

**Missouri Department of Natural Resources
Water Pollution Control Program**

Total Maximum Daily Loads (TMDLs)

for

**Shoal Creek
Newton and Barry Counties, Missouri**

Completed: October 17, 2003

Approved: November 18, 2003

**Total Maximum Daily Load (TMDL)
For Shoal Creek
Pollutant: Fecal Coliform**

Name: Shoal Creek

Location: Near Neosho and Monett in Newton
and Barry counties, Missouri

Hydrologic Unit Code (HUC): 11070207- 020001

Water Body Identification Number (WBID): 3230

Missouri Stream Class: Class P¹



Beneficial Uses:

- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health associated with Fish Consumption
- Cool Water Fishery
- Irrigation
- Whole Body Contact Recreation (Swimming)
- Boating and Canoeing

Size of Impaired Segment: 13.5 miles

Location of Impaired Segment: From Capps Creek at N ½ Section 15, T25N, R29W (downstream),
to Section 12, T23N, R29W (upstream)

Pollutant: Fecal Coliform

Pollutant Source: Unknown agricultural source(s)

TMDL Priority Ranking: Medium

1. BACKGROUND AND WATER QUALITY PROBLEMS

1.1 Geography:

Shoal Creek drains an area of approximately 440 square miles located in Barry, Lawrence, and Newton counties in southwest Missouri. It enters Kansas about 5 miles southwest of Joplin where it

¹ Streams that maintain permanent flow even in drought (dry) periods. See Missouri Water Quality Standards (WQS) 10 CSR 20-7.031(1)(F). The WQS can be found at the following uniform resource locator (URL): www.dnr.state.mo.us/wpscd/wpcpub.htm#Chap7

joins the Spring River. Its channel in Missouri is about 66 miles long and is spring fed. In studies performed from 1958 through 1979, the water quality in Shoal Creek was reported as excellent. In a United States Geological Survey (USGS) report in 1992 it was described as a true Ozarkian stream with rolling Ozark hills, picturesque mill dams, bedrock riffles, gently eddying pools and long shaded reaches.

1.2 Area History:

On January 5, 1835, Barry County was formed from Greene County. It was named for U.S. Postmaster General William T. Barry. The first county seat was Mount Pleasant, just west of present day Pierce City. In 1880, the village of Exeter was established with the goal of securing the county seat from Cassville. Exeter is 4 ½ miles west of Cassville, on the highest point (1572 ft above sea level) in Barry, Newton, Lawrence and McDonald counties. It was 25 years before the issue of the location of the county seat was put to a vote. Exeter lost that vote on November 7, 1906.

The Shortest Railroad in America ran between Exeter and Cassville. It existed from 1896 to 1956. It received national publicity, being featured in The New York Times, "Ripley's Believe it or Not" and Newsweek. The following was drawn from a book titled "Back to Barry" by Irene Horner²:

The laying of tracks began in Exeter on June 11, 1896 and they were laid into Cassville on June 20th. On July 4th 1896 during one of the biggest celebrations ever known, the first train steamed into Cassville. The name of this little short line, which connected Cassville to the Frisco line in Exeter, was "*The Cassville and Western Railroad.*" For many years this railroad was the only way into Cassville as most of the roads would be impassable during bad weather. Both passengers and shippers depended on it for [transportation] from the Frisco line in Exeter. [These] tracks stretched [uphill] from Cassville 4.8 miles to the Exeter switch.... The engines would use their steam power to go uphill and, without a way to turn around in Exeter, would make the return trip by coasting into Cassville backwards, letting gravity do the work.

1.3 Land Use and Soils:

Land use in the watershed is approximately 88.1 percent grasslands, 11.3 percent wooded and 0.6 percent in row crops. The grasslands include hay, pasture and land enrolled in the Conservation Reserve Program. Less than one percent of the watershed is urban, and those towns are generally located on the watershed divide. See the land use map in Appendix A and Table 1 (page 5).

The soils along Shoal Creek are of the Secesh-Claiborne Association with a 0-5 percent slope. They are deep, nearly level to gently sloping, well-drained silty loams that have a high content of gravel. The upland soils are of the Scholten-Tonti Association. These soils are also very deep but have more slope (2-9 percent). The Tonti silt loam has a fragipan, a dense soil layer that prevents water from infiltrating downward. Also scattered along the floodplain is the Rock outcrop-Lithic Udorthents complex with a 2-5 percent slope. This is a shallow, well-drained complex that includes ledges, vertical bluffs and boulders. The soils are also deep, gently sloping, silt loams that are moderately well drained.

² The Shortest Railroad in America, <http://www.rootsweb.com/~mobarry/Exeter/train.htm>

1.4 Defining the Problem:

Between 1992 and 1999, concentrations of fecal coliform bacteria from the upper reach of Shoal Creek averaged more than 5,000 colonies per 100 mL (milliliters), due to very high counts in 1992-1993. Crowder College (Luttrel, 1999 – 2003) collected this data. Fecal coliform are non-pathogenic (do not cause human illness) bacteria that are found in the gut of warm blooded animals and are used as indicators of the risk of waterborne disease from pathogenic bacteria or viruses. These concentrations greatly exceed the Missouri limit of 200 colonies per 100 mL for the stated uses of Shoal Creek. This resulted in upper Shoal Creek, from Capps Creek upstream for 13.5 miles, being placed on the Missouri 1998 303(d) list of impaired water bodies³. For a map of the impaired section, see Appendix B. Although these high fecal coliform counts resulted in Shoal Creek being placed on the 303(d) list, recent data indicates bacteria levels have been greatly reduced.

Given the rural nature of the basin and the large number of confined poultry operations in the watershed, animal agriculture was considered a primary source of the elevated levels of bacteria. Also, the large number of older and potentially failing septic systems was considered a likely source. Recent studies of bacteria in Shoal Creek have characterized bacteria levels in various locations at different flow conditions (Schumacher, 2001; FAPRI, 2003). These studies also attempted to determine the source of the bacteria using genetic analysis also known as DNA Source Tracking. The goal was to identify if humans or specific types of animals, such as cattle, horses, or poultry, were the primary source of contamination. These studies indicated humans and cattle were the major contributors of bacteria, with other domestic animals and wildlife making a smaller contribution. Poultry litter was found to cause significant loading mainly during periods of high surface runoff, which occur less than 15 percent of the time.

The Missouri Department of Natural Resources contracted the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri to do an analysis and simulation of bacterial loading and transport in the Shoal Creek basin. Some of the text in this document is taken directly from FAPRI's draft report to explain the results of their work and implementation recommendations.

1.5 Public Involvement Related to the Study:

A watershed steering committee was formed by FAPRI in January 2000 to participate in the Shoal Creek Watershed Assessment. It consists of 13 members, including poultry and cattle producers, a veterinarian, Soil and Water Conservation District (SWCD) board members and personnel from the Natural Resources Conservation Service (NRCS). The steering committee had interest in drafting a locally driven watershed management plan that would address not only pathogens, but also potential nutrient problems. They felt there was a need for more data to identify the baseline water quality conditions and the decision-making process needed to include economically sound alternatives.

Following the formation of the committee, a holistic study of the watershed was undertaken to estimate when the pollution occurs, the magnitude of the problem and the source of the pollutants. The study report includes analysis of the monitoring data, the results of the hydrologic model, the

³ Recent USGS sampling above Capps Creek has shown that fecal coliform levels are well below the limit. As a result, 3.5 miles of Shoal Creek immediately upstream of Capps Creek have been removed from the department's database as being impaired and will be submitted for correction in the next 303(d) listing cycle.

potential sources of contamination and the impacts of proposed management changes. FAPRI selected the Soil & Water Assessment Tool (SWAT) to model the watershed. Data inputs required by SWAT include climate data, hydrology and soil characteristics and prevalent land management practices. See Section 3 for more information on the model. The resulting report (FAPRI, 2003) details the process and the conclusions relative to the pathogen problems. It explains the total maximum daily load being established and possible implementation strategies.

1.6 Source Assessment:

No point sources exist in the watershed that would account for the high levels of fecal coliform found in the creek. There are, however, many potential nonpoint sources. These include livestock, poultry litter, other domestic animals (horses, dogs, and pigs), failing septic systems and wildlife. The George's poultry processing plant, located in Butterfield, may also be a nonpoint source of bacteria. The plant effluent is spread on hay fields and has the potential to runoff during rain events.

Livestock

Livestock in the Shoal Creek Watershed include cattle, dairy cows and a few horses. Barry County agricultural facts, adjusted for the size of the Shoal Creek watershed, indicate that there were about 4700 cow/calf pairs in the watershed and 75 steers and bulls in 1998 (Missouri Agricultural Statistics Service, 2002). NRCS sources indicate 25 dairy farms in the watershed as of 1999. Given an average size of 60 cows per farm, this would represent about 900 cows. It is estimated about half of the cattle are kept in confinement and the rest are grazing in pastures. This yields about 5000 animals grazing in pastures year round. Rotational grazing is being demonstrated on a few dairy farms, but the practice is not implemented on a scale large enough to have a positive impact on water quality.

When cattle are allowed access to the creek, the model estimates that 3 percent of the cattle are in the creek in the winter and 10 percent during the summer. Cattle are put in summer pastures around June 30, thirty days after hay is harvested. Summer grazing fields are about 50 acres large and are grazed by 20-30 head. Essentially a grazing density of one cow/calf pair per five acres. It takes 40 to 50 days until the grass is depleted. The cattle are then moved to a different farm or their feed is supplemented with hay.

Poultry litter spread on pastures

Grassland areas are used as pastures, hay fields and for fescue seed production. In the spring, about 50 percent of the pastures are fertilized with poultry litter at a rate of two tons per acre. Another 25 percent of the pasture acres and all the hay and fescue seed fields are fertilized with inorganic nitrogen fertilizer. Twenty-five to 33 percent of the grassland is never fertilized for technical reasons (high slopes for example) or financial reasons (inability to buy the fertilizer or poultry litter).

There are approximately 60 poultry producers in the Shoal Creek watershed. Concentrated Animal Feeding Operations (CAFOs) are classified according to size. Poultry operations range in size from one house to CAFO class IB (14 to 30 houses). A class 1B facility may have up to 7,000 Animal Units, which represents 210,000 laying hens, 700,000 broiler chickens or 385,000 turkeys. As of 1999, a total of about 325 houses were operating in the watershed. The department has identified the location of these poultry operations and a

poultry litter production map was developed from this information. It is assumed that each house produces 120 to 125 tons of poultry litter per year and it is spread within 10 miles of the poultry house. Using this information and the number of pasture acres in each sub-basin, poultry litter application rates were determined for the watershed (Figure 1).

