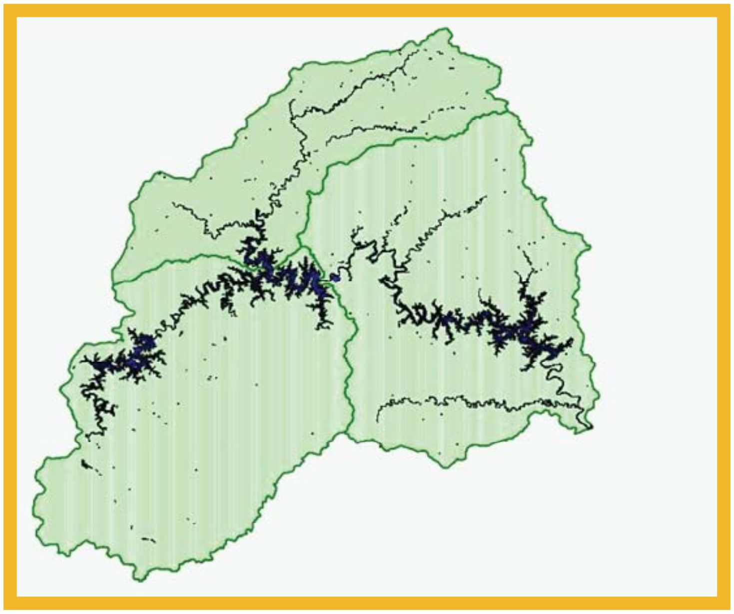
FAPRI–MU Report #09-08

Upper White River Watershed Integrated Economic



and Environmental Management Project

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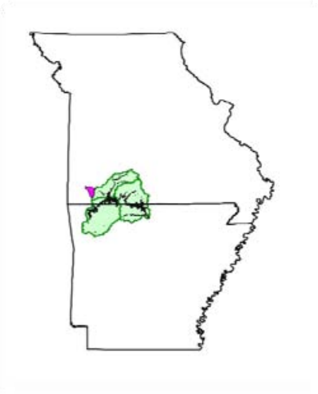

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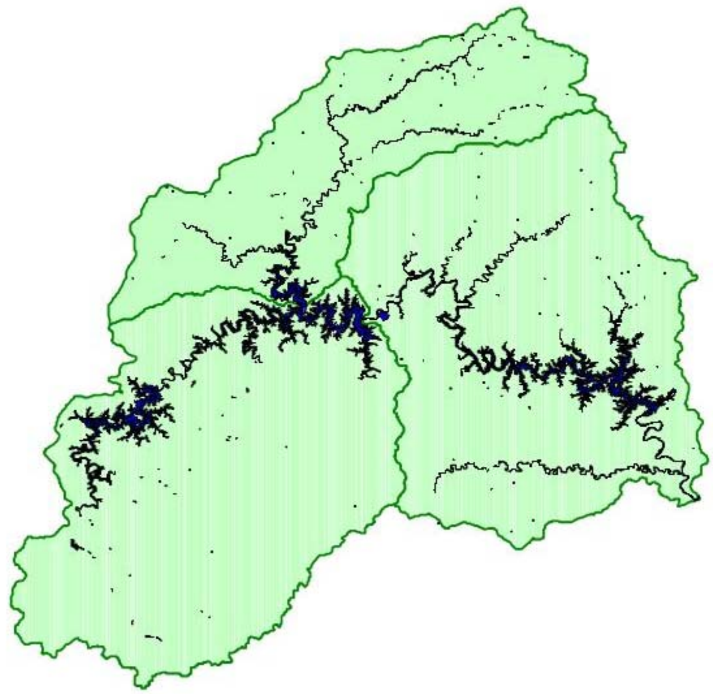
Integrated Economic and Environmental Management Project



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This project was partially funded by the US EPA Region 7, through the Missouri Department of Natural Resources (DNR) subgrant #G05-NPS-09, under Section 319 of the US Clean Water Act.

Executive Summary

The Upper White River Watershed Integrated Economic and Environmental Management Project enhanced existing local cooperative water quality efforts, compiled economic and physical data, and used that information to develop analytical models. The Shoal Creek and Little Sac watershed Total Maximum Daily Load (TMDL) analyses were used as building blocks for the Upper White River analytics. The project established a coordinating committee that included representatives from the Watershed Committee of the Ozarks, the James River Basin Partnership, the Upper White River Basin Foundation, Table Rock Lake Water Quality, Inc., Missouri Fertilizer Control, South Missouri Water Quality Project, Beaver Water District, Kings River Watershed Group, the poultry industry, commodity organizations, Missouri and Arkansas state agencies, and federal agencies.

A Soil and Water Assessment Tool (SWAT) model of the James River Basin was built to assess the effectiveness of the phosphorus restrictions defined in phase I of the TMDL implementation plan for the James River. The model was validated using historic measured weather, river flow and water quality data. Stakeholders began using the SWAT model to estimate impacts of water quality Best Management Practices (BMPs) within the Upper White River Basin.

The model was used to assess the impact of a section 319 urban nutrient management project conducted cooperatively by the James River Partnership and South Missouri Water Quality team. Stakeholders found the assessment credible and commendable.

Numerous presentations of model results and compiled data were made to various stakeholder groups and at regional water quality meetings. The presentations increased the local understanding of the complexities and complementarities of water quality BMPs. It provided quantitative environmental and economic assessments of alternative urban and agricultural management practices along with regulations for their use in comparing BMPs.

The Upper White River Symposium held April 6-7, 2006 at the Radisson Hotel in Branson, Missouri, was a key part of the educational and cooperation efforts. This symposium offered information on critical topics and issues identified by the delegates in previous forums. The symposium focused on identification of projects that would improve water quality in the Upper White River Basin. A summary list of symposium proposed efforts follows below.

Monitoring and evaluation:

- Enhance data collection processes.
- Identify hot spots.
- Add site specific water quality monitoring of BMPs to existing monitoring efforts.

Waste and health issues:

- Provide stakeholders education on new rural waste systems.
- Use DNA source tracking to identify the key sources of bacteria loading.
- Develop public policy that optimizes long-term regulatory mechanisms.

Nutrient and runoff issues:

- Develop tools for urban nutrient management.
- Facilitate poultry litter marketing.
- Assess the potential use of on-site pelleting systems.

Symposium follow-up has taken many forms, some clearly connected to the project and some only tenuously connected. The Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri–Columbia (MU) prepared a draft proposal that addressed monitoring to assess concentrations of *E. coli*, antibiotics, and endocrine disruptors. The proposal was circulated amongst the cooperators, but has not yet been pursued further. All three monitoring and evaluation thrusts are being pursued by local organizations and/or Missouri Department of Natural Resources (MODNR) and the US Environmental Protection Agency (EPA). Region 7 of the EPA recently published a request for proposals entitled "Identifying Critical Areas and Targeting BMPs for Water Quality in Region 7 Priority Watersheds" which includes the James River Basin. Dr. Benson has an accepted proposal that addresses three watersheds.

Waste and health issues continue to be pursued locally. FAPRI-MU's assessment of the impact of nutrient management and septic pumping for the James River Basin was reported in progress reports by both the South Missouri Water Quality Project and the James River Basin Partnership.

Nutrients and runoff issues were addressed by the cooperative efforts of the South Missouri Water Quality Project, the James River Basin Partnership, and the Upper White River Basin Foundation. A regional indicator of the success of this project in cooperation with many others in Southwest Missouri is reflected by the change in phosphorus use in that region as shown in figure 60. In the last five years, the region reduced commercial phosphorus purchases from 12,629 tons to 7,530 tons, a decrease of 5,099 tons or 40.38 percent. At a rate of $0.25 per pound for phosphorus that is a savings to the producers in that area of $2,549,500. The cooperative efforts of all stakeholders are responsible for this change.

FAPRI–MU prepared an analysis of the potential supply and demand for recyclable manure phosphorus in the region in and around the Upper White River Basin to begin addressing improved marketing poultry litter. The Community Policy Analysis Center (CPAC) estimated the regional economic cost of more widely distributing poultry litter to be $17.1 million for poultry producers in the White River Arkansas area and $5.3 million for producers in the White River Missouri area.

A simplified method of estimating the hauling cost to attain a geographic balance of phosphorus removed with excess recyclable manure phosphorus (P) was developed using Carroll county Arkansas as the centroid of the area to be balanced. The resulting county level manure phosphorus ton-mile map (figure 72) shows that there may be some multi-county areas that could be targeted for marketing poultry litter because of the size of the potential market and the distance from poultry litter sources.

At $0.15 per ton-mile, the simplified method estimates the total cost of manure hauling to be $27.8 million dollars per year. Storage costs and additional handling cost would be appropriate in some scenarios. If a handling and storage cost of $3.00 per ton is added to all tons estimated to be shipped over 50 miles, the cost is estimated to increase $3.8 million.

New technologies to compress poultry litter may make hauling and spreading more manageable, but they will likely add cost. These technologies may change the perception of poultry litter as a nutrient source or a bio-energy source.

