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FAPRI
Environmental Projects 2002

FAPRI-UMC Report #06-02

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Summary

The first biennial Food and Agricultural Policy Research Institute (FAPRI) Environmental Projects Report noted that the character of agriculture in the United States continues to change from diversified farms to large specialized operations. Specialization has led to livestock farms with limited cropland for recycling manure nutrients. Urban sprawl and heightened awareness of environmental issues have led to neighbors often having different goals and perceptions.

FAPRI analyses are responding to these changes by combining economic and environmental assessment at multiple decision levels. Excessive nutrient, pesticide and sediment loading, and fecal coliform contamination are the primary environmental issues addressed. FAPRI continues to broaden the scope of its environmental efforts by adding new farm and watershed environmental analyses and by addressing environmental issues in a holistic manner. The goal is to build a set of farm, watershed, and regional analyses comprehensive enough to be used by stakeholders as building blocks for each phase of an EPA Total Maximum Daily Load (TMDL) assessment. Equitable allocation of pollutant loads should be based on assessments of the costs and benefits of proposed allocations for all stakeholders (including wildlife, agriculture, urban, and recreation).

Concerns with nutrient loads in streams and lakes are becoming a basis for contention between neighbors, communities, and states. These nutrient loads tend to be identified with livestock production and animal waste. Confined animal operations concentrate large amounts of manure in one location. At the national level, recovery of nutrients present in manure could supply one-third of the current domestic phosphorus fertilizer needs. Nutrient management, a key to effective food and fiber production, is at the heart of many environmental issues.

FAPRI is also expanding stakeholder participation. Recent efforts with phosphorus balancing in southwest Missouri have helped develop a Missouri Poultry Industry Committee that will prepare a report for the Missouri General Assembly identifying potential legislative remedies that balance environmental and economic issues related to recycling nutrients produced as a byproduct of poultry production.

This report presents summaries of FAPRI's ongoing assessments.

- Preliminary information from FAPRI's holistic analysis of the Shoal Creek watershed highlights the potential value of combined environmental and economic assessment. DNA tracking results appear to contradict pre-study perceptions of fecal coliform sources. Nutrient loading may exceed future standards that are not yet established.

- FAPRI's efforts to expand stakeholder involvement have led to cooperative development of demonstration comparisons of alternative animal manure products on a farmer's field.

- The sensitivity of environmental indicators to natural variability over time, weather, topography, soil, land use, and management, is addressed by using environmental model results for the Miami Creek watershed. Interpretation of results should include assessment of uncertainty.

- FAPRI plans to examine non-traditional use of wildlife and agroforestry as sources of agricultural income and environmental enhancement.

- Environmental and economic analyses are used to address proposed phosphorus guidelines for manure application rates as applied to a 160-sow hog farm.

- Results of water quality monitoring in six northeastern Missouri lakes are reviewed.

- Recent additions and enhancements to the environmental models are explained.

These FAPRI analyses are designed to combine the current tools of modeling, monitoring, and analysis to holistically address economic and environmental issues. FAPRI also uses the analyses to determine new analytical needs and to support the development of new analytical tools.
Introduction

This report is the second biennial Food and Agricultural Policy Research Institute (FAPRI) Environmental Projects Report. The first report noted that the character of agriculture in the United States continues to change from diversified farms to large specialized operations with only 2% of the total population living on farms. This specialization has led to livestock farms with limited cropland for recycling manure nutrients and crop farms with rotations that provide little soil residue cover. Urban sprawl and heightened awareness of environmental issues have led to neighbors often having different goals and perceptions.

FAPRI analyses are responding to these changes by combining economic and environmental assessment at multiple decision levels. Through a cooperative effort between the U.S. Environmental Protection Agency (EPA), Missouri Department of Natural Resources (MDNR), and the U.S.D.A. Natural Resource Conservation Service (NRCS), FAPRI has undertaken an ongoing analytical effort focused on selected impaired waters in Missouri. The goal of the analysis is to evaluate current and alternative stakeholder identified management practices intended to lead to reduced nutrient, sediment, and pesticide losses. FAPRI’s role is to bring the same level of objective analysis to environmental issues that it brings to commodity policy analysis.

FAPRI continues to broaden the scope of its environmental efforts by adding new farm and watershed environmental analyses. FAPRI has broadened its efforts to address environmental issues in a holistic manner. The goal is to build a set of farm, watershed, and regional analyses comprehensive enough to be used by stakeholders as building blocks for each phase of an EPA Total Maximum Daily Load (TMDL) assessment. TMDL assessments must

- determine the allowable pollutant load that a stream or water body can assimilate without impairing its current planned use,
- identify the likely sources of current pollutant loads, and
- develop an allocation of allowable pollutant loads for the sources.

FAPRI is also expanding stakeholder participation efforts. Recent efforts with phosphorus balancing in southwest Missouri have helped develop a Missouri Poultry Industry Committee that will prepare a report for the Missouri General Assembly identifying potential legislative remedies that balance environmental and economic issues related to recycling nutrients produced as a byproduct of poultry production.

Excessive nutrients, pesticide and sediment loading, and fecal coliform contamination are the primary environmental issues addressed by FAPRI and its collaborators. FAPRI integrates economic and environmental assessments to help stakeholders find solutions that remove water quality impairments and maintain the economic viability of the food and fiber industries.

Concerns with nutrient loads in streams and lakes that have been viewed as fairly pristine in the past are becoming a basis for contention between neighbors, neighboring communities, and neighboring states. These nutrient loads tend to be identified with livestock production and animal waste. For many years, nitrogen was the main nutrient of concern. In recent years, however, phosphorus has become a potential long-term problem. Phosphorus has very different properties than nitrogen, necessitating very different management practices.

Nutrient management, a key to effective food and fiber production, is at the heart of many environmental issues. Crops require nutrients to attain and maintain economically viable production, phosphorus being one of the key nutrients. Phosphorus stored in soil takes several organic and inorganic forms. Some forms are readily available while others are released over a period of years. Phosphorus readily bonds to clay to become insoluble and inaccessible to plants. Less than 10% of phosphorus present in the soil-plant-animal world is available for plant use. However, if nutrients are available to crops, lawns, pastures, and other plants, they can also move with runoff water or leach with percolating water.

As difficult as it is to balance nutrient needs and availability at the field level, that is only a part of the solution. To equitably allocate pollutant loads in the TMDL process, assessments must be made of tradeoffs between food and fiber production and water quality in watersheds and regions. The same assessments can be used to determine the cost sharing necessary to maintain stakeholder economic viability while meeting water quality goals. Nutrient balancing at watershed and multi-state regions involves addi-
tional stakeholders including fertilizer manufactures and distributors.

Confined animal operations concentrate large amounts of manure in one location. At the national level, recovery of nutrients present in manure could supply one-third of the current domestic phosphorus fertilizer needs. With current technology, U.S. phosphate mines are predicted to have 30 to 40-year life expectancy. Recycling the phosphorus, nitrogen, carbon, and other minerals that are available in manure to crops would extend the life of domestic phosphorus mines.