Figure 1. Poultry litter application rates

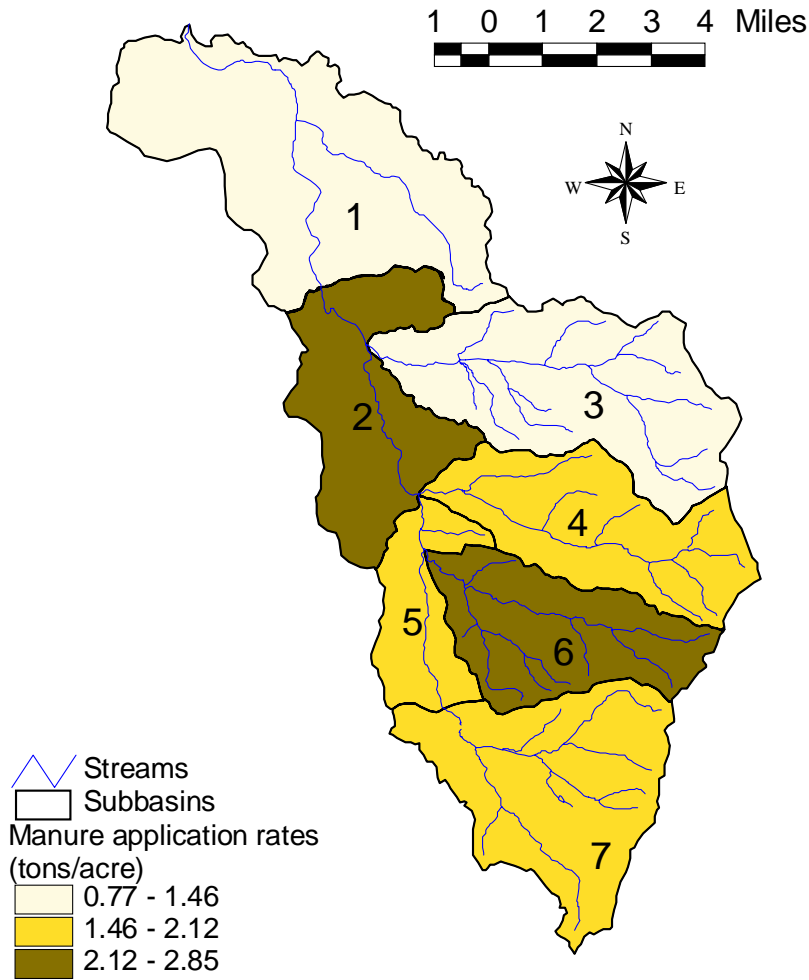


Table 1. Land use in the Shoal Creek Watershed

	Subbasin number							Watershed
	1	2	3	4	5	6	7	
Forest (%)	16	12	8	8	14	8	10	11 %
Grassland (%)	84	88	92	92	86	93	90	89 %
Area (km ²)	53.3	23.6	40.3	30.4	15.9	25.3	36.1	224.9 km ²
Area (acres)	13175	5835	9954	7504	3936	6247	8912	55563 acres

Other domestic animals

By a rough estimate, there are approximately 300 horses in the upper Shoal Creek watershed⁴. DNA analyses of the water samples collected at the Highway 97 Bridge identified horse fecal coliform in the creek. This can be explained by the fact that there is a horse pasture just above this sampling point. It is likely other horses in the watershed also contribute to the load, but there has not been any attempt to identify the origin of the patterns detected. DNA analysis also reveals that the percentage of horse fecal coliform is highest during late spring and summer. Thus, though horses are only a small part of the bacteria problem, they are considered a source of the pollutant.

Dogs are a potential source of bacteria. There are 66 licensed or registered puppy farms in Barry County, the highest concentration for any county in Missouri. The waste from dog farms consists of approximately 50 percent solids and 50 percent liquid. All waste has to be carried away from the facility to avoid health or odor problems in the operation. There are no regulations on the disposal of this waste and it is often spread in a nearby field. Although the amount of waste generated by these operations is small in comparison to other types of animal production, DNA analyses of water samples collected in Shoal Creek have shown dogs are a source of bacterial pollution.

Pigs may also be in the watershed, although no significant operation is known at this time. The agricultural Census indicates 39 pig farms in Barry County in 1997. Of these farms, 30 out of 39 had a total of 227 pigs or an average number of 6 to 7 pigs per farm. Six others had less than 100 pigs. Prorating the number of pig operations in Barry County to the Shoal Creek watershed results in six to seven small producers in the watershed. There is no information available on how the waste from these operations is managed.

Septic tanks

The Barry County Census indicates that there were 15,964 housing units in 2000, 13,398 of which were occupied with an average of 2.5 people. The 1990 census indicates that 67.4 percent of these occupied units were not connected to a public sewage system, i.e. they used a septic tank for sewage disposal. Assuming the same percentage for 2000, that would represent 9,030 units in Barry County. Assuming that the distribution of units that use on-site sewage disposal is uniform across Barry County, the number of individual septic systems in the upper Shoal Creek Watershed is estimated to be 1,005.

The rate of failure of these units can be estimated from their construction date, also determined from the 1990 Census data. Three categories of units were considered: before 1970, 1970-1984, and after 1984. The rates of failure were assumed to be 40 percent, 20 percent, and 5 percent, respectively. These rates have been used in Virginia for the development of a TMDL and were backed up by studies done in that area that found that 30 percent of all septic tanks were either failing or not functioning (Virginia DEQ, 2002). Using these rates and the number of septic systems in the watershed, we determined the number of failing systems (Table 2).

⁴ Dan Philbrick, National Resource Conservation Service, personal communication.

Table 2. Estimate of failing septic tanks in the Shoal Creek Watershed.

Structure age	% units in Barry Co.	Number units in Shoal Creek	Failure rate	Number failed septic tanks
Pre - 1970	39.7 %	399	40 %	160
1970 - 1984	33.2 %	334	20 %	67
Post 1984	27.1 %	272	5 %	14
Total	100 %	1,005	24 %	241

Wildlife

Wildlife in the Shoal Creek watershed includes many species. Wildlife inventories at the county level do not exist in Missouri. Four sets of patterns from wildlife are included in the DNA source tracking database, including deer, wild turkey, raccoons and geese.

Numbers from the Missouri Department of Conservation regarding deer harvests in Barry County help quantify the deer population. Deer harvest numbers in Barry County were 1,329 deer for 1999, 1,601 for 2000 and 2,041 for 2001. This results in an average of 1,660 deer per year being harvested by hunters. Assuming that 40 to 70 percent of the antlered bucks and 25 percent of the does are harvested each year, that the ratio of antlered bucks to does is 1:3, and that the antlered bucks represent about 20 percent of all the deer, the deer population in Barry County is estimated to be 5,724-7,216. In the absence of additional data to determine the distribution of deer within Barry County, a uniform distribution was used that results in 68-86 acres/deer or 2.9-3.6 deer/km².

George’s plant

Data obtained from the Southwest Regional Office of the Missouri Department of Natural Resources shows that an average of three inches (76 mm) of effluent has been spread on 380 acres since July 1997. The plant is planning to increase its processing capacity, which will increase the applied volume of wastewater. The number of irrigated acres is scheduled to double from 380 acres to approximately 600 acres. When George’s data was modeled, it was done on the basis of three inches of wastewater over 380 acres of canary grass hay.

George’s facility data on file with the department includes:

- Annual yields of hay harvested
- Daily records of wastewater applied
- Weekly nutrient and sediment analyses of wastewater samples (BOD, TSS, TKN, Phosphates, NO₂+NO₃ and NH₃)
- Monthly COD, NO₃ and NH₃ content in Dilbeck Spring and monitoring well samples.

It does not include fecal coliform or *E. Coli* data in the wastewater or in the spring and well samples.

1.7 DNA Source Tracking:

Since October 2001, samples have been sent to the University of Missouri for DNA source tracking analysis. This technique attempts to identify sources by linking the DNA of the bacteria contained

in the samples to the DNA from known sources. The method relies on each animal species unique strains of fecal bacteria that are adapted to the intestinal characteristics of that particular host.

A library of DNA patterns has been developed that is specific to animals and humans living in Missouri. The database contains many patterns that originate in the central region of Missouri. A Shoal Creek specific database is being developed for this project. Additional samples will be collected in 2003 and that will increase the confidence of the identification. As the samples are added to the database, source identification results may change.

From 13 to 21 isolates are obtained from each water sample and processed to obtain patterns. The method then estimates the similarity between the unknown patterns and the patterns included in the database using pattern recognition software. Even though the software always matches the unknown pattern with a known pattern, only those with the highest degree of similarity are retained. The contribution of each potential source is indicated by the relative presence of that particular pattern in the total array of water isolates and expressed as a percentage. DNA analyses of the samples determines what proportions of fecal coliform came from each potential source, including human, cattle, poultry, domestic animals and wildlife.

- Cattle includes all bovine species
- Domestic animals include dogs, hogs, and horses. Hogs are included in this category for the purposes of this study because pigs are assumed to be kept in small numbers.
- The poultry class includes chicken and turkey.
- The human class includes human samples and samples collected from wastewater.
- Wildlife includes wild turkey, deer, geese and raccoons.

By prorating these percentages to the concentrations of fecal coliform in the water samples, the contributions from each potential source are determined. The percentages of isolates identified in each host class are summarized in Table 3.

Table 3. Percentages of isolates identified in each host class during different seasons.

Host class	Cattle	Domestic animals	Poultry	Human	Wildlife
Winter 2001-2002	24%	25%	6%	27%	19%
2002 recreation season	40%	28%	18%	11%	3%
Winter 2002-2003	11%	30%	23%	23%	12%

2. DESCRIPTION OF THE APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGETS

2.1 Beneficial uses of Shoal Creek:⁵

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life and Human Health associated with Fish Consumption
- Irrigation

⁵ 10 CSR 20-7.031 Table H

- Cool Water Fishery
- Whole Body Contact Recreation (Swimming)
- Boating and Canoeing

2.2 Use that is impaired:

Whole Body Contact Recreation (Swimming)

2.3 Standards that apply:

Missouri's Water Quality Standards at 10 CSR 20-7.031(4)(C) state:

“Protections of whole-body-contact recreation is limited to classified waters designated for that use. For periods when the stream or lake is not affected by stormwater runoff, the fecal coliform count shall not exceed two hundred colonies per one hundred milliliters (200 col/100 mL) during the recreational season in waters designated for whole-body-contact recreation or at any time in losing streams. The recreational season is from April 1 to October 31.”

The stormwater exclusion in the standards is difficult to apply because there is no definition of what constitutes stormwater flow. In this TMDL, stormwater is addressed in the Load Frequency Curve (Figure 5). The curve is the 200 col/100 mL standard and different loads apply to different flows. The issue of the stormwater exclusion will be addressed in Missouri's next Standards revision.