Table of Contents

List of Tables

List of Appendices Tables

List of Figures

Introduction

The key to successful implementation of any water quality initiative is the acceptance by the stakeholders that it is necessary and that it will produce results worth the efforts and resources they must supply. This requires not only sound physical science, but also economic feasibility. This project developed both the economic and physical information needed for producers and others in the Upper White River watershed to make informed decisions regarding water quality improvement plans in their area.

The project leveraged off of current economic and environmental monitoring and modeling in the Shoal Creek watershed and different Stone and Barry county representative farm characteristics. It incorporated modeling of the entire watershed. Management alternatives within the James River watershed were assessed in detail. A more aggregated assessment was done for the rest of the watershed. The model included waste treatment plant discharges as well as urban and agricultural non-point sources of nutrients, sediment, and bacteria.

The project cooperated with the complimentary 319 project by the Arkansas Water Resources Center, University of Arkansas that focused on The Kings River Basin and Beaver Lake. In addition, the project was coordinated with the broader Upper White River Watershed Initiative.

Project Goals:

1. To enhance cooperative water quality efforts of existing local organizations
2. To develop both the economic and physical information needed by stakeholders in the Upper White River watershed
3. To leverage this project with economic and environmental monitoring and modeling in the Shoal Creek and the Little Sac watershed to address Upper White River issues
4. To use complimentary 319 projects in Missouri and Arkansas and the Upper White River Watershed Initiative to develop a comprehensive assessment of the watershed.

Project Objectives:

1. To establish a coordinating committee for the Upper White River basin in cooperation with the local organizations and the state and federal agencies
2. To assess the effectiveness of the phosphorus restrictions defined in the phase I of the Total Maximum Daily Loads (TMDL) implementation plan for the James River by simulating James River water quality impacts for 10 to 50 years into the future.
3. To provide measures of economic and environmental effectiveness of alternative management practices for use in stakeholder decision making (Management alternatives were to include nutrient management levels and transport of manure or municipal sludge to land outside the watershed. Alternatives were to be developed cooperatively with the Upper White River Water Quality Project Office, EPA, Missouri state agencies and the coordinating group and amended to include alternatives developed by the Upper White River Basin Forum participants.)
4. To increase the understanding of the local population of the combined effects on lake water quality of alternative urban and agricultural management practices and regulations
5. To help the local population afford alternative management practices by identifying the economic incentives necessary to support the cooperative efforts of the stakeholders

6. To summarize, in reports and presentations to stakeholders, the information necessary to enhance the watershed management plan developed at the April 2003 Water Quality Summit identifying economically and environmentally acceptable strategies

Coordinating Committee

A coordinating committee was established with Missouri representatives from the Watershed Committee of the Ozarks, the James River Basin Partnership, the Upper White River Basin Foundation, Table Rock Lake Water Quality, Inc., Missouri Fertilizer Control and South Missouri Water Quality Project. It also included Arkansas representatives from the Beaver Water District and the Kings River Watershed Group. In addition to the members from existing organizations, it had three poultry industry representatives and five commodity organization representatives. The Missouri Department of Natural Resources (MODNR) and the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) members assisted the committee. Lists of the committee members are presented in appendix A. This committee reviewed economic and environmental analyses during the development stages, identified invitees for the Upper White River Basin Symposium and helped set up and carry out the Upper White River Basin combined Symposium/workshop.

Environmental Impact Assessment

The Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri (MU) uses a combination of watershed, field and farm level environmental models. FAPRI–MU chose the Soil and Water Assessment Tool (SWAT) model to analyze the environmental impacts of alternative practices in the Upper White River Watershed.

SWAT is a continuous simulation, daily-time-step, process-based model that calculates crop yields and grazing productivity as well as environmental indicators such as water, sediment, pesticide and nutrient yields. Daily estimates allow the analyses to examine the distribution of impacts from weather events as well as the average annual impacts. The initial watershed analyses focused on the James River Basin.

James River Basin

The James River, a tributary of the Upper White River, flows through the Ozark region into Table Rock Lake, a valued recreation site in the state of Arkansas. Approximately 65 miles long, the river drains a basin that covers 1,512 square miles of which 30 percent is hardwood forest, 63 percent is agricultural land (mostly pasture) and 7 percent is urban (figure 1).

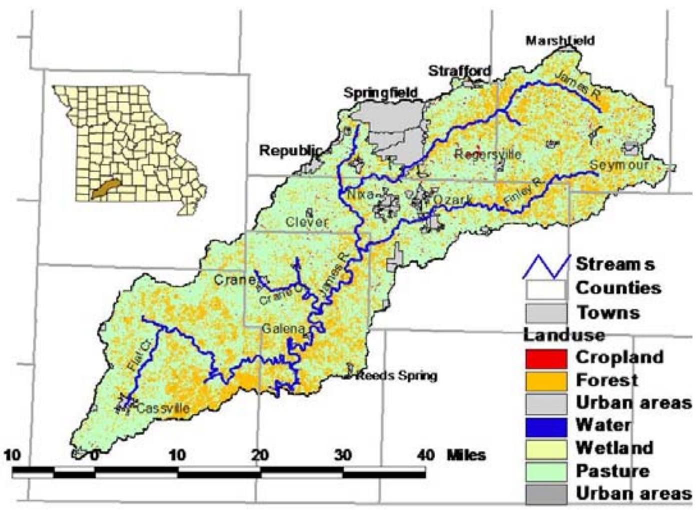

Figure 1. James River Basin land use/land cover

A major portion of the James River is currently listed as impaired for excess nutrients, in particular for excess phosphorus. The nutrient sources include urban and agricultural runoff as well as point sources. Because of the karst features of the terrain (sinkholes, caves, losing streams and springs), the potential for groundwater quality problems is high. The amount of phosphorus delivered to Table Rock Lake from the James River Basin is a major concern. As phosphorus in the lake increases, growth of algae increases and water clarity decreases. This problem involves many stakeholders: the urban populations (wastewater treatment plant and urban runoff), the agricultural populations (cattle growers and poultry producers), as well as the tourism industry (population growth around the lake and water recreation activities). Historically, these waters were low in nutrients, aquatic plant growth was limited and water clarity was excellent.

A 2001 TMDL for the James River established target concentrations of 0.075 mg/L for total phosphorus and 1.5 mg/L for total nitrogen. These were set to limit aquatic plant growth in the stream and in the lake. The implementation plan concentrated on the re-permitting of waste treatment facilities with discharge greater than 22,500 gallons/day to allow a maximum total phosphorus concentration of 0.5 mg/L. A phosphorus removal unit was installed at the Springfield Southwest Wastewater Treatment Plant in 2001. Other plants subject to this discharge criterion were due to comply by 2003 or 2007.

The next four sections of the report are focused on different aspects of phosphorus loadings into the James River and Table Rock Lake. The first section covers the development of the input information for the SWAT model. The second section describes the model calibration and validation. It shows how predicted flow and water quality indicators compare to measured values. The third section presents the analysis of the wastewater treatment plant (WWTP) policies and provides information regarding expected long-term results of the TMDL rule. The fourth and final section compares loadings from urban areas under various lawn care assumptions to loadings from agricultural and forested land, also under various management assumptions. All results presented are based on output from the James River Basin SWAT model developed at FAPRI–MU by Dr. Claire Baffaut.

The James River Basin SWAT Model: Development and Calibration

This section details the inputs and assumptions that went in to the SWAT model.

Topography The 60-m DEM was used. The automatic delineation tool in AVSWATX (ArcView Soil and Water Assessment Tool eXtendable) was utilized to delineate subbasins. Efforts were taken to match subbasin outlets with existing flow gauges, water quality stations and Hydrologic Unit Code (HUC) 14 watershed boundaries (figure 2). The average subbasin size is about 60 mi^2 (150 km^2). They vary from 13 to 125 mi^2 (35 to 325 km^2).

Soils STATSGO (state level) soil GIS was used (figure 3). Characteristics from the State Soil Geographic (STATSGO) database were generally used, replaced in some instances by characteristics from the Soil Survey Geographic (SSURGO) (county level) database for the same soils. This was done so as to have more detailed soil descriptions than provided in the STATSGO database but have only the main soils represented.

Land use Land use was based on the 30 m land use/land cover grid built from 1992 satellite images (figure 4).