This report presents some of the accomplishments of FAPRI’s environmental projects. Figure 1 shows the location of FAPRI’s previous and current project studies and related farm level economic analyses. Analyses were conducted at the field, farm, and watershed levels to analyze the impact of current management practices on the water quality of surface runoff, streams, and reservoirs. The analyses focus on the nutrient, pesticide (such as atrazine), and sediment loadings carried off the fields and entering the streams and reservoirs.

This report is divided into seven sections. The first section presents preliminary information on FAPRI’s

Figure 1. Current and past FAPRI projects in Missouri.
holistic analysis of the Shoal Creek watershed. The second highlights FAPRI’s efforts to expand stakeholder involvement in the assessment and implementation processes. The third discusses the sensitivity analysis of the Miami Creek watershed results and the implications for interpretation of environmental model results. The fourth presents FAPRI’s plans to examine potential use of wildlife and agroforestry as sources of agricultural income and environmental enhancement. The fifth reviews proposed phosphorus guidelines for manure application rates as applied to the 160-sow hog farm presented in the FAPRI 2000 report. The sixth reviews the results of the continued monitoring of water quality in lakes FAPRI modeled in the Cameron Watershed and the Monroe City Route J Watershed that will be used for model validation. The final section looks at the environmental models used by FAPRI and identifies recent additions and enhancements by the model developers in collaboration with FAPRI.
Shoal Creek Watershed Project

A 13.5-mile segment of Shoal Creek is identified as being impaired by fecal coliform from unknown agricultural sources as per the EPA Clean Water Act under Section 303 (d). EPA regulations require that a TMDL assessment be completed for impaired streams and water bodies. The high concentration of poultry houses in the watershed has led some stakeholders to believe poultry is the likely source.

Goals

FAPRI’s goals are to

1. provide quantitative information identifying the likely sources of fecal coliform,
2. work with stakeholders to develop and examine alternative management strategies, and
3. help stakeholders develop allocation, implementation, and cost-sharing plans that consider all economic and environmental costs and benefits.

The Shoal Creek watershed project is FAPRI’s first holistic project. FAPRI’s approach to a holistic level of assessment combines computer simulation modeling, analytical facts, interdisciplinary perspectives, and multiple decision-making levels that allow stakeholders to simultaneously evaluate many different economic and environmental perspectives. Combinations of environmental and economic models are used to quantify the impacts of alternative management practices at farm, watershed, and regional levels.

Cooperating Scientists

FAPRI also funds collaborative efforts with other University of Missouri interdisciplinary teams and incorporates their expertise into FAPRI analyses.

- Dr. John Jones, professor of fisheries and wildlife sciences, leads a team that monitors water quality in the Shoal Creek Watershed. Weekly water samples are collected at a US Geological Survey gauge during the spring, summer, and fall, and monthly samples are collected during the winter. Samples are analyzed to determine nutrient, sediment, chlorophyll a, and fecal coliform contents. Periodic samples are also taken at multiple locations in the watershed to identify the likely watershed reach origin of the fecal coliform. Flows are measured on a continuous basis.

- Dr. Charles A. Carson, professor of veterinary pathobiology affiliated with the World Health Organization Collaborating Center for Enteric Zoonoses at the University of Missouri, directs laboratory analysis of the fecal samples using the Repeat Element Polymerase Chain Reaction (RepPCR) technique to identify the likely human or animal source by analyzing the deoxyribonucleic acid (DNA) of the fecal coliform. This is one of the techniques more commonly referred to as DNA source tracking.

- Dr. Thomas Johnson, Frank Miller Professor of agricultural economics and director of the Community Policy Analysis Center (CPAC), is leading regional economic analyses to identify the community and regional level economic impacts of alternative management practices.

These collaborative efforts help stakeholders understand the loading of nutrients and fecal coliform, the variability of loadings over time and landscape, and the likely sources. These collaborators produce independent analyses that are combined with FAPRI assessments. The collected data is used to calibrate the FAPRI environmental models.

Watershed and Representative Farm Descriptions

The Upper Shoal Creek watershed is located in Barry and Newton Counties in southwest Missouri. It covers 90,000 acres: 85% grassland (hay and pasture) and 15% forest (Figure 2). Although some crops are grown, the amount is insignificant. Scattered rural residences are present in the watershed, but there are no small towns or municipal treatment systems. Agricultural activities consist of poultry (broilers and turkeys) production and cattle and dairy farming. A poultry processing plant is located at the upstream end of Pogue Creek, a tributary of Shoal Creek.

Downstream recipients include Spring River and the Grand Lake of the Cherokees in Oklahoma. Joplin and Neosho, west of the watershed, use Shoal Creek as a secondary source of municipal water.

Cow-calf, poultry, dairy, and combined poultry/cow-calf farms are the prevalent types of farms in the
Scholten and Tonti-Scholten soils dominate in the southern and eastern part of the watershed. Both have high rock content and a fragipan at a depth of 2 feet. A fragipan is a layer of very dense, almost rock-like soil. In the northwestern corner, Nixa silt loams and Clarksville silt loams are the dominant soils; they also have a very high rock content. Slopes are about 5% or less across the watershed, except where the stream has cut the plateau resulting in slopes between 5 and 15%.

**Cow-calf Farm**

The representative cow-calf farm* modeled in this analysis consists of 250 acres of fescue cropland, 390 acres of fescue pasture land, 200 cow-calf pairs, and 25 heifers. The farm is divided into twenty 25-acre fields, four 20-acre fields, and one 60-acre field. The 20-acre and 60-acre fields are moderately wooded and grazed by the herds. The cropland fescue is harvested for seed and partially (150 acres) for hay and is available for fall and winter grazing. The fescue pasture fields are grazed throughout the year. Five cow-calf herds and one 25-heifer herd rotate grazing on a 14-day pattern across all fields available for grazing.

The dominant soil for this farm is Scholten, a gravelly silt loam with soil depth of about 7.5 feet and a fragipan at about 2 feet. The soil has a slow rate of conductivity and the estimated crop available water within the 3.2 foot soil profile is 2.7 inches.

**Intensive Grazing Dairy Farm**

The intensive grazing dairy farm** modeled in this analysis consists of 260 acres of cropland, 130 milk cows, and 21 heifers. The farm is divided into forty 6.5-acre grazing paddocks growing a variety of grass/legume mixes. The grass/legume mixes and the rotation include 26 acres of Sudan grass/annual ryegrass, 78 acres of Red River crabgrass/cereal rye, 52 acres of perennial ryegrass/white clover, 39 acres of alfalfa/orchard grass, 13 acres of orchard grass/white clover, and 52 acres of fescue. Cows and heifers are split into a 100 milk cow herd and a 51 dry cow and heifer herd that move across all paddocks on a daily grazing pattern.

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*Lawrence and Barry Counties 200 Cow Beef Farm in FAPRI-UMC Report #04-01.

**Dade, Greene, Jasper, and Barry Counties 130 Cow Intensive Grazing Dairy Farm in FAPRI-UMC Report #04-01.
A combination of three soil types is characteristic of this representative farm. They include Hoberg (silt loam, soil depth 4.7 feet, 80% of the farm), Keeno (very gravelly silt loam, soil depth about 5.5 feet, 10% of the farm), and Gerald (silt loam, soil depth about 5.5 feet, 10% of the farm). All three soils have a fragipan at a depth of two to three feet.