2.4 Anti-degradation Policy:

Missouri's Water Quality Standards include the Environmental Protection Agency (EPA) “three-tiered” approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier I defines baseline conditions for all waters and requires that existing beneficial uses are protected. TMDLs would normally be based on this tier, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect uses.

Tier II requires that no degradation of high-quality waters occur unless limited lowering of quality is shown to be necessary for “economic and social development”. A clear implementation policy for this tier has not been developed, although if sufficient data on high-quality waters are available, TMDLs could be based on maintaining existing conditions, rather than the minimal Tier I criteria.

Tier III (the most stringent tier) applies to waters designated in the water quality standards as outstanding state and national resource waters; Tier III requires that no degradation under any conditions occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

This TMDL will result in the protection of existing beneficial uses, which conforms to Missouri's Tier I anti-degradation policy.

2.5 Target Determination:

Currently the Missouri Department of Natural Resources is conducting a Water Quality Standards review. Regarding this review, EPA has a longstanding recommendation that the standard for the

indicator bacterium be changed from fecal coliform to *Escherichia coli* (*E. coli*) (EPA 2002). The department has data in both forms in this study. For the purpose of this TMDL, the existing fecal coliform standard will be used and, until the standard is changed, the numeric water quality target will be 200 col/100 mL.

3. CALCULATION OF LOAD CAPACITY

Load Capacity (LC) is defined as the greatest amount of a pollutant that a waterbody can receive without violating Missouri Water Quality Standards. The TMDL for this watershed is a continuous curve calculated from discrete loading capacities over a range of flow conditions. Specific loading capacities are calculated by taking the flowrate times the 200 col/100 mL Water Quality Standard times a conversion factor. This load is divided among the point sources (Waste Load Allocation or WLA) and nonpoint sources (Load Allocation or LA) with an allowance for an explicit Margin of Safety (MOS). The Margin of Safety ensures a conservative estimate of the pollutant load. It is calculated due to the inherent error that exists due to the high number of variables that exist in a dynamic stream system.

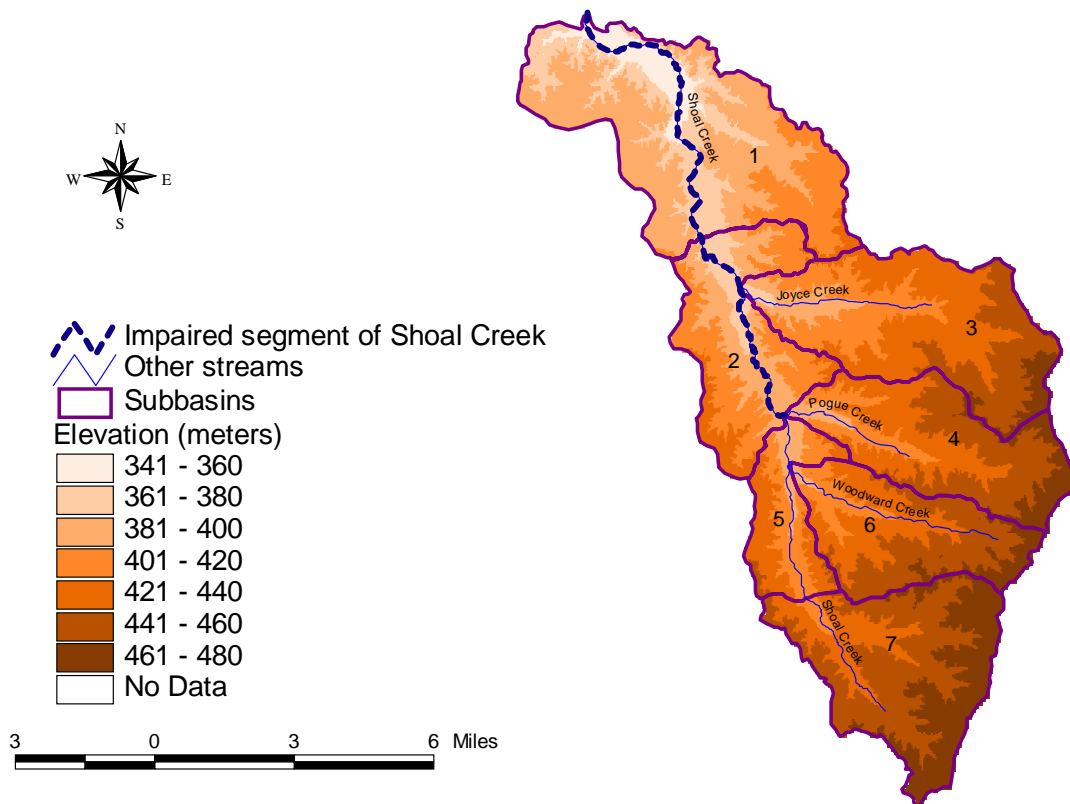
$$LC = WLA + LA + MOS$$

3.1 Model Set-up and Description:

The Soil and Water Assessment Tool (SWAT) was used to simulate fecal coliform loading (Arnold et al., 1998). The methodology relies on a mathematical computer simulation that calculates bacteria loads and concentrations. Both fecal coliform and *E. coli* were used in this study. The model takes into account climate, physical landscape features and land management factors. The purpose of using a model is to integrate the flow data and the water quality data in order to establish water quality baseline characteristics.

For modeling purposes, the watershed was divided into sub-basins and further sub-divided into nearly homogeneous units that has a distinct land use, soil type and management practice. The units are called hydrologic response units (HRU). For the Shoal Creek watershed, the sub-basins were selected on the basis of the natural tributaries to Shoal Creek and on the existing water sampling points. Figure 2 shows the sub-basins that were utilized. Once a baseline is established, the model evaluates the potential change in environmental impact if landowners in the watershed change their management practices.

Figure 2. Shoal Creek and the subbasins used in the SWAT model



SWAT simulates many of the physical processes that can impact water quality. Some of the inputs that the model requires are readily available with the use of the GIS technology (elevations, soils, slopes, land use). Other inputs are specific to the area and are not readily known (pasture management, litter management and grazing practices). The local steering committee helped determine these types of inputs into the model. Additional information for the model came from agencies, including the Natural Resources Conservation Service (NRCS), the Barry County Soil and Water Conservation District (BCSWCD) and the Missouri Agricultural Statistics Service (MASS).

The model uses daily rainfall and temperature to calculate flow values, sediment yields, pollutant loads and concentrations, as well as crop yields. The program includes equations that represent the physical processes that control water movement, sediment transport, crop growth, nutrient cycling and transport and other processes on a daily time step. Direct inflows and their associated loads are added to the background or the load that results from natural erosion processes. To validate the inputs to the model, calculated values for surface runoff, hay yields and the movement of agricultural chemicals were compared to measured values derived from actual data. The model allows for the analysis of water quality at the outlet of each sub-basin of the watershed.

3.2 Model assumptions, limitations and other considerations:

In order to facilitate the watershed modeling process, several assumptions were made. These assumptions are listed below.

1. The measured daily rainfall and temperature data from the official weather stations in Monett, Missouri, is assumed to be representative of the daily weather in the northern part of the watershed (north of Highway 97). The data from the station at Cassville, Missouri is assumed to be representative of the daily weather in the southern part of the watershed. Monett and Cassville are located 1 mile north and 3.5 miles southwest of the watershed boundary. However, the localized nature of storm events can introduce some error in the model's results.
2. In each sub-basin, the properties of the "dominant" soils for each land use are used to describe the soil characteristics for that whole soil-land use association.
3. Management operations (grazing, nutrient application, seed harvest and hay cuts) are defined by fixed dates. The model does not modify these dates based on precipitation events.
4. The different pasture management practices that are currently used were summarized in one four-year management rotation that is representative of what is being done in the watershed.

The transport of bacteria through karst features cannot be simulated with SWAT. Bacteria concentration values from a few spring samples show that these springs are contaminated. There is, however, no scientific basis for estimating bacteria loading from springs.

Fecal coliform loads that are directly deposited by cattle into the water are identified as **direct nonpoint source loading** in the model. To estimate the contributions from septic tanks, the sewage from houses within 250 ft of the stream were considered to be a direct nonpoint source loading as well. These loadings vary by month to account for seasonal differences in the likelihood of cattle standing directly in streams.

Fecal coliform that is land-applied is treated as **nonpoint source loading**. All or part of that load may be transported to the stream as a result of surface runoff during rainfall events. This includes poultry litter spread on pastures or the manure deposited by grazing animals. The fecal coliform counts are calculated proportional to the litter or the manure deposited on the pasture. Fecal coliform die-off is simulated during dry days while on the land, in the soil and in the streams.

3.3 Model Calibration:

The model was calibrated using almost two years of flow values measured at the Highway 97 Bridge. The monitoring periods span from May 17, 1999 to June 20, 2000 and from January 12, 2001 to April 2003. For a more detailed description of the model calibration and validation, see FAPRI's draft report (FAPRI, 2003).

3.4 Frequency curves:

To insure that the overall statistical characteristics of the bacteria are well reproduced, frequency curves are used. These curves plot one variable, such as the concentration of bacteria or flow, against the percent of the time, or the frequency, at which they occur. The comparison of measured (derived from actual data) and simulated (derived by the model) bacteria concentrations can be accomplished using these curves. The concentration frequency curve that results from nonpoint sources and from nonpoint source direct inputs is shown in Figure 3. It represents the average concentration frequency curve for one recreation season obtained from a 30-year simulation. Figure

3 also shows the water quality standard of 200 col/100 mL and the concentration frequency curve obtained from data collected during the 2002 recreation season. For comparison, data accumulated between 1992 and 2003 by Geoffrey Luttrell of Crowder College in Neosho are shown in Figure 4. The y-axis of both charts has been truncated to a maximum concentration of 3000 col/100 mL for clarity of the variation between the different curves. Actual counts have gone as high as 400,000 col/100 mL.