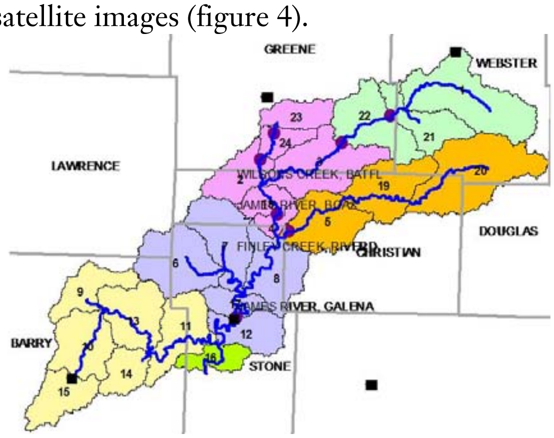

Figure 2. James River subbasins

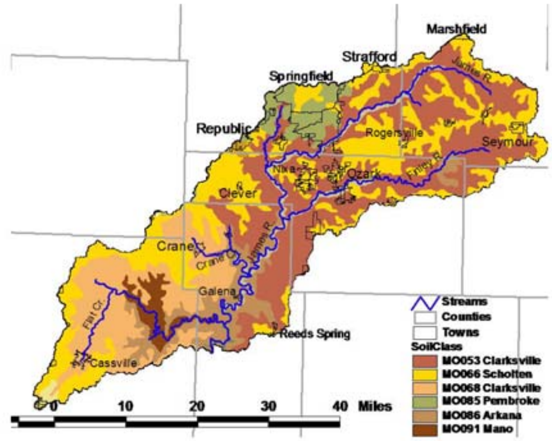

Figure 3. James River Basin soils selected

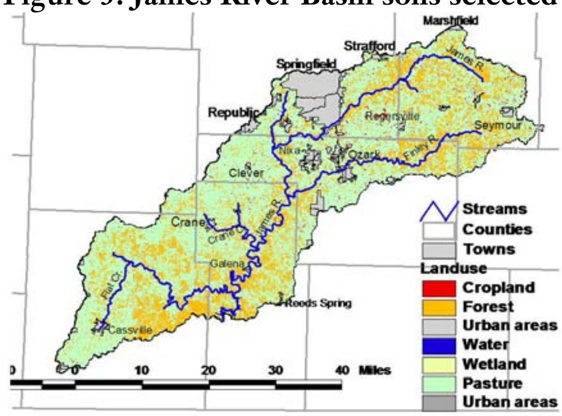

Figure 4. James River Basin land use/land cover

A more recent map is now available that was developed from images taken between 2000 and 2004. However, the available flow and water quality data are mainly from 1980 to 2000 making the older map more appropriate. Pasture (51 percent of the watershed) was divided into poor condition pasture (25 percent), fair condition pasture (25 percent), and septic fields (0.6 percent). Urban areas were underestimated in this land use distribution, possibly because medium-low and low density residential areas were misclassified. Urban management was assigned to some grassland areas around towns to compensate for under estimated urban areas. Rural population densities by townships (2000 population census) were used to estimate the area assigned to septic fields. Resulting land use distribution is presented in table 1.

Table 1. Land use in the James River Basin.

Land use category	Percent of the watershed
Forest	25.0%
Urban high density	1.5%
Urban areas low-medium density	0.8%
Hay fields	21.5%
Septic tanks	0.6%
Pastures in fair condition	25.3%
Pastures in poor condition	25.3%

In order to not overburden the model with minor areas, only land uses that represent more than 5 percent of a subbasin and soils that represent 25 percent or more of a given land use in a subbasin were considered. With 24 subbasins in the watershed, these thresholds resulted in 243 land use/soil combinations. These are called hydrologic response units (HRU).

Weather stations Five weather stations were utilized to characterize the weather in the James River Basin: Springfield airport, Galena, Ozark, Cassville and Marshfield. Daily precipitation and temperature data from 1970 to 2004 was provided by Dr. P. Guinan from the Center for Atmospheric Sciences at the MU. Monthly characteristics were derived from these series of daily values. Measured daily precipitation and temperature data were used for calibration and validation. The model's estimated flow and water quality data with measured weather data input is compared to historic measured flow and water quality data.

The analyses of alternative water quantity enhancing measure to baseline measures used model generated weather data. A 30- year sequence of daily generated weather using the monthly statistical characteristics was used to evaluate the impact of specific management practices or to compare alternative management plans to a baseline condition.

Management information The baseline management practices were estimated from work in the Shoal Creek watershed by FAPRI–MU and in the Little Sac watershed. Pastures were divided into two sets so that cattle could be moved between different pastures from month to month. Grazing periods alternate between these two sets. Estimated grazing densities in each county were based on the number of cattle in that county and the available pasture acres, hay acres, and grazed wood acres. Hay land was assumed to be harvested in June and grazed later in the season. Estimates of cattle number, harvested hay acres, wood and grass pastures came from the National Agricultural Statistical Service (NASS) county summary data for 1998 and 2003. An average between these two years was used to estimate grazing densities. Some wooded acres were reserved for winter grazing, assuming that cattle would be moved to wooded pastures that provide some protection from the weather. The county grazing rates used in the model are presented in table 2. The average annual grazing density during the summer is half the values indicated in table 2 because cattle alternate between two pastures. Grazing rates were assigned to each subbasin based on the grazing rates of the dominant county. Grazing periods, fertilizations and harvesting of hay are detailed in tables 3 and 4 for fair condition pastures, hay land and grazed woodland. Poor condition pastures were managed similarly but were fertilized only every other year. The ground cover was set at a lower value on poor condition pastures to reflect reduced grass density.

The management of urban areas was set so as to obtain reasonable ground cover and grass growth (table 5). It assumed mowing once every 10 days, at the peak of the growing season, and less frequently later. Forests are assumed to be mature forests. No forest harvesting or planting was simulated.

Table 2. Estimated grazing densities by county in the James River Basin model.

Grazing period	Barry County	Greene County	Stone County	Christian County	Webster County
grass grazing density (summer, acres/cow-calf)	2.9	3.3	4.9	3.5	2.8
wood grazing density (winter, acres/cow-calf)	1.0	0.7	1.2	0.8	0.8
hay grazing (summer, acres/cow-calf)	1.4	1.9	1.1	1.7	1.3
Total average grazing density (all year, acres/cow-calf)	5.3	5.9	7.2	6.0	4.9

Table 3. Estimated management and cattle rotation on fair condition summer pastures

Year	Operation	Pasture 1	Pasture 2
Year 1	Fertilization	March 5, 300 lbs/a 17-17-17	March 12, 300 lbs/a 17-17-17
	Grazing	Mar 26 – May 15, 51 days	May 16 – July 15, 61 days
		July 16 – Sept 15, 62 days	Nov 1 – Dec 15, 45 days
Year 2	Fertilization	March 20, 300 lbs/a 17-17-17	March 14, 300 lbs/a 17-17-17
	Grazing	May 16 – July 15, 61 days	Mar 26 – May 15, 51 days
		Nov 1 – Dec 15, 45 days	July 16 – Sept 15, 62 days

Table 4. Estimated management and cattle rotation on hay fields and wooded winter areas

Year	Operation	Hay field	Winter location (Woods)
Year 1	Fertilization	March 15, 300 lbs/a 17-17-17	
	Hay harvest	June 10	
	Grazing	Sept 16 – Oct 31, 46 days	Dec 16 – Mar 25, 100 days
Year 2	Fertilization	March 10, 300 lbs/a 17-17-17	
	Hay harvest	June 10	
	Grazing	Sept 16 – Oct 31, 46 days	Dec 16 – Mar 25, 100 days

Table 5. Estimated management of lawns and streets in residential areas

Operation	Date / Timing
Street sweeping	Six times a year in January, March, May, July, September, and November.
Fertilization of lawns	March 5: 70 lbs/a N, 27 lbs/a P
Mowing of lawns	50% grass height is mowed, 50% of clippings return to the ground. Timing: once very 10 days from mid-April to May, twice a month in June and July, once every 3 weeks in August and September, and once in October.
Grazing / feces deposit	Geese all year round at densities that reflect their life cycle.

Septic fields were assumed to be in good condition grass. A daily application of effluent was applied on these areas that reflect the estimated effluent production per household and the nutrient and bacteria content of the effluent. The variation in population density across the watershed was represented by a larger or smaller fraction of the subbasin being used by these septic fields. The values in table 6 were based on 2.5 persons per household, the average of the counties in the basin, to characterize septage per household.

Bacteria concentration in septage The University of Massachusetts Septic Tank Handbook indicates a concentration of a billion to a trillion colonies/100 ml in wastewater and a zero percent reduction through a septic tank. The EPA indicates a concentration of a million to two billion colonies/100 ml in what is released to the soil absorption system. The simulations have been done on the basis on the geometric average of the lower and upper bounds of the range given by the EPA with no differentiation between a working and failing system other than the amount of septage released.

Table 6. Septic tank characteristics for the James River SWAT model

	Working septic	Failing septic
Size of septic field	1/8 acre	
Average daily water consumption	175 gallons	
Average daily effluent production	145 gallons	
Average daily septage production	0.942 kg/day dry matter	1.884 kg/day dry matter
Total nitrogen fraction	0.0339	0.0377
Total phosphorus fraction	0.0122	0.0182

Point sources Numerous Wastewater Treatment Plants (WWTPs) discharge effluent into the James River or into its tributaries. Permit records and report information were utilized to estimate flow, nutrient and bacteria outflow from these WWTPs from 1970 to 2004 in order to calibrate the model. Current discharges were specified in the model for the purpose of comparing alternative management scenarios. Table 7 presents the design flows and the actual flows from the treatment plants into the James River Basin in million gallons per day (MGD) along with the phosphorus concentration discharged in parts per million (milligrams per liter) that were used as model input for the years prior to 2000 and for the years from 2001-2004.