**Weather Data Sources**

The environmental models used for the Shoal Creek assessment are Agricultural Policy Environmental eXtender (APEX) at the farm level and the Soil and Water Assessment Tool (SWAT) at the watershed level. Both have the capability of using daily historic weather data or a weather generator that simulates daily weather based on monthly statistical parameters developed from historic data.

The watershed level analysis uses 30 years of historic weather data based on a combination of data for Springfield, Monett, and Cassville, Missouri. Historic daily weather data, rather than generated weather, is used for the analysis to allow the model to be calibrated to historic water flow. Model simulations were performed for 30 years using measured precipitation and temperature data. The model was calibrated using one and one-half years of daily flow values as well as five years of monthly nutrient concentrations.

The farm level analyses use generated daily weather based on monthly weather statistics from the climate stations in Monett and Springfield, Missouri, to generate long-run daily weather. The computed yearly mean rainfall is about 43 inches with a yearly standard deviation of 7.6 inches. The computed monthly mean rainfall is 3.6 inches with a monthly standard deviation of 0.9 inches. The average monthly rainfall peak occurs in June with 5.1 inches.

**Integrating Monitoring and Modeling**

The TMDL process is focused at the watershed level to identify the allowable fecal coliform load Shoal Creek could assimilate and meet its current fishable/swimmable planned use. The likely fecal coliform sources are currently identified as unknown agricultural.

The fecal coliform components of the environmental models are not yet validated. However, the related runoff, nutrient, and sediment transport components have been validated. Practices that reduce these loadings will likely reduce fecal coliform loadings.

The current fecal coliform threshold for fishable/swimmable stream use is a geometric average of 200 colonies/100 ml of water. The standard is focused on the season of the year (April-October) when the planned use is likely.

Fecal coliform and E. coli concentrations have been measured for the weekly samples collected beginning May 18, 2001, when monitoring was initiated by FAPRI. The geometric mean of E. Coli concentrations in the samples collected from May 18 until October 31 was 187 colonies/100 ml just below the water quality standard for whole body contact. The arithmetic average was much higher (1,396 colonies/100 ml) and there was a large variation between the samples. The low flow concentrations vary between 100 and 200 colonies/100 ml, which suggests that the bacteria load is present in both subsurface and groundwater flow.

Since October 5, 2001, the weekly and monthly samples have also been processed to determine the source of the fecal contamination. DNA source tracking techniques are used to obtain patterns of the coliform colonies found in the water and compare them to patterns of known species including humans, cattle, poultry, dogs, horses, hogs, and wildlife.

DNA analyses of the samples determine what proportions of fecal coliform come from every potential source. The preliminary results shown in Figure 3 indicate that the contamination in the samples collected since October comes from many sources including cattle, wildlife, and humans. A very small amount originates from poultry. The geometric mean
Figure 3. Shoal Creek fecal coliform concentrations by source and by week at USGS gauge.
of fecal coliform concentrations in these samples is 295 colonies /100 ml. These results characterize the colder season. As more samples are collected over the spring and summer, a chart that is more relevant to the designated water uses of Shoal Creek will be developed. Periodically, water samples have been collected from multiple stream locations to determine uniformity of the fecal coliform levels and sources throughout the watershed. The results indicate considerable variability in both levels and sources as shown by the pie chart distribution for each water sample collected March 27, 2002 (Figure 4). Fecal coliform variability is one reason the standard is expressed as a geometric mean versus an arithmetic mean.

Figure 4. Distribution of fecal coliform in each water sample collected from Shoal Creek watershed March 27, 2002.
Since research indicates that patterns of a similar host might differ regionally, we are also in the process of developing a database of patterns that will be specific to this watershed. The results might change as this database is developed.

Flow and nutrient watershed level results provide the following information.

- Flow data and model results indicate that between 50–80% of the flow in Shoal Creek is subsurface flow (lateral and groundwater), not surface runoff.

- Measured nitrate concentrations in Shoal Creek are very stable between 2–6 mg/l. Model results confirm this with less than 1% of the simulated daily values higher than 10 mg/l.

- The model results indicate that about half of the nitrogen loadings to Shoal Creek move with the groundwater flow, a third with subsurface lateral flow, and the remainder (a little over one-tenth) with surface runoff.

- Measured and simulated phosphorus concentrations in Shoal Creek are much more varied than the nitrogen concentrations. Although the base flow concentration is around 0.02 mg/l, even small storm events can increase these concentrations to 0.3–0.5 mg/l (Figure 5).

- The simulated phosphorus concentrations are highly sensitive to the initial phosphorus levels in the soil.

- The model results indicate that between 0.4–0.8 lbs/a of soluble phosphorus and 0.6–1.1 lbs/a of total phosphorus move with runoff every year and account for 95% of the phosphorus load.

- The model shows that the southern part of the watershed contributes more to the nutrient load than the northern part (Figure 6). This is explained by the facts that:
  - more poultry houses in the south results in larger amounts of litter available,
  - litter is often spread near the source of the litter, and

- the weather patterns produce more rain in the south than in the north.

- Over thirty years of simulation using historic weather data, the model indicates there is a
significant increase of leached nitrates. This is best explained by an increase of historic annual precipitation, especially from December to February when nitrogen is not being used by pasture and hay.

The combination of monitoring and model results shows that a large proportion of the Shoal Creek flow is from groundwater origin, bringing with it the bulk of the nitrogen load and some of the bacterial load. The phosphorus load, however, is almost entirely carried by surface runoff. As expected, these loads are sensitive to weather patterns and amounts of precipitation. DNA analyses show that many sources contribute to the bacterial problem in Shoal Creek. Additional monitoring and analyses during the summer of 2002 will help determine the temporal and spatial variations of these sources.

**Potential Non-point Agricultural Sources**

Identifying potential non-point agricultural sources requires an understanding of the farms in the watershed and the current management practices that might lead to fecal coliform loading to Shoal Creek.

**Cow-calf Farm Management**

Fescue cropland is fertilized with 2 t/ac of chicken litter in alternation with 60 lbs N/ac every second year. On pastureland, only chicken litter is applied every second year. The daily grazing rate of a cow-calf pair is 33 lbs of dry matter with a daily manure production of 17.6 lbs of dry manure. (All manure nutrient contents in this report are based on “dry,” 0.0% moisture.) The heifers graze 22.0 lbs of dry matter daily and produce 11.0 lbs of manure daily. The average nutrient content of the daily manure production is taken from the APEX database: 1.0% mineral N, 0.2% mineral P, 2.0% organic N, and 0.2% organic P. The average nutrient content of chicken litter is 3.5% mineral N, 0.9% mineral P, 2.0% organic N, and 1.4% organic P.

The expected fescue seed yield is 300 lb/a and the expected hay yield is 1.5 t/a. The farm panel data indicate that the average yearly supplemental feeding amount is about 15% of total consumption. The calculated monthly dry matter forage consumption by all cattle herds is about 110 t/month. The average monthly percentages of grazing and supplemental forage feeding are presented in Figure 7. Modeled grazing activities contribute about 89% of the total yearly forage consumption on this farm. Grazing is supplemented with hay and other forages.