Figure 3. Comparison of 2001 and 2002 simulated and measured concentration frequency curves

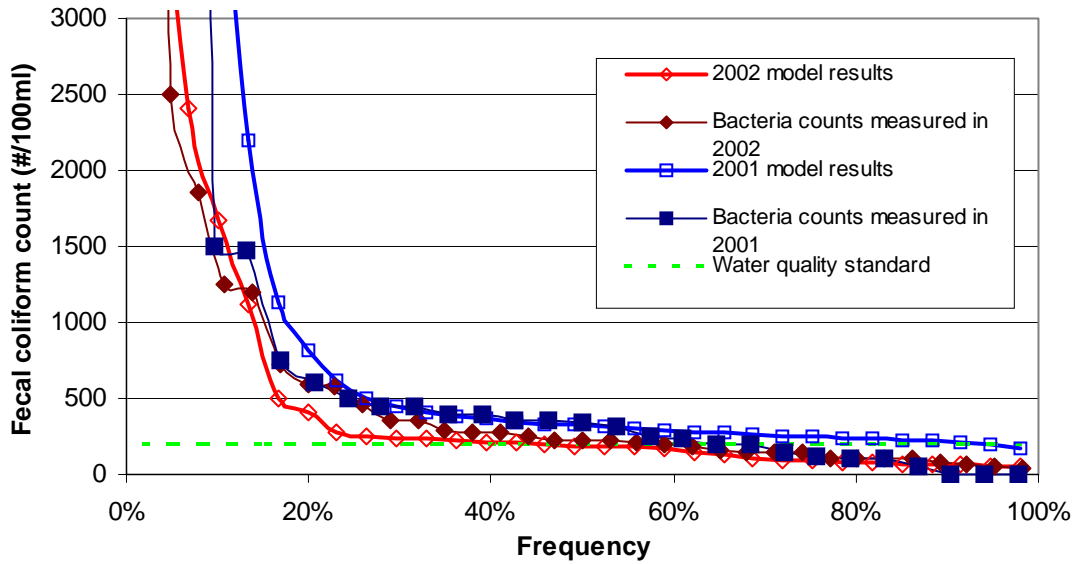
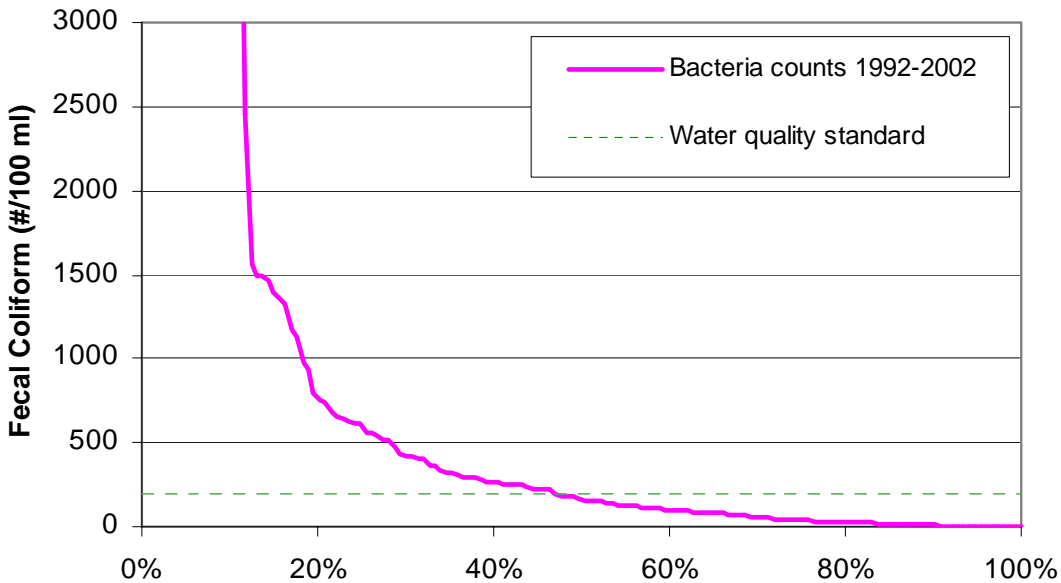


Figure 4. Frequency curve for fecal coliform measurements, 1992-2002. (Crowder College)

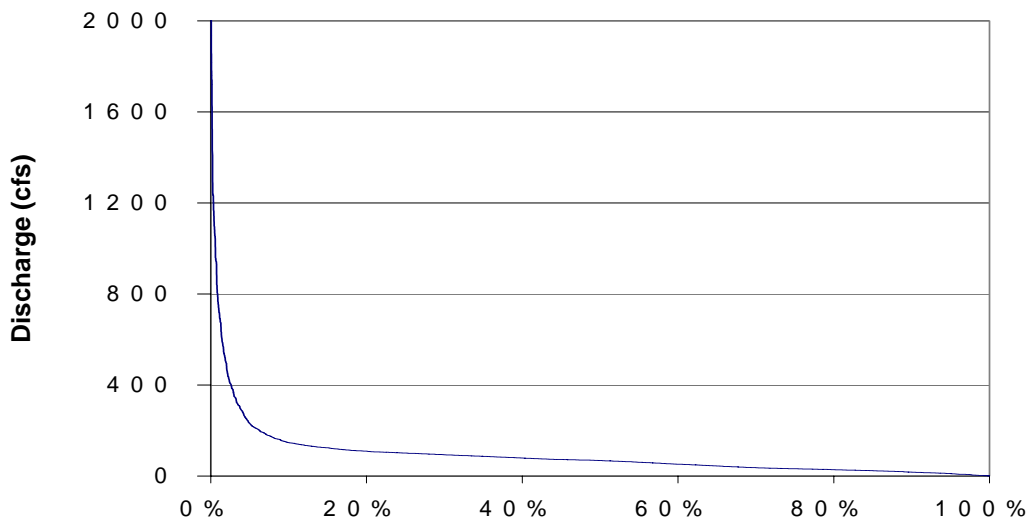


The simulated low frequency concentrations (20 percent and below) seem to be above measured concentrations. It should be noted that it is difficult to measure bacteria concentrations above 20,000 col/100mL. When counts are high, the volume of water to be filtered is greatly diluted in order to count the colonies on the plate. The highest measured concentration (13,500 col/100mL) was obtained by filtering 0.1 mL of Shoal Creek water. The possible measurement errors are therefore much greater. Despite this constraint, the simulated fecal coliform concentrations are in the correct range of magnitude and frequency when compared to measured concentrations.

3.5 Allowable Load:

A flow frequency curve was developed using the model results of a 50-year long simulation. The simulation was conducted with generated weather having the statistical characteristics of the last 30 years. The resulting flow frequency curve (Figure 5) includes only the flow values of the recreation season, from April 1 - October 31.

Figure 5. Flow frequency curve of summer flows from a 50-year long simulation.



Given that the maximum fecal coliform concentration is 200 col/100 mL, the standard bacteria load frequency curve (Figure 6) is derived from the flow frequency curve by multiplying the flow values by 200 and adjusting them to obtain the correct units. Note the numbers on the left side of Figure 6. In the calculation from flow to load, very large numbers are obtained. To express these large numbers, “E + x” is used in scientific notation, where x represents any given number. E+12 indicates that the decimal place has been moved 12 places to the left. Thus, E+12 is equal to a trillion. 1.0E+13 is equal to 10 trillion, or 10,000,000,000,000 (1 + 13 zeros).

Measured fecal coliform data (Appendix C) have been incorporated into the load frequency curve (Figure 6) to determine how much load reduction will be required to bring the affected waterbody into compliance with Missouri Water Quality Standards.

The utility of a load frequency curve is that it points out the sources of the pollutant. It also can be used to identify possible implementation strategies. High fecal coliform numbers at base flow indicate point source problems, or in this case, direct nonpoint sources. There is no runoff from rain events occurring during base flow and, therefore, there is no contribution occurring from runoff and nonpoint sources. At storm flows, rain events have resulted in considerable runoff from nonpoint sources. So, high bacteria numbers during storm flow events indicates nonpoint sources are the major concern.

Figure 6. Bacteria load frequency curve during the recreation season with a constant concentration simulation of 200col/100 mL.

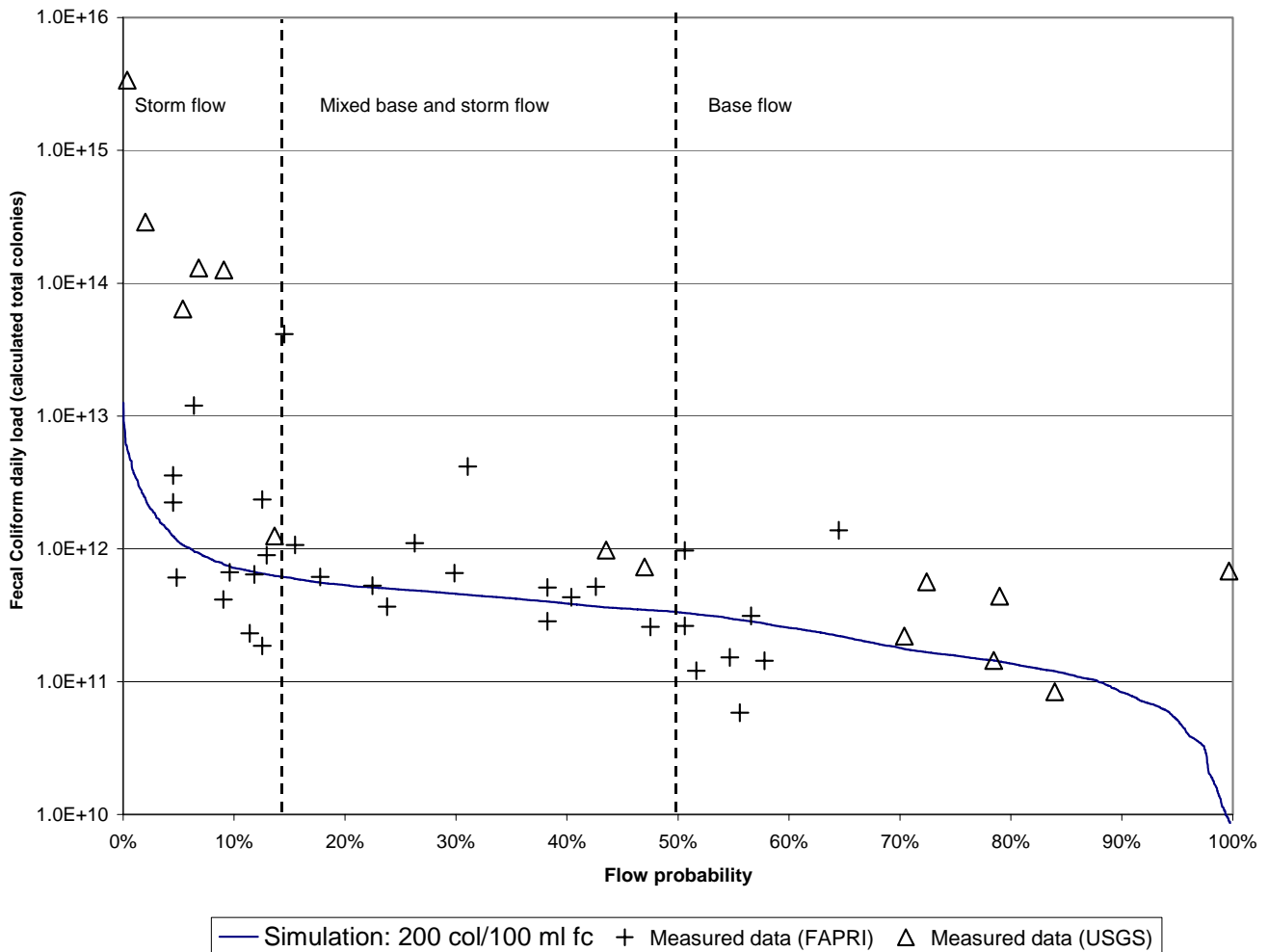


Figure 6 is a transformation of Figure 5 to include the allowable load of fecal coliform bacteria over the full range of flow frequencies. The frequency assigned to a fecal coliform load is the frequency of the flow for that day. Any data point that is under the curve indicates compliance with the Missouri water quality criteria of 200 colonies/100mL. The samples were collected during the recreation season from 1999 to 2002. Of the total of 46 samples collected, 31 samples, or 67 percent, of the total number of samples indicate bacteria loads that exceed the criteria.