The concentrations for the Springfield plant were estimated from phosphorus loads and discharged volumes presented on the plant's Web site. Prior to 1993, there was an initial period during which phosphorus was not a concern. The average concentration was calculated to be 7.3 mg/L based on a discharge of 30 MGD in 1992, the maximum capacity at that time, and a phosphorus load of 1800 lbs/day, the daily phosphorus load in 1992. According to the graphs presented by the City of Springfield, there was more than 90 percent reduction in loadings from 1993 to 2001, due to reductions in cleaning agents used by the Springfield population and the installation of phosphorus removal devices at the treatment plant.

The estimated daily load of phosphorus discharged into the James River by the Springfield plant has been 110 lbs/day on average since 2001 for an average daily flow of 39 MGD. These estimates result in an average concentration of 0.3 mg/L.[1]

Estimated phosphorus discharge for other plants came from the information presented in the 2000 James River Total Maximum Daily Load (TMDL) document. The compliance schedule contained in the rule is as follows:

- Facilities with a design flow of 1,000,000 gallons/day or greater must comply with the rule by 2003.
- Facilities with a design flow of 100,000 – 999,999 gallons/day must meet an interim phosphorus limit of 1.0 mg/L by 2003 and must attain full compliance with the 0.5 mg/L requirement by 2007.
- Facilities with a discharge of 22,500 – 99,999 gallons/day have no interim limits and must attain full compliance with the 0.5 mg/L monthly average for phosphorus by 2007.

For other plants and conditions prior to 2000, the phosphorus concentration was set at 5 mg/L. Flow estimates were taken from the National Pollutant Discharge Elimination System (NPDES) list of permitted facilities (Missouri Department of Natural Resources, 2006).

[1] (Source: http://www.ci.springfield.mo.us/egov/publicworks/sanitary/sw_plant.html).

Table 7. Characterization of wastewater discharges (SWAT input) in the James River Basin.

Name	Design flow [MGD]	Flow prior 2001* [MGD]	Flow beginning in 2001** [MGD]	P concentration prior 2001 [mg/L]	P concentration after 2003 [mg/L]
Springfield WWTP	49	30*	39**	7.3	0.3
Rogerville	0.112	0.083	0.083	5.0	1.0
Seymour/MDOC/Fordland	0.444	0.344	0.344	5.0	1.0
Sparta	0.094	0.060	0.060	5.0	5.0
Galena WWTP	0.060	0.035	0.035	5.0	5.0
Exeter/Washburn	0.121	0.081	0.081	5.0	5.0
Cassville	0.700	0.630	0.630	5.0	5.0
Purdy municipal	0.120	0.096	0.096	5.0	5.0
Clever	0.210	0.070	0.070	5.0	1.0
Crane	0.300	0.150	0.150	5.0	1.0
Nixa/Ozark	2.596	1.193	1.193	5.0	0.5
Freemont Hills/English Village	1.700	1.160	1.160	5.0	0.5

*This daily flow corresponds to the year 1992. We assumed the plant reached maximum capacity since an expansion was scheduled and was operating in 1993.

** Average daily flow for 2001 to 2004 indicated on the Springfield web site.

Permitted maximum fecal coliform bacteria concentration of outflow is 400 colonies/100ml and ammonia-N is 2.0 mg/L. The typical effluent characteristics regarding these two pollutants at the Springfield wastewater treatment plant are 10 colonies/100 ml and 0.2 mg/L, respectively, according to their Web site. Nitrate-N and ammonia-N are the two principal forms of nitrogen released by a municipal wastewater treatment plant. We did not find acceptable data on nitrate-N or total nitrogen content of effluent from municipal wastewater facilities in Southwest Missouri. Nitrate-N concentration has been set at 5.0 mg/L. These values were used to calculate daily loads of bacteria and nutrients into the James River and its tributaries.

Springs According to the MODNR Division of Geology and Land Survey there are 537 springs identified in the James River Basin. Only a fraction (15 percent) has recorded flow information: a flow magnitude or a mean flow with or without minimum and maximum flow values. The available flow information is described in appendix B table B-1. Springs in each subbasin were grouped together and flows were summed. A sinusoidal function was applied to the resulting mean, maximum and minimum values so that the maximum and minimum spring flows would occur in March and September, respectively. When no minimum and maximum flow data was available, a constant flow was applied year-round.

USLE Cover factor Differences in land management often result in changes in the soil ground cover, leading to increased or decreased soil erosion. The parameter that reflects the ground cover is the Universal Soil Loss Equation (USLE) Cover (C) factor. The SWAT model uses the minimum value of the C factor to calculate a daily C factor as a function of plant growth (table 8). This value varies between zero, for a completely protected soil (no erosion), and one, for a completely bare soil (no ground cover).

Initial Soil Phosphorus Alternative Phosphorus concentrations in the top soil layer, both labile and organic, were specified to evaluate the impact of phosphorus management on pastures and lawns. The concentrations used in the model are presented in table 9. The effect of management alternatives that reduced applications of phosphorus fertilizer were estimated by the model.

Table 8. Minimum values of the USLE C factor used in the James River Basin model.

Ground cover description	Minimum value of the USLE C factor
Forest – Wooded areas	0.001
Forest – Grazed	0.059
Hay fields	0.003
Urban lawns	0.003
Septic fields	0.003
Pasture – fair condition	0.003
Pasture – poor condition	0.11

Table 9. Initial phosphorus concentration in the top soil layer for different model runs.

	Labile P (ppm)	Organic P (ppm)	Total P (ppm)	Total P (kg/ha)
Lawns – baseline	5	60	65	126
Lawns – reduced P	1.25	15	16.25	32
Pasture fair condition	6	30	36	70
Pasture poor condition	5	30	35	68
Septic fields	4	30	34	66

Calibration and Validation of the Model

The purpose of watershed modeling is to create systematic estimates of flows and concentrations where measured data is incomplete, too expensive to collect, or projections into the future are needed. The James River Basin model was calibrated with flow data from the 1973-1986 period, e.g. input parameters were adjusted so that measured flow matched values predicted by the model during this period. The years 2001-2004 were used to validate the model. The measured flows were compared to model predicted flows for this period without adjusting any input parameter value. Data for pollutant

concentrations was not extensive enough to use for calibration prior to 2001. Data for the years 2001 to 2004 were used for calibration. The pollutant concentrations must be validated as new data becomes available.

Data from five flow and water quality gauging stations was used for the calibration and validation of the model (figure 5).

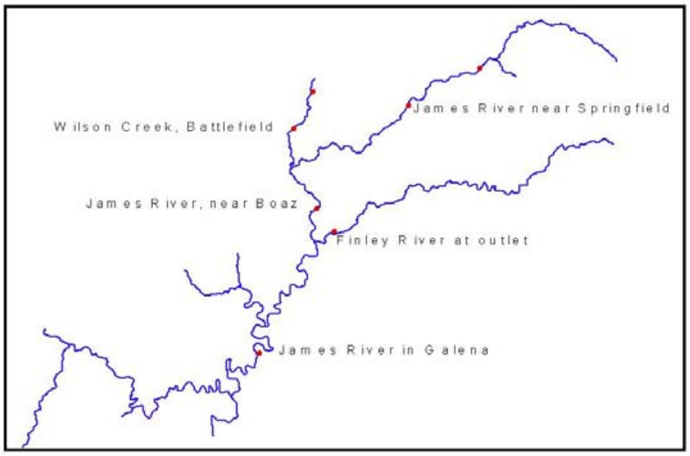

Figure 5. Flow and water quality stations used for the calibration and validation of the James River model.

The goodness of fit of the model was evaluated by visual comparison of measured and estimated hydrographs and plots of pollutant concentrations with time. In addition, several calibration indicators were used to quantify how well the model reproduced the measured values.

The percent deviation gives a measure of how the annual flow deviates from what has been measured. It is calculated as:

$$\text{Dev} = \frac{Q_{measured} - Q_{predicted}}{Q_{measured}} \bullet 100$$

A positive value indicates an under prediction; a negative value indicates an overprediction. Predicted flow that deviates less than 10 percent from measured flow is considered acceptable.

The Nash-Sutcliffe coefficient (NSE) indicates whether and how much the model simulates flows or pollutant concentrations better than the average annual value of the measured data. It is calculated as:

$$NSE = 1 - \frac{\sum_i (Q_{i,measured} - Q_{i,predicted})^2}{\sum_i (Q_{i,measured} - \overline{Q_{measured}})^2}$$

An acceptable value should be greater than 0.5 while a good value should be greater than 0.7.

Flow calibration and validation The calibration and validation indicators for flow are presented in table 10. The percent deviations are within acceptable range toward the outlet of the James River watershed but they are greater than the 10 percent threshold at the outlet of the upstream tributaries, especially for Wilson Creek.

Flow and surface runoff were within 10 percent at all flow gauges for the calibration period. Results were not as good for the validation period, yet predicted values remained within 25 percent of the measured values, except for surface runoff in the Wilson Creek watershed (33 percent deviation).

Daily Nash-Sutcliffe efficiencies were acceptable (around 0.5) for the James River near Boaz and in Galena. For the other flow gauges, they varied between 0.3 and 0.4 (nearly acceptable) and results were similar for the calibration and validation period.

Table 10. Measures of flow goodness of fit for the James River Basin SWAT model.