**Intensive Grazing Dairy Farm Management**

Total commercial fertilizer amounts for all forages are shown in Table 1. Grass/legume mixes are commercially fertilized 3–4 times a year at different rates. The daily grazing rate of a milk cow is 27 lbs of dry matter and the daily manure production is 17.6 lbs. The heifers and dry cows graze daily 22 lbs of dry matter and produce 12.0 lbs manure. Grain, hay, and other forages are bought off farm. Milk cow manure nutrient content from the APEX database is 1.7% mineral N, 0.5% mineral P, 2.3% organic N, and 0.3% organic P. Dry cow and heifer manure nutrient content is 1.2% mineral N, 0.2% mineral P, 2.4% organic N, and 0.2% organic P.

The farm panel expected average yearly supplemental forage feeding to be about 25% of total consumption. The calculated monthly dry matter forage consumption of both herds is about 60 t/month. The average monthly percentages of grazing and supplemental feeding are presented in Figure 8. Modeled grazing provides about 75% of the total yearly forage consumption and the rest is supplemented with hay or other forages.

![Diagram](image)

**Figure 7.** Cow-calf Farm average and range of monthly shares on grazing and supplemental forage feeding in percentages.
Table 1: Total commercial fertilizer applied on grass mixes

<table>
<thead>
<tr>
<th></th>
<th>N lbs/ac</th>
<th>P2O5 lbs/ac</th>
<th>K2O lbs/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan grass</td>
<td>100</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>130</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Red River crabgrass 1</td>
<td>140</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cereal Rye 1</td>
<td>210</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Fescue</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Perennial Ryegrass-White Clover mix</td>
<td>170</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Alfalfa-Orchardgrass mix</td>
<td>18</td>
<td>138</td>
<td>180</td>
</tr>
<tr>
<td>Orchardgrass-White Clover mix</td>
<td>120</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Red River Crabgrass 2</td>
<td>90</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cereal Rye 2</td>
<td>170</td>
<td>60</td>
<td>120</td>
</tr>
</tbody>
</table>

Estimated Farm Nutrient and Sediment Loading

The current management practices of the Shoal Creek cow-calf and intensive grazing dairy farms do result in some loadings of organic N and P, mineral N and P, and sediment. The estimated loads are present in Table 2. The sediment loadings are small because there is seldom any land not covered by a growing pasture or hay crop. The intensive grazing dairy has planting operations and short-term, high-level grazing that result in slightly higher soil erosion. The next step in the farm level analyses is to identify alternatives that might reduce loadings and evaluate them with the APEX model.

Figure 8. Intensive Grazing Dairy Farm average and range of monthly shares on grazing and supplemental forage feeding in percentages.

Table 2: Preliminary nutrient and water flows leaving the cow-calf and intensive grazing dairy farms in Shoal Creek watershed

<table>
<thead>
<tr>
<th></th>
<th>Cow/Calf mean</th>
<th>Cow/Calf Stdev</th>
<th>Intensive Grazing Dairy mean</th>
<th>Intensive Grazing Dairy Stdev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual water flow in inches</td>
<td>7.3</td>
<td>4.2</td>
<td>7.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Annual sediment transport in lbs/ac</td>
<td>227</td>
<td>150</td>
<td>290</td>
<td>194</td>
</tr>
<tr>
<td>Annual organic N in lbs/ac</td>
<td>8.7</td>
<td>6.2</td>
<td>15.7</td>
<td>13.6</td>
</tr>
<tr>
<td>Annual organic P in lbs/ac</td>
<td>3.0</td>
<td>3.6</td>
<td>5.1</td>
<td>6.5</td>
</tr>
<tr>
<td>Annual soluble N in lbs/ac</td>
<td>6.9</td>
<td>3.9</td>
<td>30.7</td>
<td>17.7</td>
</tr>
<tr>
<td>Annual soluble P in lbs/ac</td>
<td>2.5</td>
<td>1.8</td>
<td>9.2</td>
<td>5.9</td>
</tr>
</tbody>
</table>
This process will proceed like the Lawrence/Barry (Shoal Creek) broiler farm assessment. As per the 2000 report, the Lawrence/Barry county broiler farm produced fescue hay, cattle, and broilers. Broiler litter was applied at a rate of 2 t/a/year on all pasture and hay land. Environmental model results projected a phosphorus increase in the upper six inches of soil of over 50 lb/a after 50 years. The farm panel suggested lowering the rate by applying 2 tons of litter every other year. The phosphorus continued to increase, but at a rate of less than 10 lb/a after 50 years.

The broiler farm economic assessment with the Farm Level Income and Policy Simulation (FLIPSIM) indicated only a slight reduction in income with the reduction in litter application. However, this was based on selling unused litter at current market prices. Would that price remain at that level if many farmers adopted the same management?

FAPRI is collaborating with CPAC to address community and regional economic impacts as well as farm level economic impacts. Economic impacts of stakeholder-developed alternatives will be analyzed in the coming year.

If requested by the stakeholders, alternatives such as pollutant trading, public or private cost sharing, reassessment of planned stream use, and others may be analyzed. All economic and environmental analyses will be summarized and discussed with the stakeholders to develop a comprehensive strategy to meet environmental goals and maintain economic viability.

**Shoal Creek Conclusions**

Preliminary monitoring and modeling analyses indicate that the perception of poultry as the major source of fecal coliform loadings may have been faulty. In fact, it appears so infrequently and in such small quantity that it is hardly visible in Figure 3. Perhaps that should not surprise us because fecal coliform is vulnerable to light, air, and temperature. Poultry manure is excreted in a confined environment, subjected to some natural heat as it composts in the poultry house and stacking sheds, and then exposed to light and air when spread on a field. Other sources such as wildlife droppings may be excreted near or in the stream, greatly increasing the likelihood of fecal coliform survival. Non-agricultural sources may account for a significant part of the loading. Changes in agricultural management may help remove the stream impairment, but the contributions of wildlife may make it economically prohibitive for any stakeholder group to make adjustments great enough to meet standards. Cooperative efforts of all stakeholders may need to be explored.
Stimulating Stakeholder Involvement

The Shoal Creek watershed is one of a number of watersheds in southwest Missouri and the neighboring states faced with complex environmental issues that have major economic implications. The number of lawsuits now active concerning these issues is an indication that stakeholders are not currently finding economically viable solutions for the environmental issues. The first step in resolving these issues is to bring representatives of all the stakeholder groups together and help them understand each other’s perspectives. The next step is to facilitate the development of solutions by the stakeholders. The last is to help them recognize and carry out their joint roles in implementing solutions developed by them.

There are many roles that need to be played by the various stakeholders. Figure 9 presents a simplified diagram of the cooperative processes of the various stakeholder groups. Note that cooperation is the main driver with funding, technology, and communication facilitating their cooperative efforts. The following are some of the stakeholder roles.

