.10	33.16
4/14/2007	89.40	47.00	54.81	178.75	30.27
4/15/2007	79.72	42.35	51.72	169.41	27.37
4/16/2007	70.04	37.70	48.64	160.06	24.48
4/17/2007	60.37	33.05	45.55	150.71	21.58
4/18/2007	50.69	28.40	42.47	141.36	18.69
4/19/2007	41.01	23.75	39.39	132.02	15.80
4/20/2007	31.33	19.10	36.30	122.67	12.90
4/21/2007	21.66	14.45	33.22	113.32	10.01
4/22/2007	11.98	9.80	30.13	103.98	7.11
4/23/2007	2.30	5.15	27.05	94.63	4.22
4/24/2007	3.62	0.10	23.96	85.28	2.11
4/25/2007	3.11	0.10	20.88	75.94	0.10
4/26/2007	2.59	0.10	17.80	66.59	0.10
4/27/2007	2.08	0.10	14.71	57.24	0.10
4/28/2007	1.57	0.10	11.63	47.89	0.10
4/29/2007	1.05	0.10	8.54	38.55	0.10
4/30/2007	0.54	0.10	5.46	29.20	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
5/1/2007	228.10	0.10	2.23	28.56	0.10
5/2/2007	207.48	165.00	244.30	486.79	122.31
5/3/2007	186.85	220.00	223.75	509.53	135.67
5/4/2007	166.23	266.00	203.19	532.26	149.04
5/5/2007	145.60	312.00	182.64	555.00	162.40
5/6/2007	448.50	358.00	410.12	916.42	372.40
5/7/2007	399.21	351.11	407.87	907.41	347.66
5/8/2007	349.93	344.22	405.62	898.39	322.93
5/9/2007	300.64	337.33	403.36	889.38	298.19
5/10/2007	251.35	330.44	401.11	880.37	273.45
5/11/2007	202.06	323.56	398.86	871.35	248.71
5/12/2007	152.78	294.15	396.61	862.34	223.98
5/13/2007	103.49	264.75	394.35	853.32	199.24
5/14/2007	254.20	235.34	392.10	844.31	174.50
5/15/2007	274.00	205.94	456.40	998.57	189.60
5/16/2007	152.44	176.53	394.70	863.31	162.53
5/17/2007	130.89	147.13	333.00	728.05	135.46
5/18/2007	109.33	117.72	271.30	592.79	108.39
5/19/2007	87.77	88.32	209.60	457.52	81.31
5/20/2007	66.21	58.91	147.90	322.26	54.24
5/21/2007	44.66	29.51	86.20	187.00	27.17
5/22/2007	23.10	0.10	24.50	51.74	0.10
5/23/2007	1856.40	1128.00	1256.91	2684.42	987.51
5/24/2007	1922.53	975.67	1290.61	2761.32	949.77
5/25/2007	1988.67	823.33	1324.30	2838.22	912.04
5/26/2007	2054.80	671.00	1358.00	2915.12	874.30
5/27/2007	1751.35	688.00	1281.88	2581.14	785.92
5/28/2007	1447.90	705.00	1205.76	2247.16	697.54
5/29/2007	1144.45	722.00	1129.64	1913.17	609.16
5/30/2007	841.00	739.00	1053.52	1579.19	520.78
5/31/2007	1156.00	756.00	977.40	1245.21	432.40

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
6/1/2007	1324.60	870.00	1152.12	1921.30	641.00
6/2/2007	1215.92	820.77	1058.14	1766.14	512.82
6/3/2007	1107.23	771.54	964.15	1610.98	384.64
6/4/2007	998.55	722.31	870.17	1455.83	256.46
6/5/2007	889.87	673.08	776.18	1300.67	128.28
6/6/2007	781.18	0.10	682.20	1145.51	0.10
6/7/2007	672.50	0.10	588.21	990.35	0.10
6/8/2007	563.82	0.10	494.23	835.19	0.10
6/9/2007	455.13	0.10	400.24	680.03	0.10
6/10/2007	346.45	0.10	306.26	524.88	0.10
6/11/2007	237.77	0.10	212.27	369.72	0.10
6/12/2007	129.08	0.10	118.29	214.56	0.10
6/13/2007	20.40	0.10	24.30	59.40	0.10
6/14/2007	55.10	0.10	24.09	57.42	0.10