	Wilson Creek Battlefield	James River near Springfield	James River near Boaz	Finley River	James River in Galena
	Percent deviations on total flow				
1973-1980	-5%	-2%	5%	No data	9%
2001-2004	-16%	-5%	-8%	8%	10%
	Percent deviations of surface runoff				
1973-1980	9%	3%	9%	No data	-2%
2001-2004	16%	33%	21%	13%	23%
	Daily Nash-Sutcliffe coefficients				
1973-1980	0.28	0.37	0.50	No data	0.57
2001-2004	0.36	0.34	0.47	0.34	0.49

One possible source of errors is the use of the 1992 land use and land cover map for simulation of a period prior and after 1990. This could have important effects around the Springfield area and could explain the larger deviations for Wilson Creek.

Another possible source is that the SWAT model was not originally developed for flow simulation in regions that have karst geology. To resolve this problem, we have specified higher hydraulic conductivities (infiltration rates) in loosing streams. Practically all the channels in the James River Basin are loosing streams. In addition, we have specified springs as point discharges, instead of trying to link their flow to their recharge area. A monthly flow variation is specified to reflect the seasonal flow conditions. However, that does not accurately simulate spring flow in extremely dry or wet conditions.

Water quality calibration and validation

Phosphorus input parameters were calibrated based on total phosphorus concentrations measured from 2001 to 2004. In previous years, the stream pollutant concentrations were mostly dependent on the discharge from the Springfield plant. While it gave a rationale and a basis to estimate the effluent volumes and concentrations with more detail, it did not give any insight for the parameters that control the surface runoff processes.

The correlation coefficient (R^2) is typically calculated for measured and predicted values that correspond to the same day. It can also be calculated for measured and predicted values that correspond to the same frequency of occurrence. It is then called prediction efficiency (P_E) and is utilized to evaluate how the range and the distribution of the predicted values match the range and distribution of measured values.

The number of days for which a sample was collected and total phosphorus concentrations were measured varies by location from 23 to 46. The goodness of fit criteria was calculated based on these data points.

Tables 11 and 12 present the goodness of fit for total phosphorus concentrations and loads, respectively, using NSE, R^2, P_E, and percent of deviation. The prediction efficiencies of phosphorus concentrations were high. The prediction efficiencies of phosphorus loads were lower, especially for the James River near Boaz. The lower number of grab samples at that station (18) may have been a factor.

The percent deviations were large. Large deviations are not uncommon because daily measured loads and concentrations are based on only one grab sample in spite of the fact that concentrations can vary by large amounts during storm runoff events.

Table 11. Measures of total phosphorus concentrations goodness of fit for the James River Basin model.

	Wilson Creek Battlefield	James River near Boaz	Finley River	James River in Galena
Number of samples	34	23	46	43
NSE	0.29	-1.9	-0.17	-2.9
R^2	0.29	0.14	0.11	0
P_E	0.93	0.98	0.88	0.93
% deviation	3%	14%	12%	-38%

Table 12. Measures of total phosphorus loads goodness of fit for the James River Basin model.

	Wilson Creek Battlefield	James River near Boaz	Finley River	James River in Galena
Number of samples	34	18	42	43
NSE	-0.03	-5.5	-6.18	0.25
R^2	0.41	0.16	0.03	0.29
P_E	0.85	0.59	0.86	0.96
% deviation	-32%	-73%	-52%	-26%

The low NSE and R^2 values indicate poor performance of the model on an event basis. However, the high prediction efficiencies indicated that the model can provide useful information in terms of load and concentration ranges and probabilities of occurrence. Therefore, it was possible to analyze policies and management scenarios based on average annual pollutant loads and daily frequencies.

To further verify the validity of the model, simulations were made with measured weather from 1971 to 2005 with pre-2000 and current wastewater treatment plants outflow and phosphorus loadings. Water quality measurements in Wilson Creek (figure 6, site 1) and at Galena (site 2) were used to compare the measured and predicted phosphorus concentrations and their reduction at both locations.

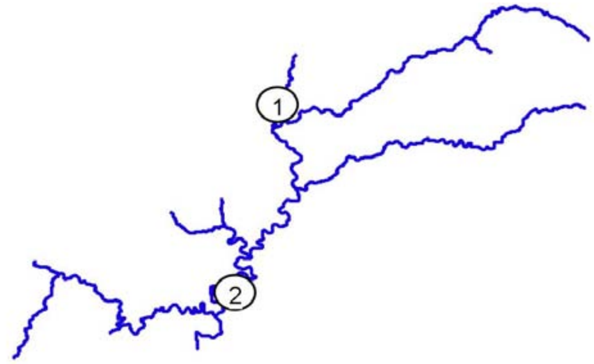

Figure 6. Wilson Creek and Galena site location for median concentration comparisons

Table 13 presents median concentrations pre and post-March 2001 calculated from measured data and predicted values for the same days. The model over-estimated phosphorus concentrations, especially with pre-March 2001 conditions. Nevertheless, these numbers indicate that predicted and measured reductions in median total phosphorus concentrations due to phosphorus removal at the wastewater plants were similar.

Table 13. Wilson Creek and Galena site location for measured and predicted median phosphorus concentrations before and after March 2001

Location	Pre – March 01 measured (mg/L)	2001-2004 measured (mg/L)	Measured decrease (%)	Pre –March 01 predicted (mg/L)	2001-2004 predicted (mg /L)	Predicted decrease (%)
Brookline 1993-2004	3.050	0.370	-88%	4.090	0.209	-95%
Galena 1999-2004	0.295	0.070	-76%	0.795	0.076	-90%

Impact of Urban areas

Sources of sediment, nutrient, and bacteria in urban areas Urban areas can be divided into impervious and pervious areas. The mechanisms of sediment erosion and nutrient and pathogens transport are different for each of these surfaces.

On pervious areas, the mechanisms are similar to those in rural areas with lawns being the main ground cover. Therefore, it is assumed all pervious areas are covered with fescue grass and did not make any distinction for other grass species, flower beds, gardens or urban forestry. Lawns are commonly fertilized annually and they are mowed several times a year.

Erosion can occur with high intensity rains when the lawn cover is less in early spring, before new growth occurs, or when grass is stressed by heat, drought, fertility or excessively short mowing. Movement of nutrients occurs when it rains shortly after fertilizer application. Bacteria buildup and transport occur if animals including dogs, geese or urban wildlife spend time on these lawns.

With no infiltration, impervious areas typically contribute 99 percent of precipitation to runoff. Solid particles tend to accumulate on these areas, especially in the street gutters. These particles come from several sources such as car tires, soil particles from lawns or dust fallout from smokestacks. The SWAT model assumes all solid particles are assimilated to soil particles and added to soil particles from pervious areas. Nutrient loadings from impervious areas are estimated as a fraction of the solid particles.

Monitoring campaigns in the US have determined that urban runoff from impervious areas often have very large concentration of bacteria. These are due to bird droppings, pets' deposits on the streets and other sources. Since there is limited information on how bacteria and pathogens survive on impervious areas and how they are transported by surface runoff, it was assumed that runoff from impervious areas would have a constant fecal coliform concentration of 5000 colonies/100 ml.[2]

Nutrient and sediment contributions from impervious and pervious areas Figure 7 compares predicted sediment and nutrient contributions from urban areas relative to pastures and wooded areas. Pastures in poor condition have poor ground cover including some bare spots. Consequently sediment loads from these areas can be high. Poor pasture condition is often due to grazing rates in excess of sustainable grazing capacity and/or to poor fertilization. In this simulation, poor condition pastures are fertilized every other year instead of every year and the ground cover is poor. Hence, phosphorus runoff is high in all forms, dissolved in runoff (Soluble P) and attached to sediment (Organic and Sediment P).

[2] Wright Water Engineers, Inc, Prepared for WCO Urban Storm Water Impacts; Structural Control Strategies and Erosion Prevention/Sediment Control.

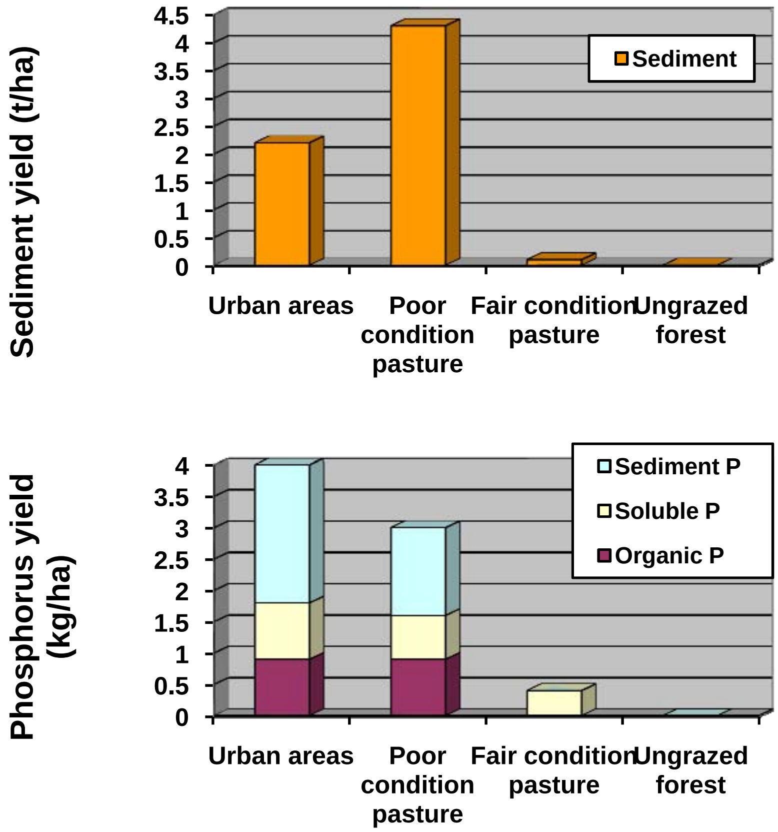

Figure 7. Contributions of sediment and phosphorus from urban and rural areas.