- Poultry producers can select litter material, antibiotics, and chemicals to maximize litter product value in addition to poultry product quality and quantity; and handle litter in a manner that maintains litter value-added product consistency and quality.
- Poultry integrators and field service staff can assist poultry producers in finding and implementing technologies that increase poultry litter value and make adjustments in feed rations to enhance litter value as well as poultry product value.
- Litter marketing contractors can establish contracts for future pickup of litter from poultry producers and delivery of litter to users.
- Poultry litter processors can produce energy, feed, or fertilizer products from poultry litter.
- Fertilizer manufacturers and distributors can produce blended manure and commercial fertilizers and market the products using existing facilities and marketing channels.
- Crop producers can use poultry litter products and cooperate with agency and university scientists to quantify the benefits/costs of using value-added poultry litter products.
- USDA, Missouri Department of Agriculture, and university staffs can design sampling techniques to estimate benefits and costs of using value-added poultry litter products and can determine cost effectiveness of value-added poultry litter production as a means of reaching phosphorus TMDL goals in watersheds.
- EPA, Missouri Department of Natural Resources, and university staffs can assess analyses and information to determine the effectiveness of results relative to water quality rules, regulations, and laws and can provide suggestions to remedy any remaining issues.

- Community and environmental organizations can assess potential economic and environmental benefits to the communities and watersheds and share information with entire communities and environmental organizations.

Figure 9. Stakeholder groups functioning in cooperative synchronized roles.
Finally, national and state legislators can provide support via new or amended legal authority and provide new or continuing funding to public and private cooperators as necessary to provide incentives to attain environmental goals and maintain economic stability.

FAPRI, University of Missouri Extension, USDA-NRCS, Crowder College, and others set up a workshop at Crowder College in Neosho, Missouri, July 12, 2001 to identify positive approaches to balancing phosphorus in southwest Missouri. Balancing the phosphorus available from confined animal production with crop, pasture, forest, and urban needs can be accomplished if many stakeholders work together to find solutions economically and environmentally acceptable to all the stakeholders. The meeting brought together 90 stakeholders representing many perspectives. The participants were divided into six groups with each group having members from as many different perspectives as possible. Each group was asked to identify potential solutions and present them to all participants.

At the end of the day the entire group agreed on two thrusts. The two thrusts are:

1. Bioenergy production. This alternative consists of burning litter to produce heat or energy. The burning could take place either on-farm or at a regional level. If on-farm, it could be burned in a litter fueled furnace that would heat the poultry houses and the home.

   Alternatively, the litter could be processed first and mixed with sawdust to produce pellets that could burn in a wood-burning stove. It could fuel an engine connected to a small generator that would produce electricity for heating in the winter and cooling in the summer. At a regional level, it would produce electricity. The ash by-product would be recycled as a fertilizer, either as is or by incorporating it with other compounds.

2. Litter hauling and adding value. This alternative consists of transporting processed litter, and spreading it on crop fields where fertilizers are needed. Composting and pelleting were viewed as part of this alternative to make the transport easier. Effective Microorganisms (EM) or similar technologies based on beneficial bacteria and/or enzymes was one of the value-added technologies to be considered. There was a general consensus that for environmental issues to be solved, manure had to be transported to areas where local manure production does not meet fertilizer needs.

Two teams were formed with volunteers from many of the interest groups present at the workshop. Both teams met two months later and began developing pilot tests of alternative fertilizer and bioenergy poultry litter products.

Bioenergy Team Progress

The first meeting focused on defining the general scope of the team effort. FAPRI prepared a document that contained an overview of types of bioenergy systems and literature about the systems for each team member. The team discussion led to the conclusion that the team members should each explore the potential of the systems presented and possibly others. The team communicated via email with FAPRI as a coordinator. FAPRI researched new systems and provided information and contacts as requested by team members. A tour of the Northwest Missouri State University (NWMSU) biomass fired heating system was suggested as a starting point for collecting bioenergy system information. The NWMSU system pelletes the biomass materials (Figures 10 and 11) and then burns them. FAPRI and NWMSU organized a tour that included team members and other interested stakeholders.

The team is selecting two or three bioenergy systems to be considered for pilot testing.
A broiler grower team member has offered to allow pilot testing on his farm. Crowder College has expressed interest in collaborating with the broiler grower to conduct pilot studies.

**Litter Hauling Team Progress**

The first meeting focused on two topics: 1) creating value-added poultry litter products and 2) developing marketing and distribution systems for raw poultry litter and value-added products. A number of alternative value added products were discussed: EM, pelleted litter, treated pelleted litter, and combinations of litter and other materials. A crop producer team member volunteered to allow poultry litter products to be tested on his farm.

**Poultry Litter Demonstration**

The team includes members of an EPA 319 project that includes litter hauling as one component of nutrient balancing in a watershed in southwest Missouri. However, the project was not funded in time to begin pilot tests before 2002 corn planting dates.

In late March, the crop producer who had offered his farm for the demonstration suggested that the demonstration could be started with voluntary contributions. FAPRI worked with the crop farmer, a broiler grower, a turkey grower using EM, a distributor and producer of a treated pelleted poultry litter product, an egg producer with layer manure, a fertilizer distributor, University of Missouri Extension staff, the Six State Animal Waste Consortium, University of Missouri Fertilizer Control, USDA, NRCS, the local Soil Conservation District, and others to start the demonstration in early April, 2002. All participants contributed time, material, and funds to allow this demonstration to be established.

Nine poultry manure demonstrations plots were established April 3 and 4 with five different materials on a crop farm near Lamar, Missouri. The demonstration includes: untreated broiler litter, plot 1; granulated value-added poultry litter, plot 2; pelleted value-added poultry litter, plots 3 and 4; EM turkey litter, plots 5, 6 and 7; and layer manure plots 8 and 9 (Figures 12 and 13). The remainder of the field was fertilized with commercial fertilizer. Plant tissue analyses, crop yields, and post harvest soil tests will be measured and analyzed. APEX is being used to simulate nutrient losses. The willingness of all stakeholders to collaborate to begin this pilot test in 2002 instead of allowing it to be delayed to the next crop year is a strong indicator of the stakeholder interest in finding solutions to the current nutrient imbalance in southwest Missouri.

**Missouri Poultry Industry Committee**

The Missouri Legislature established a 27-member committee that will represent the many stakeholders who should be involved in balancing food production and water quality issues. FAPRI is identified as one of the members of this committee. This committee has an opportunity to bring all stakeholders into the development process of any legislative measures designed to balance environmental quality and economic viability.
Sensitivity Analysis of the Miami Creek Watershed

Interpreting measures of environmental quality should be coordinated with sensitivity analyses or at the very least knowledge of the variability and sensitivity of the measures. You and your banker balance accounts to the nearest penny because the only variability you accept is a rounding error of less than a penny. You attribute differences in balance greater than a penny to either errors in your math or the bank’s translation of your handwriting. Many measures of environmental quality can vary by a factor of ten or more before they are perceived to represent significant change in the estimate of environmental quality. For example, the fecal coliform standard is based on a geometric mean that reflects the large expected variability of this measure and the lack of precision as an indicator of health hazard.