6/15/2007	51.94	0.10	23.88	55.44	0.10
6/16/2007	48.79	0.10	23.67	53.47	0.10
6/17/2007	45.63	0.10	23.46	51.49	0.10
6/18/2007	42.48	0.10	23.24	49.51	0.10
6/19/2007	39.32	0.10	23.03	47.53	0.10
6/20/2007	36.17	0.10	22.82	45.56	0.10
6/21/2007	33.01	0.10	22.61	43.58	0.10
6/22/2007	29.86	0.10	22.40	41.60	0.10
6/23/2007	67.90	0.10	38.17	62.55	0.10
6/24/2007	56.70	0.10	30.65	59.17	0.10
6/25/2007	45.50	0.10	23.12	55.78	0.10
6/26/2007	34.30	0.10	15.60	52.40	0.10
6/27/2007	228.60	0.10	214.36	398.20	0.10
6/28/2007	220.88	0.10	186.83	355.93	0.10
6/29/2007	213.17	0.10	159.30	313.66	0.10
6/30/2007	205.45	43.23	131.76	271.38	28.60

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
7/1/2007	197.73	86.35	104.23	229.11	56.70
7/2/2007	190.02	129.48	165.84	301.52	99.67
7/3/2007	182.30	172.61	227.46	373.93	142.63
7/4/2007	256.80	215.74	289.07	446.34	185.60
7/5/2007	293.80	258.86	321.82	535.81	219.90
7/6/2007	330.80	301.99	354.56	625.28	254.20
7/7/2007	367.80	345.12	387.31	714.76	288.50
7/8/2007	404.80	388.25	420.05	804.23	322.80
7/9/2007	441.80	431.37	452.80	893.70	357.10
7/10/2007	419.71	474.50	432.50	854.64	317.69
7/11/2007	397.61	421.79	412.20	815.57	278.29
7/12/2007	375.52	369.08	391.90	776.51	238.88
7/13/2007	353.42	316.37	371.60	737.45	199.47
7/14/2007	331.33	263.66	351.30	698.38	160.07
7/15/2007	309.23	210.94	331.00	659.32	120.66
7/16/2007	287.14	158.23	310.70	620.26	81.25
7/17/2007	265.04	105.52	290.40	581.19	41.85
7/18/2007	242.95	52.81	270.10	542.13	2.44
7/19/2007	220.85	0.10	249.80	503.07	0.10
7/20/2007	198.76	0.10	229.49	464.00	0.10
7/21/2007	176.66	0.10	209.19	424.94	0.10
7/22/2007	154.57	0.10	188.89	385.87	0.10
7/23/2007	132.47	0.10	168.59	346.81	0.10
7/24/2007	110.38	0.10	148.29	307.75	0.10
7/25/2007	88.28	0.10	127.99	268.68	0.10
7/26/2007	66.19	0.10	107.69	229.62	0.10
7/27/2007	44.09	0.10	87.39	190.56	0.10
7/28/2007	22.00	0.10	67.09	151.49	0.10
7/29/2007	29.60	0.10	46.79	112.43	0.10
7/30/2007	415.20	312.00	388.24	715.12	288.39
7/31/2007	383.08	292.51	357.80	673.87	267.47

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
8/1/2007	350.95	273.01	327.36	632.62	246.55
8/2/2007	318.83	253.52	296.91	591.38	225.63
8/3/2007	286.70	234.03	266.47	550.13	204.71
8/4/2007	254.58	214.53	236.03	508.88	183.80
8/5/2007	222.45	195.04	205.59	467.63	162.88
8/6/2007	190.33	175.54	175.14	426.39	141.96
8/7/2007	158.20	156.05	144.70	385.14	121.04
8/8/2007	154.60	136.56	114.26	343.89	100.12
8/9/2007	145.07	117.06	95.60	297.65	83.51
8/10/2007	135.53	97.57	76.94	251.40	66.90
8/11/2007	126.00	78.08	58.29	205.16	50.30
8/12/2007	116.47	58.58	39.63	158.91	33.69
8/13/2007	106.93	39.09	20.97	112.67	17.08
8/14/2007	97.40	19.59	2.31	66.42	0.47
8/15/2007	87.87	0.10	0.10	20.18	0.10
8/16/2007	78.33	0.10	0.10	20.01	0.10
8/17/2007	68.80	0.10	0.10	19.85	0.10