SWAT results indicate that grazed pastures in fair condition do not contribute excessive amounts of sediment or phosphorus to streams. Even when they are fertilized with poultry litter every other year, the phosphorus loadings remain low because there is little erosion. Pastures in poor condition are more erosive and contribute much more sediment and associated phosphorus from cattle manure deposited on the ground or surface applied fertilizer.

Urban SWAT subbasins contain imperious areas that allow runoff to carry all sediment and nutrients to the stream. Lawns and shrubbery are assumed to be fertilized every year with fertilizers that are a blend of nitrogen, phosphorus, and potassium. The blends often contain more phosphorus than needed for plant growth which increases soil P and consequently phosphorus loads.

Effectiveness of the Phosphorus Restrictions from Phase I of the James River TMDL

Expected changes from phosphorus removal- Phase I of the James River TMDL led to a rule related to phosphorus discharges into the James River and its tributaries.
The rule’s impact was simulated with three SWAT model simulations using 30 years of model generated weather with phosphorus releases from the WWTPs into the James River Basin at (1) pre 2000 rates (baseline conditions), (2) 2004 rates (interim

conditions) and (3) 2007 rates (post rule conditions). Table 14 shows the concentrations of wastewater municipal discharges before and after the rule.
The rule's impact was quantified by comparing the average annual phosphorus load downstream of Galena and at the outlet of each tributary of the James River (Figure 8): the upper James River, Wilson Creek, Finley River, and Flat Creek.

The impact is most sensitive at the outlet of Wilson Creek (Figure 9, Table 15), with an 88% reduction predicted. For other tributaries, the impact varies from 5% in Flat and Crane Creek to 20% in Finley River. Downstream Galena, the phosphorus loads are reduced by 50%, even though the phosphorus released from the waste water treatment plants has been reduced by 90%. The reason is that the phosphorus loadings in the tributaries also come from non point sources in surface runoff.

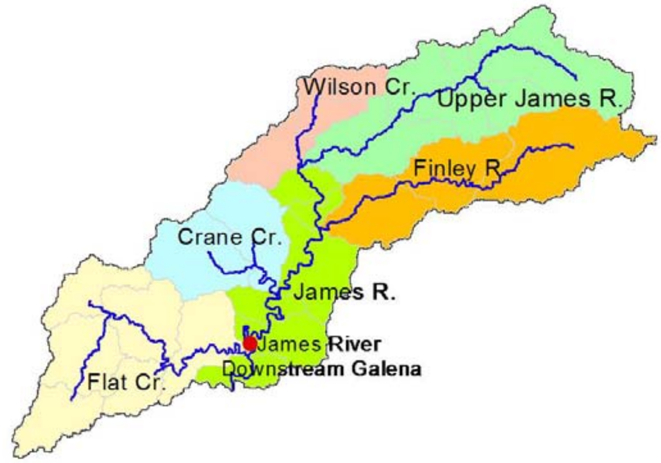

Figure 8. Tributaries of the James River.

Table 14. Phosphorus concentrations of permitted WWTP discharges into the James River

Name	Design flow [MGD]	Actual flow [MGD]	P concentration [mg/L]		
			prior 2000	2003	2007
Springfield WWTP	49	39	7.3	0.3	0.3
Rogerville	0.112	0.083	5.0	1.0	0.5
Seymour/MDOC/Fordland	0.444	0.344	5.0	1.0	0.5
Sparta	0.094	0.060	5.0	5.0	0.5
Galena WWTP	0.060	0.035	5.0	5.0	0.5
Exeter/Washburn	0.121	0.081	5.0	5.0	0.5
Cassville	0.700	0.630	5.0	5.0	0.5
Purdy municipal	0.120	0.096	5.0	5.0	0.5
Clever	0.210	0.070	5.0	1.0	0.5
Crane	0.300	0.150	5.0	1.0	0.5
Nixa/Ozark	2.596	1.193	5.0	0.5	0.5
Freemont Hills/English Village	1.700	1.160	5.0	0.5	0.5

In figure 9, one may note the higher phosphorus loading from Flat Creek compared to other James River's tributaries. This is primarily caused by high phosphorus runoff due to the availability and use of poultry litter to fertilize pastures around Cassville. The phosphorus discharges from the wastewater treatment plants of Cassville, Washburn and Exeter represent only a small fraction of the Flat Creek phosphorus load.

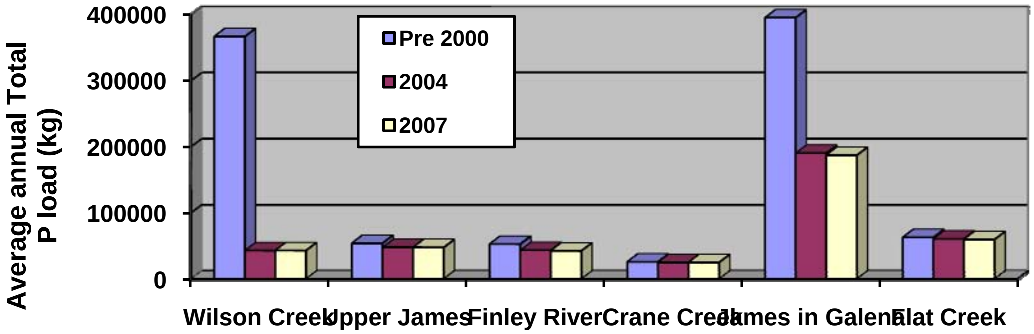

Figure 9. Predicted average annual total phosphorus stream loads for different stages of phosphorus removal from the wastewater plants in the James River Basin, everything else held constant.

Table 15. Predicted reductions in total phosphorus stream loads for different stages of phosphorus removal at the wastewater treatment plants in the James River Basin, everything else held constant.

Tributary	Relevant WWTP	Change in average annual Total P load relative to pre-2000 conditions	
		2004	2007
Wilson Creek	Springfield	-88%	-88%
Upper James	Rogerville, Freemont Hills, English Village	-12%	-12%
Finley River	Nixa, Ozark, Seymour, MDOC, Fordland, Sparta	-18%	-19%
Crane Creek	Crane, Clever	-3%	-3%
James in Galena	All except Cassville, Exeter/Washburn	-52%	-53%
Flat Creek	Cassville, Exeter/Washburn	-4%	-5%

Expected and measured changes pre and post 2000- Table 16 lists for each tributary the percentage of the average annual phosphorus load that is due to wastewater treatment discharges, assuming pre 2000 and 2007 treatment levels. Relative changes in phosphorus loadings seem smaller than that measured in the James River Basin and in Table Rock Lake. Phosphorus loadings estimated from measurements reflect the agricultural and urban management and land uses in the watershed and the weather from 1994 to 2005.

The southwest region of Missouri had less rainfall than normal for the 2000 to 2004 period which led to a reduction of all pollutants loadings other than direct discharges to the streams. Figure 10 describes how annual precipitation has varied across the James River Basin since 1971. While there is no long term trend, there is a shorter term cycle in the precipitation. Hence, the 2001-2005 precipitation was 11% or 5 inches (120 mm) less than the 1994-1998 precipitation.

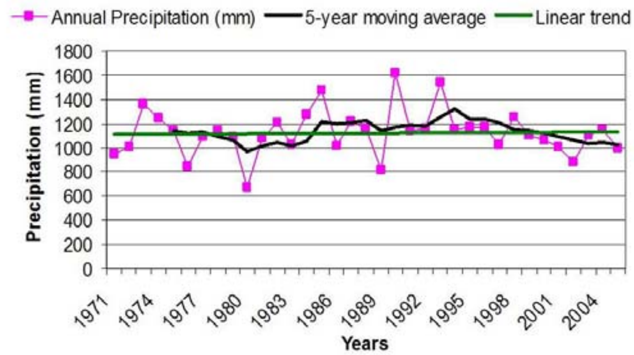

Figure 10. Annual precipitation in the James River Basin from 1971 to 2005.

Relative changes in precipitation translate into greater relative changes in runoff, sediment and pollutant loadings. In fact, using measured weather instead of generated weather for model simulation results in larger reductions in phosphorus loadings (Table 17, Figure 11).

Table 16. Percent of average annual phosphorus load that is due to wastewater treatment plant discharges, by tributary.