Just as annual expenses may change from one year to the next due to uncontrollable events, environmental indicators vary from year to year due to weather variability. Sensitivity analysis quantifies the range of values that the average annual model outputs can take due to this variability. It also examines the sensitivity of the model results to the variability in the estimates of the model inputs. Results of the Miami Creek analysis were presented in FAPRI-UMC Reports #01-01 and #02-01. This analysis is used to show how the results are interpreted in light of weather and input variability.

Miami Creek Watershed

The Miami Creek watershed comprises nearly 80,000 acres in Bates County in west central Missouri. Land use is primarily agricultural with 23% cropland, 66% grassland, and 11% forest. It includes several pork, beef, and dairy confined animal operations. The majority of cattle graze freely on pasture and have unlimited access to streams and ponds. Seven rotations involving corn, soybeans, and wheat were identified in the watershed. Hartwell silt loam, 1% slope, and Kenoma silt loam, 2% to 5% slope, were the two soil mapping units used to represent pasture and cropland soils.

Miami Creek is the primary source of drinking water for the city of Butler and five rural water districts. Stakeholders were concerned with the high concentrations of atrazine and nutrients found in Miami Creek.

The MDNR and EPA commissioned FAPRI to
- evaluate alternative programs for their environmental and economic impacts at the farm level and
- evaluate the cumulative impact of decisions made at the farm level on the overall Miami creek water quality by integrating other land uses such as pasture, forest, and streams in the watershed.

Previous reports focused on the analyses of the alternatives at the farm and watershed levels. This sensitivity analysis is based on SWAT model inputs and outputs at the watershed level.

Sensitivity Analysis

The analysis examines results of the comparisons of management alternatives with baseline management to estimate the likelihood that the model results are significantly different from the baseline considering the variability of weather and of model inputs. The baseline management practices for the watershed reflected 1999 practices and included applying atrazine at a rate of 0.9 lbs of active ingredient per acre. The three alternatives gradually reduce the amount of tillage applied to the field, ultimately moving to a no-till management system in the third alternative.

Alternative 1 has a slight reduction of tillage. Alternative 2 converts soybeans and wheat to no-till practices and retains some tillage with corn. Alternative 3 converts all crops in the rotation to no-till. Alternatives 1 and 2 assume the same application rate for atrazine. Roundup Ready™ seeds are used for soybeans and corn whenever no-till practices are implemented and atrazine is not applied.

Alternatives are compared on the basis of average annual values. A confidence interval of these values is calculated that is related to the year-to-year variability. Table 3 presents some of the variables and the extent

<p>| Table 3: Variability of model outputs due to annual variability |
|-------------------|-----------------|-------------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet runoff</td>
<td>9.7 in</td>
<td>5.8 in</td>
<td>[7.2 in; 12.1 in]</td>
</tr>
<tr>
<td>Outlet sediment yield</td>
<td>0.76 t/a</td>
<td>0.58 t/a</td>
<td>[0.26 t/a; 0.8 t/a]</td>
</tr>
<tr>
<td>Outlet nitrates</td>
<td>11 lb/a</td>
<td>4/4 lb/a</td>
<td>[8.8 lb/a; 12.6 lb/a]</td>
</tr>
<tr>
<td>Outlet atrazine</td>
<td>540 lb</td>
<td>110 lb</td>
<td>[330 lb; 760 lb]</td>
</tr>
<tr>
<td>Sediment yield, subbasin 5</td>
<td>2.8 t/a</td>
<td>1.6 t/a</td>
<td>[1.6 t/a; 3.1 t/a]</td>
</tr>
<tr>
<td>Nitrate yield, subbasin 5</td>
<td>12.9 lb/a</td>
<td>5.34 lb/a</td>
<td>[10.6 lb/a; 15.1 lb/a]</td>
</tr>
</tbody>
</table>
Conclusions

Significant change means that a change in a model result is greater than the variability due to the input uncertainty. However, it may be comparable to the inter-annual variability and not necessarily observable from one year to the next.

The proposed alternatives do not produce any significant change in surface runoff and/or groundwater contribution. Consequently, the estimated loads of nitrates are not significantly reduced. The estimated loads of phosphorus transported by the surface runoff increase when no-till practices are adopted because the phosphorus is not incorporated in the soil and remains available to be carried off by the runoff.

Significantly less sediment reaches the streams when no-till practices are adopted. However, sediment contributions from the subbasins are still greater than the carrying capacity of the streams, and the sediment yield leaving the watershed does not decrease significantly. Nonetheless, less sediment settles at the bottom of the streams.

As erosion decreases, the estimated loads of organic nitrogen and organic phosphorus decrease as well. Even though the dissolved phosphorus increases when no-till practices are adopted, the estimated total phosphorus contributions decrease.

The adoption of no-till practices for corn also meant using Roundup Ready™ corn and Roundup™ instead of atrazine to control weeds. Alternative 3, therefore, resulted in no atrazine being used in the watershed, and no atrazine being found in the streams because atrazine is only used on corn. When no-till practices are implemented, estimated concentrations of Roundup™ increase but remain low.
Agroforestry and Wildlife - Non-traditional Environmentally Enhancing Income Sources

In 2001, FAPRI began expanding its analytical capabilities to include the analysis of non-traditional farm managements that could provide both environmental and economic benefits. FAPRI has initiated projects in the areas of agroforestry and wildlife management. The goal of these initiatives is to provide objective analysis of agroforestry and wildlife options for producers and decision makers. This thrust is currently centered on two projects whose research and outreach efforts will be expanded over time. Field days will be conducted and the results will be published in reports, scientific papers, and extension publications.

Conservation Buffers as Wildlife Habitat

The primary effort of this thrust is the development of the Agriculture/Wildlife Initiative at the University of Missouri. The Agriculture/Wildlife Initiative is an interdisciplinary investigation of the impacts of farm-land management policies and practices on wildlife populations. Contributors include university staff in the Department of Fisheries and Wildlife Sciences, University Outreach and Extension, state and federal agency personnel, and producers.

The initiative’s pilot project received funding in November 2001. This project, An Economic and Environmental Analysis of Conservation Buffers, will evaluate the efficacy of herbaceous conservation buffers from economic, water quality, and wildlife habitat perspectives. This three-year project is funded through a cooperative grant between Missouri Department of Conservation and Missouri’s Soil and Water Conservation District Commission and will assess the relative habitat quality of various types of herbaceous sediment trapping buffers for quail and other avian species.

Simultaneously, the project will evaluate the environmental benefits (water quality and carbon sequestration) of differing buffer strip design parameters and the farm-level income impacts of differing agricultural policies (e.g., levels of incentive payments or cost-shares). For example, the project will examine the potential benefits of buffer designs that consider the complimentary impacts of irregularly shaped buffers that enhance wildlife habitat and the resulting field shapes, which are symmetric. This project will increase cooperation between agencies and producers for the benefit of wildlife populations.

Agroforestry

Agroforestry is a broad term that encompasses five production practices—windbreaks, riparian forest buffers, silvopasture, alley cropping, and forest farming—that aim to optimize benefits from the biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock. Agroforestry practices, developed in tropical regions of the world, are becoming more widely used in temperate areas. Some practices, such as windbreaks, are familiar sights in agricultural areas of the United States, and forest riparian buffers are rapidly gaining acceptance.