8/18/2007	59.27	0.10	0.10	19.68	0.10
8/19/2007	49.73	0.10	0.10	19.52	0.10
8/20/2007	40.20	0.10	0.10	19.35	0.10
8/21/2007	30.67	0.10	0.10	19.18	0.10
8/22/2007	21.13	0.10	0.10	19.02	0.10
8/23/2007	11.60	0.10	0.10	18.85	0.10
8/24/2007	24.50	0.10	3.42	18.69	0.10
8/25/2007	23.19	0.10	3.24	18.52	0.10
8/26/2007	21.87	0.10	3.06	18.35	0.10
8/27/2007	20.56	0.10	2.88	18.19	0.10
8/28/2007	19.25	0.10	2.71	18.02	0.10
8/29/2007	17.93	0.10	2.53	17.86	0.10
8/30/2007	16.62	0.10	2.35	17.69	0.10
8/31/2007	15.30	0.10	2.17	17.52	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
9/1/2007	13.99	0.10	1.99	17.36	0.10
9/2/2007	12.68	0.10	1.81	17.19	0.10
9/3/2007	11.36	0.10	1.63	17.03	0.10
9/4/2007	10.05	0.10	1.45	16.86	0.10
9/5/2007	8.74	0.10	1.28	16.69	0.10
9/6/2007	7.42	0.10	1.10	16.53	0.10
9/7/2007	6.11	0.10	0.92	16.36	0.10
9/8/2007	4.79	0.10	0.74	16.20	0.10
9/9/2007	3.48	0.10	0.56	16.03	0.10
9/10/2007	15.60	0.10	0.51	15.86	0.10
9/11/2007	14.10	0.10	0.46	15.70	0.10
9/12/2007	12.60	0.10	0.42	15.53	0.10
9/13/2007	11.10	0.10	0.37	15.37	0.10
9/14/2007	9.60	0.10	0.32	15.20	0.10
9/15/2007	154.00	0.10	9.67	44.03	0.10
9/16/2007	199.13	0.10	19.01	72.85	0.10
9/17/2007	244.27	0.10	28.36	101.68	0.10
9/18/2007	289.40	0.10	37.71	130.51	0.10
9/19/2007	274.27	0.10	47.05	159.33	0.10
9/20/2007	259.15	0.10	56.40	188.16	0.10
9/21/2007	244.02	0.10	51.18	170.91	0.10
9/22/2007	228.89	0.10	45.97	153.66	0.10
9/23/2007	213.76	0.10	40.75	136.41	0.10
9/24/2007	198.64	0.10	35.54	119.16	0.10
9/25/2007	183.51	0.10	30.32	101.91	0.10
9/26/2007	168.38	0.10	25.10	84.66	0.10
9/27/2007	153.25	0.10	19.89	67.41	0.10
9/28/2007	138.13	0.10	14.67	50.16	0.10
9/29/2007	123.00	0.10	9.46	32.91	0.10
9/30/2007	107.87	0.10	4.24	15.66	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
10/1/2007	92.74	0.10	6.40	23.11	0.10
10/2/2007	77.62	0.10	8.56	30.56	0.10
10/3/2007	62.49	0.10	10.73	38.01	0.10
10/4/2007	47.36	0.10	12.89	45.46	0.10
10/5/2007	32.23	0.10	15.05	52.91	0.10
10/6/2007	17.11	0.10	17.21	60.36	0.10
10/7/2007	1.98	0.10	19.38	67.81	0.10
10/8/2007	15.43	0.10	21.54	75.26	0.10
10/9/2007	21.81	0.10	23.70	82.70	0.10
10/10/2007	28.19	0.10	25.86	90.15	0.10
10/11/2007	34.57	0.10	28.03	97.60	0.10
10/12/2007	40.94	0.10	30.19	105.05	0.10
10/13/2007	47.32	0.10	32.35	112.50	0.10
10/14/2007	53.70	0.10	34.51	119.95	0.10
10/15/2007	106.27	0.10	36.68	127.40	0.10
10/16/2007	158.83	0.10	38.84	134.85	0.10
10/17/2007	211.40	0.10	41.00	142.30	0.10
10/18/2007	197.05	0.10	38.46	134.86	0.10
10/19/2007	182.71	0.10	35.92	127.42	0.10
10/20/2007	168.36	0.10	33.38	119.97	0.10
10/21/2007	154.02	0.10	30.84	112.53	0.10
10/22/2007	139.67	0.10	28.30	105.09	0.10
10/23/2007	125.33	0.10	25.76	97.65	0.10
10/24/2007	110.98	0.10	23.22	90.21	0.10
10/25/2007	96.63	0.10	20.68	82.76	0.10