Tributary	Relevant WWTP	Pre 2000	2007
		Percent of average annual P load (%)	
Wilson Creek	Springfield	105%	37%
Upper James	Rogerville, Freemont Hills, English Village	16%	2%
Finley River	Nixa, Ozark, Seymour, MDOC, Fordland, Sparta	21%	3%
Crane Creek	Crane, Clever	6%	1%
Flat Creek	Cassville, Exeter/Washburn	9%	1%

Table 17. Predicted change of total phosphorus stream loads in 2001-2005 relative to 1994-1998, assuming 2007 rule requirements were implemented in 2000 using measured weather data.

Reach	Relevant WWTP	Av. annual load (kg) 1994-1998	2001-2005	Relative change
Wilson Creek	Springfield	375,050	39,995	-89%
Upper James	Rogerville, Freemont Hills, English Village	52,020	37,549	-28%
Finley River	Nixa, Ozark, Seymour, MDOC, Fordland, Sparta	48,410	29,569	-39%
Crane Creek	Crane, Clever	28,219	18,210	-35%
James in Galena	All except Cassville, Exeter and Washburn	502,320	104,678	-79%
Flat Creek	Cassville, Exeter/Washburn	87,685	72,165	-18%

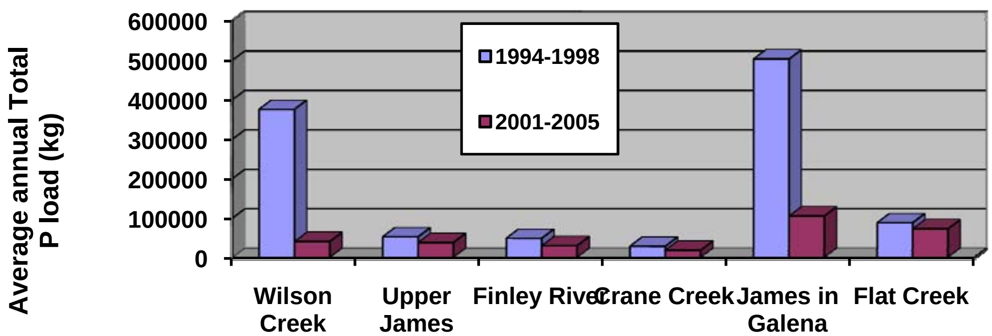

Figure 11. Predicted phosphorus loads from each tributary in 2001-2005 compared to 1994-1998 using measured weather data.

Loads are important to assess what enters Table Rock Lake. However, one may want to consider concentrations to relate to possible measurements. Figure 12 and Table 18 show the predicted flow-weighed concentrations before and after the wastewater treatment plant upgrades, and the relative decrease.

In Flat Creek and Crane Creek, the discharges from the wastewater treatment plants are small in comparison to the phosphorus runoff from pastures. We have not investigated why there is an increase of concentrations but a possibility is that the bulk of the phosphorus load comes with the first flush of rain events and subsequent rain contributes to dilution. It is possible that with less precipitation, runoff concentrations are higher even though the total load is lower.

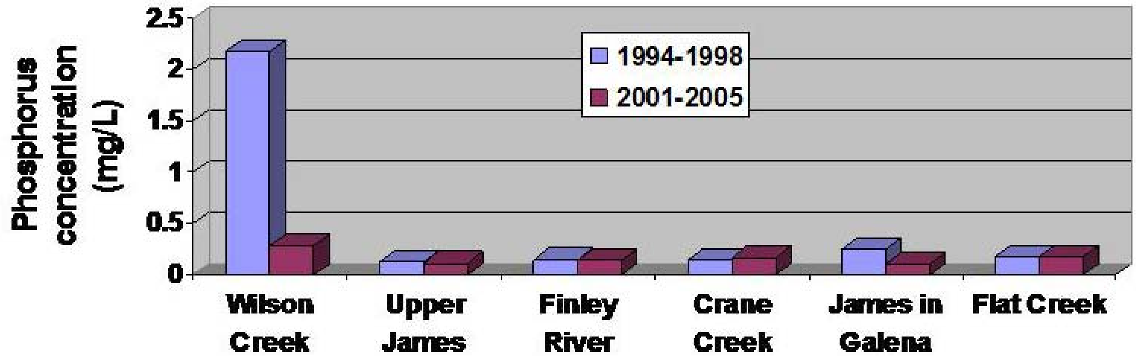

Figure 12. Predicted flow-weighed total phosphorus concentrations in 1994-1998 and 2001-2005, assuming 2007 rule requirements were implemented in 2000.

Table 18. Predicted changes of total phosphorus concentrations in 2001-2005 relative to 1994-1998.

Reach	Relevant WWTP	Flow weighed concentrations (ppm)		Predicted change
		1994-1998	2001-2005	
Wilson Creek	Springfield	2.170	0.286	-87%
Upper James	Rogerville, Freemont Hills, English Village	0.132	0.124	-6%
Finley River	Nixa, Ozark, Seymour, MDOC, Fordland, Sparta	0.158	0.151	-4%
Crane Creek	Crane, Clever	0.145	0.176	21%
James River in Galena	All except Cassville, Exeter and Washburn	0.249	0.119	-52%
Flat Creek	Cassville, Exeter/Washburn	0.180	0.191	7%

Conclusion Reductions of phosphorus discharges from the wastewater treatment plants in the James River Basin have allowed significant reductions in phosphorus loadings and concentrations entering Table Rock Lake. The drought that has occurred during the recent years has accentuated what appears to be the result of the phosphorus removal of treated effluent. Loads and concentrations were decreased by a combination of phosphorus removal at the wastewater treatment plants and a decrease in precipitation and surface runoff. A key implication is that, should it start raining again in more "normal" amounts, we expect the phosphorus concentrations and loadings in the James River and to Table Rock Lake to increase. However, we do not expect them to reach the pre-2000 levels.

Arkansas Upper White River Basin Watershed Modeling

Parallel efforts were conducted in Arkansas White River and other tributaries that flow into the Beaver Reservoir and then into Table Rock Lake. The Arkansas researchers completed a set of studies to:

1. identify data collection intensity necessary to attain statistically accurate measures of nutrient and sediment movement [3],
2. evaluate nutrient yield predictions of alternative modeling approaches[4],
3. calibrate the SWAT model and conduct sensitivity analyses in the Beaver Reservoir[5],
4. quantify predictive and parametric uncertainty for artificial neural network based hydrologic models[6],
5. determine the potential for phosphorus release from bottom sediments located in different parts of the Beaver Reservoir[7], and
6. examine the LANDSAT Thematic Mapper Data to assess lake water quality using neural network techniques to decorrelate satellite data in order to assess water quality[8].

The first study used a short-term sampling program to assess watershed-scale influences such as catchment size and land use and seasonal variability in the War Eagle Creek tributary. Thirteen subbasins were identified within War Eagle Creek watershed for sampling and assessment. They're objective was to identify strategic subbasin sampling locations that would minimize the number of sampling sites yet fully characterize seasonal water quality. They also compared results from each sampling station (subbasin) to suggest ecoregion nutrient and sestonic chlorophyll-a criteria. Wastewater treatment plant effluent discharge impacts were evident for subbasin 8 (figure 13).
All constituent concentrations, soluble reactive phosphorus (SRP), total phosphorus (TP), Nitrite nitrogen (NO2-N), nitrate nitrogen (NO3-N), and total nitrogen (TN) were significantly greater ($p < 0.10$) downstream from the effluent discharge site compared with the majority of the other subbasins.

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[3] Migliaccio, K. W.; Haggard, B.E.; Chaubet, I,; and Matlock, M.D. "Linking Watershed Subbasin Characteristics to Water Quality Parameters in War Eagle Creel Watershed", 2007 Transactions of the American Society of Biological Engineers Vol. 50(6) 2007-2016.

[4] Migliaccio, K. W.; Chaubet, I; and Haggard, B.E. "Evaluation of landscape and instream modeling to predict watershed nutrient yields"; Elsevier, www.sciencedirect.com.

[5] White, Katie L. and Chaubey, Indrajeet. "Sensitivity Analysis, Calibration, and Validations for a Multisite and Multivariable SWAT Model, Journal of the American Water Resources Association October 2005.

[6] Srivastav, R.K.; Sudheer, K.P.; AND Chaubey, I. "A simplified approach to quantifying predictive and parametric uncertainty in artificial neural network hydrologic models", Water Resources Research, Vol. 43, W10407.

[7] Sen, Sumit; Haggard, Brian E.; Chaubey, Indrajeet; Brye, Kristofor R.; Costello, Thomas A.; and Matlock, Marty D. "Sediment Phosphorus Release at Beaver Reservoir, Northwest Arkansas, USA, 2002-2003: A Preliminary Investigation", Water Air Soil Pollut, DOI 10.1007/s11270-006-9214-y.

[8] Sudheer, K. P.; Chaubey, Indrajeet; and Garg, Vijay. "Lake Water Quality Assessment from LANDSAT Thematic Mapper Data Using Neural Network: An Approach to Optimal Band Combination Selection", Journal of the American Water Resources Association, December 2006.