To develop agroforestry analysis capabilities, FAPRI has teamed up with the University of Missouri’s Center for Agroforestry (UMCA). FAPRI is calibrating the APEX hydrologic model using data gathered as part of UMCA’s paired watershed study. This study consists of three watersheds (4.1, 7.8, and 11.0 acres) at the University of Missouri’s Greenley Memorial Research Center in Novelty, Missouri. The control watershed is entirely cropped, the contour strip watershed has grass strips, and the agroforestry watershed has trees planted in the contour grass strips (Figure 15).

Calibrating APEX using measured crop yield, runoff, sediment, and nutrient data from each watershed will allow FAPRI to confidently predict the environmental impacts of using trees in combination with crops. APEX can then be used to simulate the application of agroforestry practices such as alley cropping, shelterbelts, and riparian forest buffers to watershed and farm analyses throughout Missouri and nearby states.

Agroforestry benefits include controlling erosion (wind and water), enhancing wildlife habitat, sequestering carbon, and perhaps changing the areas of manure concentration in pastures from areas near
Figure 15. Greenley Agroforestry Watersheds.

streams to well-buffered areas. Creating areas of shade where minerals could be fed to livestock far from stream drainage channels might reduce fecal coliform loadings to stream. All these alternatives could be simulated by an agroforestry calibrated APEX to provide stakeholders quantitative estimates of economic and environmental benefits.
Assessing the Impacts of Proposed Environmental Regulations

The Montgomery County 160-Sow (MDNR Class II) Hog Farm presented in FAPRI-UMC Report #02-01 was used to assess economic and environmental implications of current nitrogen-based nutrient management and of proposed phosphorus-based regulations. Commercial phosphorus application rates are held constant for all fertilizer management alternatives based on the farm panel data. Manure application is viewed by some farm panel members as a disposal operation, not part of the crop fertilization. The financial performance and environmental fate of nutrients, both commercial fertilizer and animal manure (liquid and solid), are estimated.

Farm Description

The representative farm is located in east central Missouri. Surface application of manure slurry is simulated on a specific geographic location (not an actual farm) that is the source of soil hydrology and field size data for the farm. The farm includes 1,228 acres of cropland with three major crop rotations: corn-soybean-wheat; corn-soybean-wheat/double crop soybean; and corn-soybean. Fields are modeled to account for physical characteristics of soil map units, slopes, drainage ways, and terraces. GIS-based software was utilized to identify field sizes, waterways, buffers, setbacks, streams, and travel distances from the farm buildings to each single field (Figure 16).

The APEX model incorporates the physical data from the GIS system with information on weather, physical and chemical soil properties, management practices, field topography, and water and sediment routing directions of each field. Manure slurry spreading can take place when the moisture content in the upper six inches of soil is equal to or less than 75% of field capacity and the soil is not frozen. APEX estimates of crop yields and daily field moisture conditions are input into a linear programming model (LP). The LP simulates the farmer's decision-making process to estimate the optimal combination of spreading activities and crop rotations.

Cropping rotations included no-till cropping with Roundup Ready™ Soybeans to provide options that required less labor in the spring. The LP model maximizes the farmer's annual net return subject to labor time availability, days when field conditions meet requirements, pit capacity, and other technical resources available for each 4-week time period over 10 years. The farm produces 56,000 gallons of slurry per time period and has the capacity to store six months of effluent.

Under a nitrogen-based standard, about 4,800 gallons/acre of slurry may be spread. Under the proposed phosphorus-based standard this is reduced to 2,600 gallons/acre. This implies that the farmer spends additional time and money for expanded spreading activities. The computed farm-level decisions under both standards are input to FLIPSIM and average annual net cash farm income, by debt level, is calculated.

Results

The pit capacity and land availability are sufficient to allow implementation of the proposed phosphorus standard. The LP model slightly expands the portion of Roundup Ready™ Soybeans in the crop rotation to meet the additional time requirements for slurry spreading. The pit capacity and land availability are sufficient to allow implementation of the proposed phosphorus standard. The LP model slightly expands the portion of Roundup Ready™ soybeans in the crop rotation to meet the additional time requirements for slurry spreading. Because soil moisture content and operator time availability limit spreading, the pit

![Figure 16. Montgomery County Class II Hog Farm with 160 sows.](image-url)
needs to be at the lowest possible level before spring planting. Major spreading activities occur after fall harvesting when the soil is often dry.

The additional spreading costs for this farm are about $400 a year. If farm debt is 20% of assets (land, buildings, machinery, and livestock), the reduction in average annual net cash farm income is $819, or 67 cents per acre. If the farm debt is 60% of assets, the reduction in average annual net cash farm income increases to $878, or 72 cents per acre.

With respect to changes in phosphorus in runoff and transported with sediment, the environmental impacts of a phosphorus standard on this farm are minimal. Phosphorus in runoff and in sediment from the additional manure application acres nearly offset the reduction of phosphorus in runoff and sediment under the nitrogen-based standard, which has a higher manure application rate on fewer acres. The impact of a phosphorus-based regulation was also reduced because current commercial phosphorus application rates exceed crop uptake. The model simulated small increases in the phosphorus stored in the upper 12 inches of the soil profile: about 4 lbs/a under a phosphorus-based standard; 6 lbs/a under the nitrogen-based standard; and 2 lbs/a for the commercial fertilizer only application.

Conclusion

Under a phosphorus-based standard little changes in water quality can be expected on an operation of this size. The regulatory implications from this case study are that surface spreading manure at lower rates over more acres may fail to accomplish the goal of increased water quality.

Suggestions that manure slurry be injected at nitrogen-based rates or higher, but at lower frequencies, such as every third or fourth year, (phosphorus banking) have not yet been assessed. However, logic suggests that injection and phosphorus banking may prove effective if total application of phosphorus (manure and commercial phosphorus) is in balance with crop needs for the planned time period and erosion control is adequate.
Monitoring and Validation

FAPRI has maintained a long-term relationship with the Dr. Jones, University of Missouri and his water quality monitoring team. One of the first cooperative efforts was a study of the farms, watersheds and reservoirs that supply water for the city of Cameron in northwest Missouri. The water supply reservoirs for Monroe City in northeast Missouri were also modeled at farm and watershed levels. FAPRI has continued to fund the Cameron and Monroe City water quality monitoring. The data will be used to validate new versions of the models and assess the success of any environmental measures developed by earlier studies.

Cameron Water Supply

The Cameron municipal water supply includes four reservoirs (Figure 17). All four reservoirs have high concentrations of phosphorus, nitrogen, and chlorophyll relative to other northwest Missouri lakes (Table 5). Only Reservoir 3 approaches average turbidity for the region as measured by inorganic suspended solids and the depth at which a Secchi disk is visible. Water quality in the reservoirs is related to precipitation events. During dry periods, water clarity increases while nutrient concentrations lower. During wet periods, water clarity decreases while nutrient concentrations increase. Chlorophyll concentrations have a significant negative relationship with inorganic turbidity: the more inorganic turbidity there is in the water, the lower the chlorophyll concentrations. Chlorophyll concentrations in these reservoirs are related to total phosphorus concentrations. Reservoir 2 is the most P-limited and the least turbid of the four Cameron reservoirs.