Bacteria concentrations in storm flow conditions, as indicated on the left side of the graph, are expected to be primarily from runoff. This would include land applied poultry litter and cattle manure from pastures. Concentrations during base flow, as shown on the right side of the graph, are generally attributable to cattle in the stream and possible illegal discharges from on-site septic systems.

4. WASTE LOAD ALLOCATION (POINT SOURCE LOADS)

The Waste Load Allocation (WLA) is that portion of a receiving stream's load capacity that is allocated to existing or future point source discharges. Missouri requires a State Operating Permit for all concentrated animal feeding operations (CAFOs) for poultry facilities in excess of 100,000 birds. A permit for CAFOs requires the facility to be designed, constructed and operated to have no discharge, unless caused by a catastrophic storm (24-hour duration exceeding the 25-year recurrence frequency). Based on the number of poultry permits in the watershed (see Appendix D) and the potential for runoff from land application of manure, CAFOs could cause or contribute to the impairment of Shoal Creek. But because CAFO facilities must comply with their no-discharge permit requirements, releases from a properly designed, operated and maintained facility should be extremely rare. Therefore the WLA for these facilities is set to zero.

One of these facilities is currently under enforcement action. George's Processing, Inc. (permit #MO-0108618), a poultry processing plant, was referred to the Water Pollution Control Program's enforcement section on February 10, 1999. George's was referred for exceeding their permit limits for nitrate in their monitoring wells. This was likely a result of inappropriate land application during the winter. Other violations resulted from a force-main break, which caused a discharge of effluent off their property. A Settlement Agreement was reached May 7, 2001. The terms of the agreement include a penalty, a timeline for upgrading the facility and additional penalties for any future violations of the 10 mg/L nitrate limit in the monitoring wells. Since George's has a no-discharge permit, their WLA is set to zero, like the facilities above.

However, within the watershed there is one point source that does discharge to the impaired portion of Shoal Creek. That is Camp Barnabas, (permit #MO-0125164). Located next to Shoal Creek, downstream of where other measurements were taken at Highway 97, the facility is a recirculating sand filter with chlorination. The design population is 350 and the design flow is 12,000 gallons per day, or 0.0186 cubic feet per second. The permit includes fecal coliform limits of 1000 colonies per 100 mL daily maximum and a monthly average of 400 colonies per 100 mL. As the potential load contribution from this facility is relatively small, the WLA is based on the maximum daily limit at design flow conditions. It is calculated as follows:

$$\text{Fecal Coliform (cfu}^6\text{/day)} = (1000 \text{ cfu}/100 \text{ mL}) * (1000 \text{ mL}/\text{L}) * (\text{L}/0.264 \text{ gal}) * (12000 \text{ gal}/\text{day}) = \underline{4.5455\text{E}+8 \text{ cfu}/\text{day}}.$$

⁶ Cfu stands for colony forming unit. This is very similar to "colonies/100mL". Technically, cfu denotes only live bacteria, while col/100mL can include dead bacteria (e-mail communication, Claire Baffaut, FAPRI, 8/14/03).

5. LOAD ALLOCATION (NON-POINT SOURCE LOAD)

The Load Allocation (LA) includes all existing and future nonpoint sources plus the natural background conditions.

To compare the impact of different sources, model scenarios were run with each of the bacteria sources contributing to the load during the recreation season. These conclusions are based on the hypotheses regarding the number of on-site septic systems that may result in direct bacteria inputs, the number of cows that stand in the stream and the loading from pastures. Other scenarios were simulated to estimate the loadings from various sources:

- Cattle direct deposits only
- Nonpoint source direct inputs only (cattle + sanitary)
- Nonpoint source loadings from grazing cattle only
- Nonpoint source loadings from poultry litter only

The results indicate that direct nonpoint source inputs have the largest impact on the stream loads and bacteria concentrations 50 percent of the time. Bacteria loads carried by surface runoff are the dominant source of loading and bacteria 15 percent of the time. The loads delivered by surface runoff are equal to those directly contributed to the stream 35 percent of the time. Contributions from each source can be estimated during the three different types of flow conditions and are shown in Table 4.

During base flow, cattle are responsible for the majority of the bacteria. On-site systems make a smaller contribution. During periods of mixed base flow and stormwater runoff, cattle again are the major source of fecal coliform loading. Under these flow conditions, both direct deposits of manure and runoff from pastures add to the load. Poultry litter is a significant source of bacteria mainly during periods of high surface runoff. Poultry litter is spread in the spring when large storm events are likely to occur. The litter is spread at one time in large quantities. This increases the potential for large, one-time bacteria loadings if a rain event immediately follows the spread of the litter. However, the probability of a rain event occurring after the current single application is lower than would be expected if smaller amounts of litter were spread more frequently. The timing of the spreading of poultry litter is critical to prevent one-time, large bacterial loadings.

Table 4. Averaged simulated contributions in percentages from each source to the fecal coliform loading in Shoal Creek.

Flow type	Base flow (>50% frequency)	Mixed base and storm flow (15-50% frequency)	Storm flow (< 15% frequency)	All flows (0 – 100 %)
Cattle in streams	82.5%	31.5%	0.7%	2.7%
Sanitary sewage	16.8%	5%	0.1%	0.4%
Grazing cattle	0.7%	63.1%	28.5%	29.4%
Poultry litter	0%	0.4%	70.7%	67.5%

Due to the variations in loading from different sources over the range of flow conditions, determination of the load allocation is appropriated to the differing flow regimes. The Load

Allocation is equal to the Load Capacity (Total Maximum Daily Load) minus the Wasteload Allocation minus the Margin of Safety.

$$LA = LC - WLA - MOS$$

The Load Capacity or TMDL is based on the curve in Figure 5. The Margin of Safety is based on the standard deviations that result for each segment of the curve. Results are in Table 5.

6. MARGIN OF SAFETY (MOS)

A margin of safety (MOS) is necessary due to uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

- (1) Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- (2) Implicit - Incorporate the MOS as part of the design conditions for the waste load allocation and the load allocation calculations (making conservative assumptions in the analysis itself).

The measurement and simulation of fecal coliform concentrations includes many uncertainties and possible sources of error.

Sources of error during sampling and measurement include:

- Variability of bacteria counts within the cross-section of a stream
(Two samples from the same location but in different parts of the stream may vary)
- Variability of bacteria results collected on a given day and the meaning of an individual sample relative to an average daily concentration
(Two samples from the same location collected at different times of day can have varying results)
- Potential contamination by monitoring equipment
- Potential decay or growth of bacteria during transport to the laboratory

Sources of error for the simulation of bacteria concentrations include:

- Uncertainty about the average daily coliform production of cows and humans
- Bacteria content of poultry litter
- Decay rate of bacteria from different sources on the land and in the water

Cows are known to spend a significant amount of time standing in streams, particularly during hot weather. It is difficult, however, to quantify precisely how much time they spend in the stream or how that time is related to the amount of manure defecated. Also, the karst features of this watershed were not taken into account. Finally, the impact of a pollutant is dependent on the stream flow and therefore, on weather conditions.

Even with efforts to minimize the sampling and measurement errors, the uncertainties on the inputs cannot easily be reduced. For this TMDL, the Margin of Safety will be the standard deviations that result for each segment of the curve in Figure 5, based on the variability of the weather.

Because flows are different from one year to another, the fecal coliform load that results in a concentration of 200 colonies per 100 ml varies. Based on the 30-year long simulation, the department has calculated the average flow frequency curve that can be expected during any year. For each frequency value, the standard deviation of the flows that occur with that frequency was calculated and multiplied by 200 colonies/100ml to obtain the standard deviation of the load capacity. These standard deviations were then averaged within each flow segment. Results are in Table 5.

Table 5. Fecal Coliform Load Allocations and Percent Reductions in Pollutant Load Needed to Meet Water Quality Standards

Flow Probability (%)	0-15 (Storm flows)	15-50 (Mixed Flows)	50-100 (Base flows)
LC(cfu)	1.4114E+12	4.4492E+11	1.6614E+11
MOS (cfu)	5.3109E+11	1.4097E+11	9.2589E+10
WLA (cfu)	4.5455E+08	4.5455E+08	4.5455E+08
LA (cfu)	8.7985E+11	3.0349E+11	7.3096E+10
Measured data geomean (cfu)	5.7677E+12	6.4848E+11	2.6324E+11
Reduction (cfu)	4.8878E+12	3.4499E+11	1.9014E+11
Reduction (%)	85 %	53 %	72 %

7. SEASONAL VARIATION

Shoal Creek is designated for whole body contact recreation during the period from April 1 to October 31. During this season, human activities increase in and around the stream. The TMDL addresses seasonal variation by associating a daily load to every flow. The critical season extends from June to October when the flow is at its lowest and the stream use is at its peak.

8. MONITORING PLANS UNDER THE PHASED APPROACH

Monitoring of flows, water quality and DNA host identification will be terminated at the end of 2003. Future water quality monitoring will track the changes during and after implementation of alternative management practices.

In order to observe and quantify the temporal variation of water quality indicators in Shoal Creek, monitoring of water quality occurred frequently at one location (Highway 97 bridge). A few samples were collected at other points and from springs to obtain data that could confirm or contradict the water quality data collected at Highway 97. These verification data sets did not have a sufficient number of samples to adequately characterize the water quality of tributaries or springs. This might be a consideration in future monitoring plans.