10/26/2007	82.29	0.10	18.14	75.32	0.10
10/27/2007	67.94	0.10	15.60	67.88	0.10
10/28/2007	53.60	0.10	13.06	60.44	0.10
10/29/2007	39.25	0.10	10.52	52.99	0.10
10/30/2007	24.91	0.10	7.98	45.55	0.10
10/31/2007	10.56	0.10	5.44	38.11	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
11/1/2007	10.30	0.10	5.37	37.65	0.10
11/2/2007	10.03	0.10	5.29	37.19	0.10
11/3/2007	9.77	0.10	5.22	36.73	0.10
11/4/2007	9.51	0.10	5.14	36.27	0.10
11/5/2007	9.24	0.10	5.07	35.81	0.10
11/6/2007	8.98	0.10	5.00	35.35	0.10
11/7/2007	8.72	0.10	4.92	34.89	0.10
11/8/2007	8.46	0.10	4.85	34.42	0.10
11/9/2007	8.19	0.10	4.77	33.96	0.10
11/10/2007	7.93	0.10	4.70	33.50	0.10
11/11/2007	7.67	0.10	4.63	33.04	0.10
11/12/2007	7.40	0.10	4.55	32.58	0.10
11/13/2007	7.14	0.10	4.48	32.12	0.10
11/14/2007	6.88	0.10	4.40	31.66	0.10
11/15/2007	6.61	0.10	4.33	31.20	0.10
11/16/2007	6.35	0.10	4.26	30.74	0.10
11/17/2007	6.09	0.10	4.18	30.28	0.10
11/18/2007	5.83	0.10	4.11	29.82	0.10
11/19/2007	5.56	0.10	4.03	29.36	0.10
11/20/2007	5.30	0.10	3.96	28.90	0.10
11/21/2007	5.04	0.10	3.89	28.44	0.10
11/22/2007	4.77	0.10	3.81	27.98	0.10
11/23/2007	4.51	0.10	3.74	27.51	0.10
11/24/2007	4.25	0.10	3.66	27.05	0.10
11/25/2007	3.98	0.10	3.59	26.59	0.10
11/26/2007	3.72	0.10	3.52	26.13	0.10
11/27/2007	3.46	0.10	3.44	25.67	0.10
11/28/2007	3.20	0.10	3.37	25.21	0.10
11/29/2007	2.93	0.10	3.29	24.75	0.10
11/30/2007	2.67	0.10	3.22	24.29	0.10

Table D-5 Average stream flowrate per day (cfs) for sites in the Little Arkansas River paired watershed study for 2007.

Date	Site				
	Running Turkey Cr	Dry Turkey Cr	Upper West Emma Cr.	Lower West Emma Cr.	Black Kettle Cr.
12/1/2007	3.59	0.10	3.20	23.93	0.10
12/2/2007	3.56	0.10	3.19	23.58	0.10
12/3/2007	3.52	0.10	3.17	23.22	0.10
12/4/2007	3.49	0.10	3.15	22.87	0.10
12/5/2007	3.45	0.10	3.14	22.51	0.10
12/6/2007	3.42	0.10	3.12	22.15	0.10
12/7/2007	3.38	0.10	3.10	21.80	0.10
12/8/2007	3.35	0.10	3.08	21.44	0.10
12/9/2007	3.31	0.10	3.07	21.09	0.10
12/10/2007	3.28	0.10	3.05	20.73	0.10
12/11/2007	3.24	0.10	3.00	20.10	0.10
12/12/2007	3.21	0.10	15.62	47.89	0.10
12/13/2007	3.17	0.10	15.13	47.40	0.10
12/14/2007	3.14	0.10	14.64	46.91	0.10
12/15/2007	3.10	0.10	14.14	46.42	0.10
12/16/2007	3.07	0.10	13.65	45.93	0.10
12/17/2007	3.03	0.10	13.16	45.43	0.10
12/18/2007	3.00	0.10	12.67	44.94	0.10
12/19/2007	2.96	0.10	12.18	44.45	0.10
12/20/2007	2.93	0.10	11.68	43.96	0.10
12/21/2007	2.89	0.10	11.19	43.47	0.10
12/22/2007	2.86	0.10	10.70	42.98	0.10
12/23/2007	2.82	0.10	10.21	42.49	0.10
12/24/2007	2.79	0.10	9.71	42.00	0.10
12/25/2007	2.75	0.10	9.22	41.51	0.10
12/26/2007	2.72	0.10	8.73	41.02	0.10
12/27/2007	2.68	0.10	8.24	40.52	0.10
12/28/2007	2.65	0.10	7.75	40.03	0.10
12/29/2007	2.61	0.10	7.25	39.54	0.10
12/30/2007	2.58	0.10	6.76	39.05	0.10
12/31/2007	2.54	0.10	6.27	38.56	0.10