During summer stratification, surface waters become clearer and less enriched, as external inputs plunge to the deep water. In any given year, chlorophyll concentrations tend to be highest during the late summer months, but peak concentrations can occur at any time of year.

![Figure 17. Cameron water supply reservoirs](image)

Table 5: Water quality indicator means for the Cameron water supply reservoirs, 1998-2001

<table>
<thead>
<tr>
<th></th>
<th>Grindstone Reservoir</th>
<th>Reservoir 1</th>
<th>Reservoir 2</th>
<th>Reservoir 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphate, µg/L</td>
<td>207.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>198.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>69.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>97.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total nitrogen, mg/L</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total chlorophyll, µg/L</td>
<td>37.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inorganic suspended solids, mg/L</td>
<td>19.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean Secchi depth, m</td>
<td>0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>In the top 5% of values reported for reservoirs in the glacial plains region of Missouri.

<sup>b</sup>In the bottom 5% of values reported for reservoirs in the glacial plains region of Missouri.

<sup>c</sup>In the top 50% of values reported for reservoirs in the glacial plains region of Missouri.

<sup>d</sup>In the bottom 50% of values reported for reservoirs in the glacial plains region of Missouri.

Reservoir 3 is an artificially mixed reservoir, which tends to eliminate any seasonal patterns of water quality variables that were observed in the other reservoirs, such as water clarity and phytoplankton biomass. Surface outflows from
Monroe City Water Supply

The Monroe City water supply includes the Monroe Lake B and Route J Reservoirs (Figure 18). The reservoirs have high concentrations of phosphorus, nitrogen, and chlorophyll relative to other northeast Missouri lakes (Table 6). The Monroe City Route J Reservoir is less subject to mixing with precipitation than the Monroe Lake B Reservoir. It seems to be prone to cyanobacteria blooms (>100 µg/L chlorophyll) during the summer months. Noxious taxa such as Aphanizomenon and Microcystis (commonly called bluegreen algae) have been observed in these blooms.

The Monroe Lake B Reservoir, south of Monroe City, is thermally mixed more often than not during the summer months, although the reservoir tends to remain anoxic during this time. Water quality in this reservoir is likely related strongly to precipitation events.

Table 6: Water quality indicator means for the Monroe City water supply reservoirs, 1998-2001

<table>
<thead>
<tr>
<th>Rte. J Reservoir</th>
<th>Monroe City Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphate, µg/L</td>
<td>106.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total nitrogen, mg/L</td>
<td>1.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total chlorophyll, µg/L</td>
<td>56.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inorganic suspended solids, mg/L</td>
<td>5.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NVSS*, mg/L</td>
<td>0.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean Secchi depth, m</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>In the top 5% of values reported for reservoirs in the glacial plains region of Missouri.
<sup>b</sup>In the bottom 50% of values reported for reservoirs in the glacial plains region of Missouri.
<sup>*</sup>Non-Volatile Suspended Solids

Reservoirs 1 and 2 influence the water chemistry and minimize the impact of inflow on Reservoir 3. Not only are phytoplankton limited by either nutrients or light availability, they are also constantly being mixed throughout the water column, acting as another source of light limitation. However, the data collected resemble those of a reservoir that is P-limited the majority of the time. Lastly, the artificial mixing system was employed to alleviate historical, seasonal taste and odor problems with Cameron’s drinking water. This seems to have been a success for the most part; however a summer bloom of cyanobacteria occurred in 2000-01, after having been absent since the commencement of artificial mixing in 1998.
Enhancements of Environmental and Economic Models

FAPRI uses three environmental models, three economic models, and a number of analytical systems to analyze the economic and environmental issues facing today's decision-makers. The environmental models used by FAPRI are the

- Environmental Policy Integrated Climate (EPIC) model to examine a single farming system on a single field under defined conditions (soil map unit, crop rotation, pesticide and nutrient management, tillage practices, livestock management,

- Agricultural Policy Environmental eXtender (APEX) model to evaluate the interaction of different management practices in adjacent fields controlled by the same manager, and

- Soil and Water Assessment Tool (SWAT) to evaluate the combined environmental impacts of various agricultural and non-agricultural land uses within a watershed. The analysis of subbasin results indicates areas in the watershed that may contribute most to nutrient, pesticide, and sediment problems in the receiving stream or lake.

The models simulate many of the physical processes that impact soil nutrient accumulation and water quality. New understandings of physical processes and recognition of new environmental issues necessitate model additions and enhancement. FAPRI contracts with cooperating model developers to provide additions and model enhancements that address new environmental issues or alternative management options. Figure 17 identifies and highlights any additions and enhancements.

Some of the recent additional enhancements are:
- automatic grazing options based on available biomass that can move multiple herds of livestock from field to field;
- manure erosion from feed lots calculated independently of water erosion;
- dust distribution from feedlots;
- improved carbon sequestration equations;
- fecal coliform equations;
- biological injection of manure nutrients below the soil surface;
- revised universal soil loss equation features;
- farm level interfaces; and
- pipe and crack preferential water flow in the soil.

Three economic models were used in these studies.

- Farm Level Income and Policy Simulations (FLIPSIM) farm system, developed at Texas A&M. Representative farm panels provide the input needed to build the representative farms used for this analysis. The panels are interviewed using the consensus building process. The panel members develop farms that are representative of the members by drawing on their personal operations and experience.

- Input/output analysis is used to develop regional economic estimates of the value of the poultry and recreation industries and their relationships.

- FAPRI econometric models are used to develop commodity price projections.

The economic models are revised to reflect changes such as a new farm bill. As new economic models become available, they are incorporated into the FAPRI analyses.
Field Level: Environmental Policy Integrated Climate model

Processes in EPIC include:
- Weather (simulated or actual)
- Hydrology, evapotranspiration, runoff, percolation
- Erosion (wind and water)
- Crop growth (N, P & K uptake, stresses, yields, N-fixation)
- Fertilization (application, runoff, leaching, mineralization, denitrification, volatilization, nitrification)
- Tillage
- Irrigation and furrow diking
- Drainage
- Pesticide (application, movement, degradation)
- Manure application
- Grazing
- Crop rotations, inter-cropping, weed competition

Farm Level: Agricultural Policy Environmental eXtender model

APEX includes all EPIC processes, plus:
- Ponds and reservoirs
- Grazing management
- Buffer strips and grassed waterways
- Subsurface flow between subbasins
- Manure erosion
- Preferential soil water flows
- Biological manure incorporation

Watershed Level: Soil and Water Assessment Tool

SWAT includes most EPIC processes, plus:
- Instream degradation of chemicals
- Ponds and reservoirs
- Lake water quality
- Ability to combine watersheds to simulate river basins
- GIS interfaces
- Fecal coliform modeling under development

- Recent Enhancements

Figure 19. Environmental Models Enhancements