Crowder College is under contract with the department to collect fecal coliform data at the Hwy 97 bridge through mid 2004. Post implementation monitoring will commence three years after the strategies discussed in the next section are implemented. Fecal coliform and *E. coli* data will be

collected. Other parameters may be collected, but the sampling plan will be based on the assessment needs that exist at the time post implementation monitoring is initiated. One option is to obtain data through 319 grants that may be awarded in the Shoal Creek watershed in the future.

All Missouri TMDLs are phased. If future monitoring reports reveal that water quality standards are not being met, this TMDL will be re-opened and re-evaluated.

9. IMPLEMENTATION

Efforts have already occurred in the Shoal Creek watershed to deal with excessive nutrients reaching the creek. From 1995 – 2000, a 319 grant provided education on poultry litter land application. The positive result was that phosphorus levels in soil decreased. Also, there is an Agricultural Nonpoint Source Special Area Land Treatment (AgNPS SALT) Project that was recently completed. It was funded from 1997 until June 2003. The first objective of this project was to educate and train landowners in nutrient management. Future monitoring will reveal the impact and effectiveness of this project. Although these projects were aimed at nutrient management, the BMPs employed also help reduce the amount of bacteria entering the stream.

Additionally, there is a current 319 project that impacts upper Shoal Creek. The Elk River and Shoal Creek 319 Project was initiated in 2002 and a good start has been made. Some of the aims of the project are enrolling farms in Comprehensive Nutrient Management Plans, constructing stacking sheds, installing livestock watering wells in combination with rotational grazing systems, adding exclusion fencing along the riparian corridor, and conducting a feasibility study of transporting litter out of the watershed to intensive crop production areas in need of nitrogen and phosphate fertilizers.

Several scenarios were run using the SWAT model to assess which alternative management practices would lead to stream fecal coliform concentrations that would meet water quality criteria. The following scenarios were evaluated:

- Scenario 1: no septic discharge, a 50 percent reduction of cattle standing in the streams, and a 50 percent reduction of the nonpoint source load
- Scenario 2: no septic discharge, no cattle standing in the streams, and a 50 percent reduction of the nonpoint source load
- Scenario 3: no septic discharge, a 50 percent reduction of cattle standing in the streams, and a 66 percent reduction of the nonpoint source load
- Scenario 4: no septic discharge, no cattle standing in the streams, and a 66 percent reduction of the nonpoint source load

The frequency curves that result from the simulation of the scenarios are shown in Figure 7. The figure shows that 85 to 90 percent of concentration values that result from the implementation of scenarios 3 and 4 are lower than 200 colonies per 100 mL

However when looking at the variation of the 30-days average concentrations over time, scenario 3 produces a geometric average that goes above 200 colonies/100mL every single year. Scenario 4 only has a few similar events occurring during the last 10 years and was limited to when poultry litter is applied just before rain events (Figure 8).

Figure 7. Comparison of the concentration frequency curves from scenarios 1 to 4.

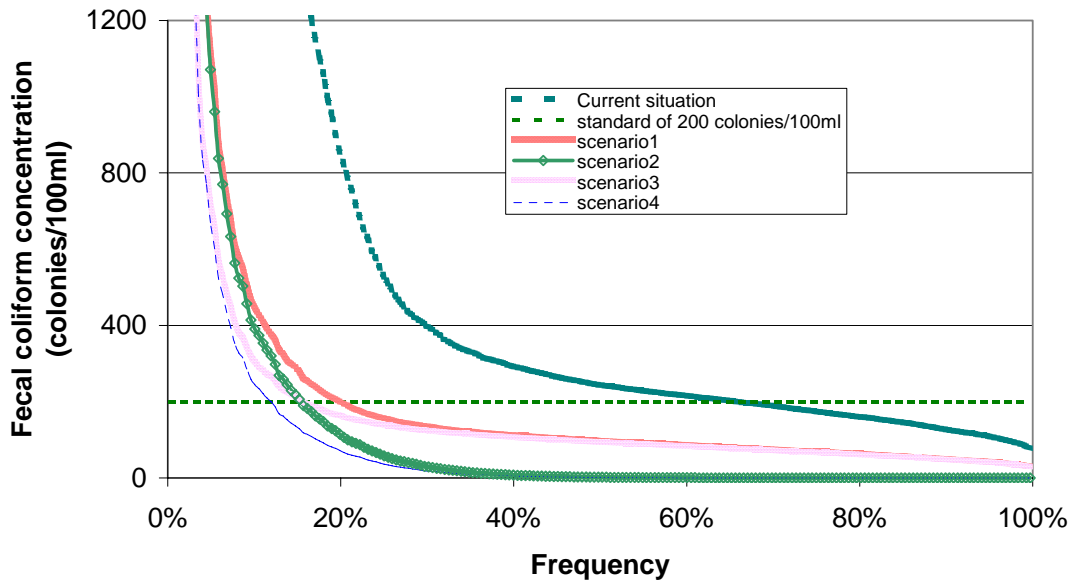
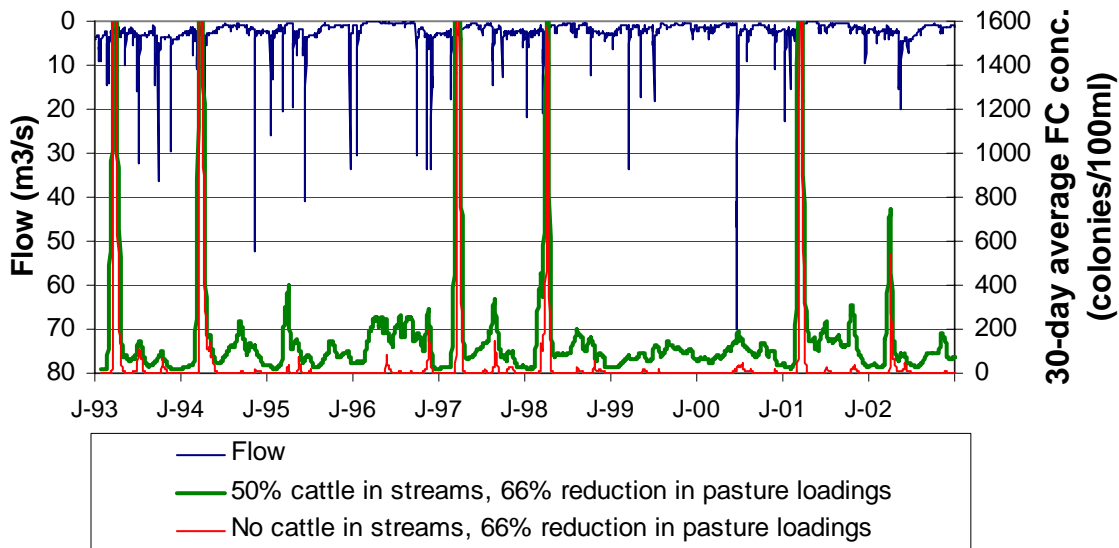


Figure 8. Simulated 30-day geometric average for scenarios 3 and 4 from 1993 to 2002.



The following scenarios show the most promise for reducing the fecal coliform concentrations in Shoal Creek:

- A 100 percent reduction of the sanitary sewage that reaches the stream
- A 50 – 100 percent reduction of the cattle standing in the streams
- A 66 percent reduction in the fecal coliform loadings due to surface runoff events

Implementation of this TMDL will involve finding ways to achieve these reductions. Pumping of on-site septic systems is a routine maintenance procedure and should take place every three years for a household of four people. After many years of a system being in place, it is possible that some on-site systems need to be replaced. Education is needed, possibly in combination with local ordinances, to identify and replace failing septic systems and encourage the proper maintenance of the systems that are still functional.

A 50 percent reduction of the cattle standing in the streams could be accomplished through a combination of stream fencing, providing shade outside the riparian corridor and locating feeding areas some distance from the stream. Another option is to diversify the diet of the cattle to avoid fescue toxicity. Fescue toxicity elevates the body temperature of cattle, which encourages them to stand in water in order to “cool down”. Achieving 100 percent reduction of cattle standing in streams would require the installation of alternative drinking water sources and fencing for all livestock producers in the watershed. The feasibility of achieving 100 percent reduction of cattle standing in the streams is low. However, local stakeholders (see Section 11) are organizing to work on this problem and time will tell how much reduction they actually achieve.

A reduction of the fecal coliform loadings in surface runoff could be attained with vegetated filter strips at the downstream edge of the pastures. The model assumes that a 30 foot filter would provide a 50 percent reduction and a 40 foot filter would provide a 66 percent reduction. These reduction coefficients are based on studies conducted in Kentucky and elsewhere that showed degrees of reduction between 50 and 100 percent (Coyne, 1995; Glenn, 1984; Young, 1980). Other ideas suggested by the local stakeholders include removing poultry litter from the watershed, incinerating it and composting it in-house before field application.

10. REASONABLE ASSURANCES

A Shoal Creek watershed partnership has been formed (see Section 11) and will consider the various methods available to address the impairment issue. This group can identify the funding mechanisms available to finance the watershed action strategies of their choice and has the option to develop a watershed management plan.

A reduction of sanitary sewage inputs is considered achievable due to an existing law that sanitary sewage should not leave a landowner’s property. According to Jamie Cornell, Barry County Health Department, about one-third of the septic systems in Barry County are failing.⁷ To address this concern, one option being considered is to canvass the watershed and determine the condition of the septic systems. Funding sources are being investigated to help with maintenance of functioning systems and replacement of failing ones. The department is working on utilization of State Revolving Funds for low or no interest loans for on-site septic system upgrades. Another idea is to explore the possibility of starting regular inspection and maintenance of these systems.

The U.S. Environmental Protection Agency Region VII, through the Missouri Department of Natural Resources, has provided partial funding for projects in this watershed under Section 319 of the Clean Water Act. In the past, the funding has been used to implement best management practices for livestock (such as providing alternate watering systems), fencing cattle out of riparian

⁷ Stated in Shoal Creek Public Meeting in Monett, Missouri, June 26, 2003

areas and construction of stacking houses for storage of animal waste. This funding is available for watershed planning and projects through the department's nonpoint source water pollution grants program.

Another source of funding is the department's Soil and Water Conservation Program. That program can provide cost-share on best management practices for livestock, exclusion of livestock from sensitive areas, management of animal waste and stormwater runoff controls.

A relatively new funding option is the Farm Security and Rural Investment Act of 2002, commonly called the 2002 Farm Bill. This bill places a "strong emphasis on the conservation of working lands, ensuring that land remain both healthy and productive". For a summary of the conservation practices covered under this bill, see the following website:
<http://www.nrcs.usda.gov/programs/farmbill/2002/pdf/ProgSum.pdf>

Lastly, funding is available for agricultural best management practices through the US Department of Agriculture's EQIP program. The Soil & Water District, working in conjunction with the Natural Resources Conservation Service, may provide cost share on a wide variety of management practices, including grass buffer strips and riparian corridor restoration.

11. PUBLIC PARTICIPATION

In addition to the steering committee formed to provide input into FAPRI's study (Section 1; Public Involvement), two public meetings were held in Monett on May 22 and June 26, 2003. The purpose of the meetings was to present results from the FAPRI study and familiarize local citizens with TMDL concepts and how they are developed. These meetings also provided local citizens an opportunity to have input into the TMDL implementation plan. At a third meeting on August 14, 2003, participants focused on the three main problems (septic, litter and cattle in the stream) and came up a list of possible solutions. As a result, a watershed partnership has formed that is composed of local citizens, landowners and businesses to implement the suggestions. This partnership, the Shoal Creek Watershed Group, is meeting monthly in Monett.

This water quality limited segment is included on the approved Missouri 1998 303(d) list, which was itself public noticed. A 30-day Public Notice period was held for this TMDL from August 29 to September 28, 2003. Groups that received the public notice announcement include:

- The Missouri Clean Water Commission
- The Water Quality Coordinating Committee
- The TMDL Policy Advisory Committee
- The Shoal Creek Watershed Group
- Stream Teams in the Shoal Creek watershed (142)
- The appropriate legislators (5)
- Others that routinely receive the public notice of Missouri State Operating Permits

A copy of the notice, the comments received and the department responses have been placed in the Shoal Creek file.

12. ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTATION

Shoal Creek Poultry Litter Management (319 Project) – 1995-2000
Upper Shoal Creek AgNPS SALT Project – 1997-2003
Draft Upper Shoal Creek Watershed Bacteria Total Maximum Daily Load (FAPRI's report)
Soil and Water Assessment Tool model results
Crowder College data
U.S. Geological Survey data
Public Notice announcement
Shoal Creek Information Sheet

13. APPENDICES

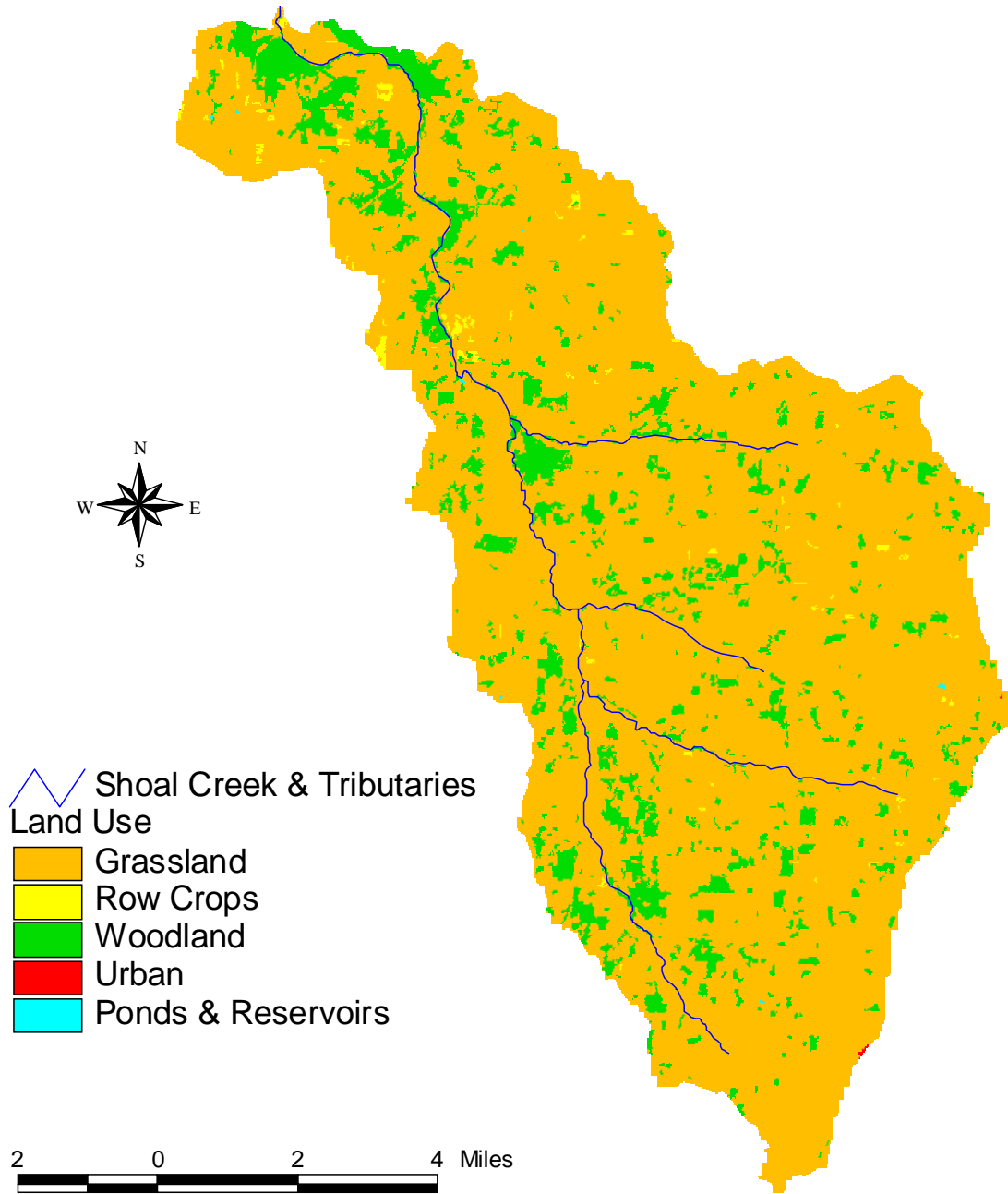
Appendix A – Land Use Types for the Shoal Creek Watershed
Appendix B – Map of Sample Locations and Impaired Stream Segment
Appendix C – Fecal Coliform Data
Appendix D – Permitted Facilities in the Upper Shoal Creek Watershed

REFERENCES

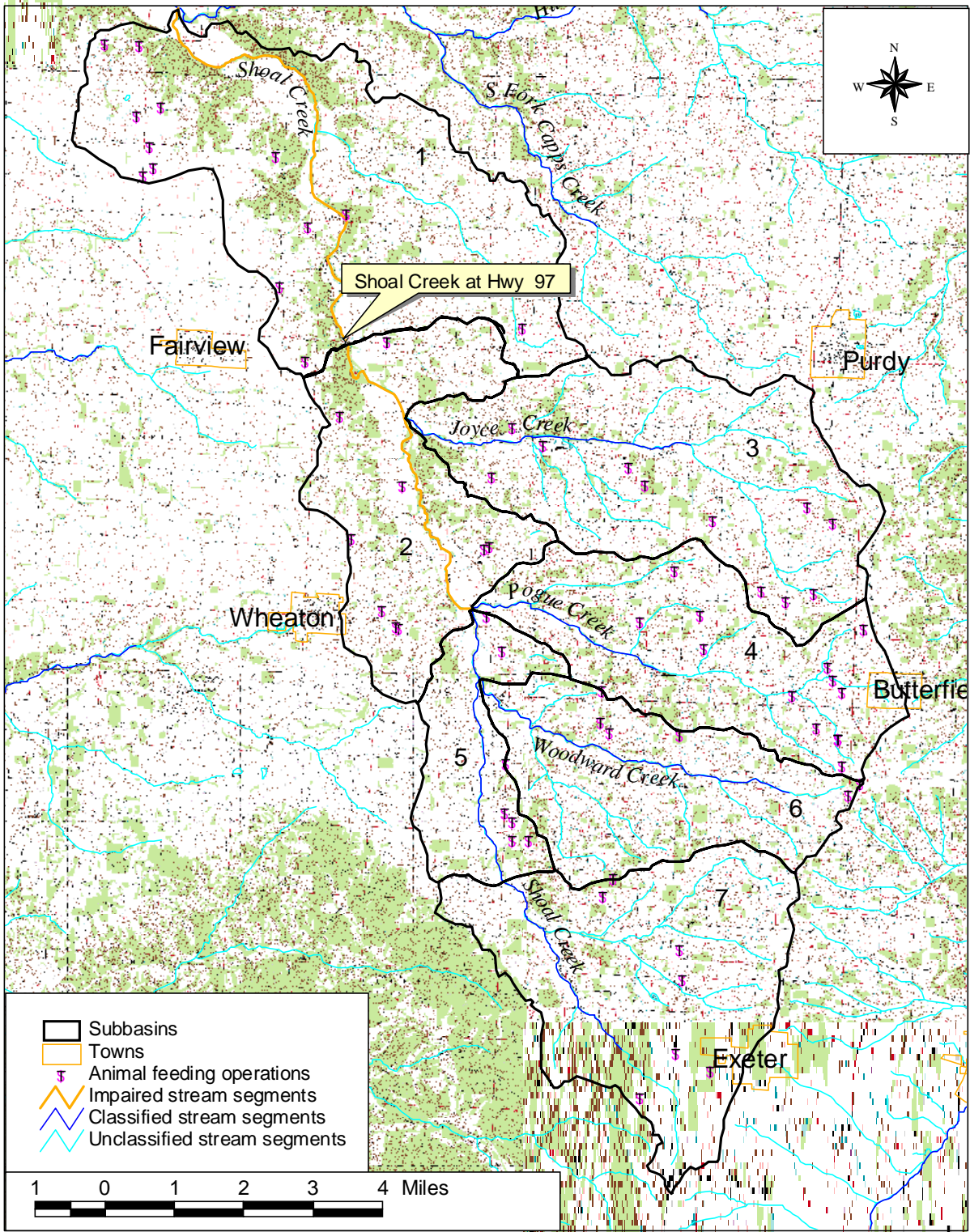
- Arnold, J.G., R. Srinivasan, R. S. Muttian, and J.R. Williams. 1998. Large area hydrologic modeling and assessment part I: model development. *Journal of American Water Resources Association* 34 (1): 73-89.
- Coyne M.S., R.A. Gilfillen, R.W. Rhodes, and R.L. Blevins. 1995. Soil and fecal coliform trapping by grass filter strips during simulated rain. *Journal of Soil and Water Conservation* 50(4) 405-408.
- Glenne, B. 1984. Simulation of water pollution generation and abatement on suburban watersheds. *Water Resources Bulletin*. (April) 20:2.
- Food and Agriculture Policy Research Institute (FAPRI) & University of Missouri College of Agriculture, Food, and Natural Resources. 2003. Upper Shoal Creek Watershed Bacteria Total Maximum Daily Load. (Draft). FAPRI-UMC Report 04-03. Columbia, MO.
- Luttrel, G. 1991-2003. Bacteriological data. Crowder College. Neosho, MO.
- Missouri Agricultural Statistics Service. 2002. Barry County Hay Production, accessed in 2002. <http://agebb.missouri.edu/mass/agrifact/barry/hayprod.htm>
- Schumacher, J.G., 2001. Water Quality in the Upper Shoal Creek Basin, Southwestern Missouri, 1999-2000. U.S. Geological Survey Water-Resources Investigations Report 01-4181. Rolla, MO.
- USDA. 2000. National Engineering Handbook. Part 651. Agricultural Waster Management Field Handbook, chapter 4: agricultural Waste Characteristics. Washington, D.C., also available at: <http://www.ftw.nrcs.usda.gov/awmfh.html> (accessed May 2003).
- U.S. Environmental Protection Agency. 2001. *Protocol for Developing Pathogen TMDLs*. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC.
- US Environmental Protection Agency. 2002. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. (May 2002 Draft). EPA-823-B-02-003.
- United States Geological Survey, 1992. Water-Quality Characterization of the Spring River Basin, Southwestern Missouri and Southeastern Kansas. Water Resources Investigations Report 90-4176. USGS, Rolla, MO
- Virginia Department of Environmental Quality, 2002. Fecal Coliform TMDL for Naked Creek in Augusta and Rockingham Counties, Virginia. Prepared by Department of Biological Systems Engineering, Virginia Tech. Accessed at: <http://www.deq.state.va.us/tmdl/apptmdls/shenrvr/nkdcreek.pdf>

Young, R.A., A.T. Huntrods, and W. Anderson. 1980. Effectiveness of vegetated buffer strips in controlling pollution from feedlot runoff. *Journal of Environmental Quality* 9(3):483-487.

Appendix A
Land Use Map of Upper Shoal Creek Watershed



Appendix B: Topographic Map of Shoal Creek Watershed



Appendix C

Fecal Coliform Data Used in the Load Frequency Curve and in Figure 3.

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100mL
02/13/2002	59.56	2
03/05/2002	68.87	17
03/12/2002	59.56	1
03/19/2002	56.55	375
03/28/2002	87.04	130
04/05/2002	67.29	160
04/09/2002	92.22	1850
04/16/2002	70.47	150
04/23/2002	58.05	220
04/30/2002	45.05	1250
05/07/2002	125.30	13500
05/14/2002	254.10	575
05/21/2002	237.30	105
05/30/2002	254.10	360
06/03/2002	139.00	68
06/11/2002	133.10	57
06/14/2002	196.00	2500
06/18/2002	131.10	280
06/25/2002	157.30	108
07/02/2002	121.50	360
07/10/2002	81.95	255
07/16/2002	78.61	225
07/23/2002	93.97	285

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100mL
07/30/2002	102.90	146
08/06/2002	133.10	720
08/15/2002	151.10	180
08/20/2002	137.00	192
08/27/2002	113.90	220
09/04/2002	99.28	455
09/09/2002	56.0	105
09/16/2002	104.70	206
09/23/2002	81.95	142
09/30/2002	75.32	282
10/07/2002	65.72	75
10/14/2002	61.08	102
10/21/2002	59.56	40
10/28/2002	67.29	590
11/04/2002	61.08	80
11/11/2002	72.07	21
11/18/2002	68.87	20
11/25/2002	61.08	33
12/02/2002	61.08	30
12/17/2002	53.60	330
01/07/2003	55.07	380
02/12/2003	45.05	19

Source: Food & Agriculture Policy Research Institute

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
4/6/1999	74	540
4/26/1999	1150	120000
4/26/1999	190	28000
4/27/1999	218	12000
4/27/1999	491	24000
5/11/1999	128	400
6/23/1999	156	33000
7/20/1999	71	420
8/30/1999	36	250
9/15/1999	34	680

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
10/20/1999	24.5	140
11/17/1999	23	640
12/14/1999	39.7	260
1/11/2000	22.5	43
2/22/2000	23.1	260
3/22/2000	30.4	180
3/23/2000	32	510
8/8/2000	29	620
7/23/2001	24.6	1130
8/27/2002	29.5	200

Source: United States Geological Survey

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
2/4/1992		360
4/9/1992	6	560
4/20/1992	243	1500
5/5/1992	28	740
6/9/1992	153	400
7/22/1992	22	930
7/30/1992	28	4800
8/19/1992	15	320
9/8/1992	1433	87000
9/30/1992	43	230
10/26/1992	28	310
11/11/1992	48	610
11/20/1992	238	33000
12/13/1992	262	5800
1/29/1993	131	120
3/22/1993	139	300
4/14/1993	206	8600
5/10/1993	138	4400
5/30/1993	221	35000
6/9/1993	164	10000
6/29/1993	405	53000
7/6/1993	2166	8000
8/5/1993	103	6900
8/26/1993		27
9/14/1993		53000
9/24/1993		400000
10/28/1993		0
11/18/1993		1500
9/13/1995		27
10/5/1995		47
10/31/1995		60
12/1/1995		8
1/12/1996		8
2/10/1996		1
3/9/1996		6
4/13/1996		81
5/4/1996		100
6/8/1996		340
7/6/1996		630
8/11/1996		750
9/19/1996		115
10/30/1996		105
11/12/1996		430
12/11/1996		75
1/7/1997		147

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
2/5/1997		4
3/17/1997		125
4/24/1997		180
5/12/1997		28
6/19/1997		364
7/8/1997		162
8/7/1997		53
9/9/1997		116
10/13/1997		1330
11/4/1997		34
2/19/1998		27
4/6/1998		64
5/11/1998		1350
6/15/1998		131
7/6/1998		156
8/10/1998		108
9/8/1998		120
10/12/1998		253
1/11/1999		24
2/8/1999		1400
3/22/1999		95
4/12/1999		75
5/10/1999		660
6/8/1999		1170
7/13/1999		259
8/3/1999		560
9/13/1999		800
10/5/1999		226
11/9/1999		99
12/7/1999		480
1/11/2000		88
2/7/2000		5
3/13/2000		0
4/10/2000		25
5/1/2000		88
5/22/2000		296
6/12/2000		181
7/10/2000		290
7/31/2000		1560
8/21/2000		153
9/14/2000		250
10/2/2000		280
10/23/2000		220
11/5/2000		50
11/27/2000		320

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
12/28/2000		219
1/8/2001		12
1/28/2001		12
2/20/2001		79
3/12/2001		13
4/1/2001		102
4/23/2001		510
5/14/2001		78
6/11/2001		93
6/25/2001		86
7/16/2001		150
8/6/2001		29
8/27/2001		29
9/16/2001		237
10/29/2001		3
11/18/2001		40
12/9/2001		7
12/31/2001		3
1/21/2002		2
2/11/2002		3

Date	Flow	Fecal Coliform
mo/da/yr	cu ft/sec	cfu/100ml
3/11/2002		13
4/1/2002		5
4/22/2002		16
5/20/2002		49
6/11/2002		63
7/18/2002		29
8/7/2002		33
9/5/2002		36
9/30/2002		425
10/10/2002		38
10/22/2002		37
10/29/2002		3
11/6/2002		12
11/22/2002		11
12/3/2002		18
12/12/2002		3
12/28/2002		1
1/28/2003		1
3/19/2003		143
4/9/2003		46
5/14/2003		257

Source: G. Luttrell, Crowder College, MO

Main channel characteristics of the Shoal Creek Watershed

Subbasin	Channel width (m)	Channel depth (m)	Channel slope	Channel length (km)	Manning coefficient	Hydraulic conductivity (mm/hr)	Erodibility factor	Cover factor	Alpha for the banks
1	33.246	1.134	0.002	18.637	0.035	25.00	0.1	0.2	0.5
2	28.262	1.018	0.003	6.114	0.05	50.00	0.1	0.2	0.5
3	11.849	0.57	0.005	10.898	0.04	50.00	0.1	0.2	0.5
4	10.001	0.509	0.005	9.761	0.05	50.00	0.1	0.2	0.5
5	17.515	0.74	0.003	7.969	0.045	50.00	0.1	0.2	0.5
6	8.959	0.473	0.006	6.823	0.08	50.00	0.1	0.2	0.5
7	11.088	0.545	0.004	9.349	0.125	50.00	0.1	0.2	0.5

Appendix D
Permitted Facilities in the Upper Shoal Creek Watershed

Wastewater Facilities

Permit #	Facility Name	Wastewater type	Design flow (gal/day)	Disposal	Facility Type	Enforcement
MO0108618	GEORGE'S PROCESSING	Food Processing	2.800	Irrigation	Aerated lagoon	x
MO0125164	CAMP BARNABAS	Domestic	0.012	Shoal Creek	Sand Filter and Chlorination	

Animal Feeding Operations

Permit #	Animal type	# Animals	# Animal units	Facility Type	Enforcement
MOG010121	Broiler Chickens	114000	1140	Dry Manure Storage and Compost	
MOG010183	Broiler Chickens	132000	1320	Dry Manure Storage and Compost	
MOG010279	Turkeys	220000	4000	Dry Manure Storage and Land Application of Sludge	
MOG010304	Broiler Chickens	120000	1200	Dry Manure Storage and Compost	
MOG010345	Turkeys	71309	1297	Dry Manure Storage and Compost	
MOG010347	Broiler Chickens	200200	2002	Dry Manure Storage	
MOG010349	Broiler Chickens	120000	1200	Dry Manure Storage and Compost	
MOG010350	Broiler Chickens	100000	1000	Dry Manure Storage and Compost	
MOG010352	Broiler Chickens	100000	1000	Dry Manure Storage and Compost	
MOG010380	Turkeys	66930	1217	Dry Manure Storage and Compost	
MOG010410	Broiler Chickens	138400	1384	Dry Manure Storage and Compost	
MOG010420	Broiler Chickens	102400	1024	Dry Manure Storage and Compost	
MOG010516	Broiler Chickens	132000	1320	Dry Manure Storage and Compost	
MOG010562	Broiler Chickens	125000	1250	Dry Manure Storage and Compost	
MOG010576	Broiler Chickens	120000	1200	Dry Manure Storage and Compost	
MOG010582	Broiler Chickens	120000	1200	Dry Manure Storage and Compost	

Animal Feeding Operations with Letters of Approval
(For Operations Under 1,000 Animal Units)

Number of Permits	Animal Type	Range of Number of Animals in These Facilities	Range of Animal Units in These Facilities	Facility Type	Enforcement
21	Broiler chickens	12000-89000	120 – 890	Dry Manure Storage and Compost	
10	Turkey	8300-49020	151 – 891	Dry Manure Storage and Compost	
2	Laying hens	8800-17600	293 - 578	Dry Manure Storage and Compost	
1	Dairy	100	143	Concrete Manure Pit	