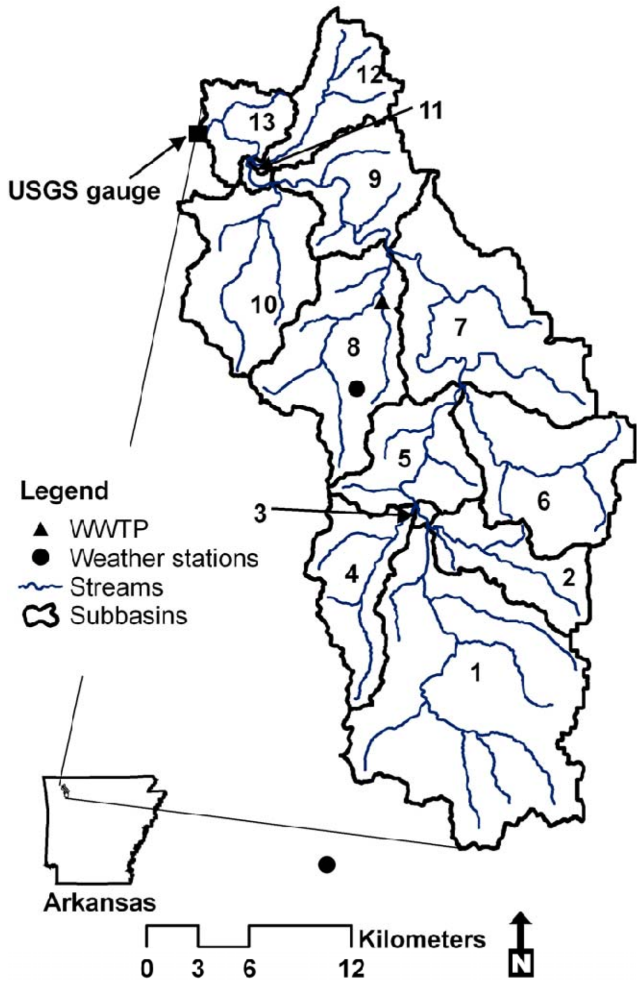

Figure 13. War Eagle Creek catchment with stream segments and subbasins identified.

NO3-N plus NO2-N and TN median concentrations for pasture-dominated subbasins 10 and 12 were greater than most other values and regression analyses indicated a strong correlation between TN and % pasture cover ($r = 0.912$) and between NO3-N and % pasture cover ($r = 0.925$). Chlorophyll A median concentration was greatest for subbasin 11, which was above median ecoregion criteria values. The lowest concentrations were often measured in the winter-spring season and greatest loads calculated for winter-spring and fall seasons. Results indicated that the number of sites sampled could be reduced more than 50 percent without losing information on the variability of the selected water quality parameters. The reduction of sampling sites allowed focused and frugal water quality monitoring to determine the quality of water in War Eagle Creek for assessing designated uses.

The second study loosely coupled the SWAT and the QUAL2E models and compared their combined ability to predict total phosphorus (TP) and NO3-N plus NO2-N yields to the ability of the SWAT model to predict TP and NO3-N plus NO2-N yields from War Eagle Creek. Model prediction compared using two variations of the Pearson product-moment correlation ($p < 0.05$) indicated that correlation coefficients and regression slopes for the two data sets were not significantly different. Neither modeling method appears to be significantly better in predicting monthly TP and NO3-N plus NO2-N yields from the watershed. Also, no significant differences were present between predicted outputs of the SWAT model with or without instream components active, indicating a need for further testing and refinement of the SWAT algorithms simulating instream processes.

The third study assessed the ability of SWAT to mimic specified watershed processes through the calibration and validation. Calibration and validation are key factors in reducing uncertainty and increasing user confidence in the SWAT model's predictive abilities and the effectiveness of the application.

The Beaver Reservoir Watershed was modeled with SWAT to:
(1) calibrate a multi-site and multivariable SWAT model
(2) conduct sensitivity analysis, and
(3) perform calibration and validation at three different sites for flow, sediment, TP, NO3-N and NO2-N (figure 14).

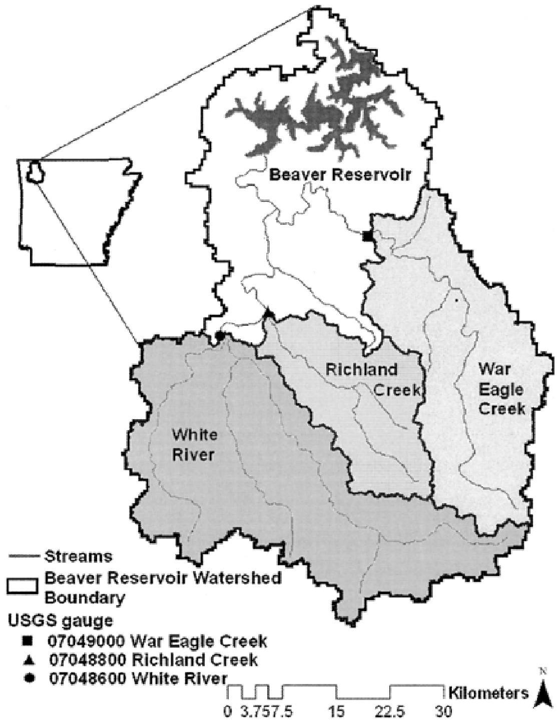

Figure 14. Location of Beaver Reservoir Watershed, Subbasins, and Stream Gauges Used for Model Calibration.

Sensitivity analysis was conducted to identify parameters that most influenced predicted flow, sediment, and nutrient model outputs. A multiple objective function analysis was developed that optimized three statistics: percent relative error (RE), Nash-Sutcliffe Coefficient (RNS2), and coefficient of determination (R2). This function was used to successfully calibrate and validate a SWAT model of Beaver Reservoir Watershed.

The fourth study developed an effective simplified method to conduct uncertainty analyses for artificial neural network (ANN-based) hydrologic models. The method demonstrated through a case study of the Kolar River basin located in India. The method quantifies uncertainty in the model output and the parameters due to variation in input data used for calibration. Uncertainty due to model architecture and the input vector were not directly considered because they were minimized during the model calibration. The results of the case study suggest that the sampling variability of the training patterns as well as the initial guess of the parameters of ANN do not have significant impact on the model performance. Most of the models examined failed to capture the hydrograph peak flow characteristics. The proposed method of uncertainty analysis can be easily applied to an ANN-based hydrologic model to illustrate the strong and weak points of model.

The fifth study examined phosphorus (P) release from bottom sediments, potentially a significant source to the overlying water column, which could maintain and enhance algal growth and eutrophic conditions in lakes and reservoirs. The study objectives were to:
(1) measure P flux under aerobic and anaerobic conditions from intact sediment cores collected from Beaver Reservoir .
(2) evaluate the spatial variability in measured sediment P flux under aerobic and anaerobic conditions within the reservoir, and
(3) compare external and internal P loads. Six intact sediment cores were collected from lacustrine, transitional and riverine zones of the reservoir during June and September 2003, and February 2004.

Samples were incubated for 21 days in the dark at 22°C. Three cores from each zone were incubated under aerobic conditions and anaerobic conditions. Water samples were collected daily from the overlying water column of each core for the first five days of incubation and every other day for the remaining 16 days. The water samples were analyzed for soluble reactive phosphorus (SRP). Water removed from the core was replaced with filtered lake water, maintaining a constant overlying water volume of one liter.

Sediment P flux under anaerobic conditions (<0.01–1.77 mg m−2 day−1) was generally greater than that measured under aerobic conditions (<0.01– 0.89 mg m−2 day−1). P flux was generally greatest at the sites in the riverine and transitional zones. Maximum sediment P flux was observed under anaerobic conditions in cores collected from the transitional zone in September 2003. Average sediment P flux under aerobic conditions (0.09 mg m−2 day−1) and anaerobic conditions (0.31 mg m−2 day−1) was greater than the external P flux (0.05 mg m−2 day−1) estimated from the Beaver Reservoir tributaries. Results showed that the annual internal P load (7 Mg year−1) from bottom sediments in Beaver Reservoir was less than 10 percent of the annual external P load (81 Mg P year−1). Although the internal P load was significant, it would not currently be cost effective to manage this P source given the large surface area of Beaver Reservoir.

The sixth study examined the LANDSAT Thematic Mapper Data to assess lake water quality using neural network techniques to decorrelate satellite data in order to assess water quality. Many researchers use the artificial neural network (ANN) technique to decorrelate satellite data in order to assess water quality. They examined a method that establishes the output sensitivity to changes in the individual input reflectance channels. It also models water quality from remote sensing data collected by LANDSAT Thematic Mapper (TM). A hypothesis about the importance of each band can be made from the sensitivity and used as a guideline to select appropriate input variables (band combination) for ANN models based on the principle of parsimony for water quality retrieval. The results of a case study of Beaver Reservoir were highly promising validating the case study input selection procedure. This approach could significantly reduce the effort and computational time required to develop ANN water quality models.

Watershed Modeling of the Entire Upper White River Basin

The detailed analyses of different aspects of the James River and the Beaver Reservoir watershed were used to create a less detailed SWAT model of the entire Upper White River Basin. Major staffing changes in both Arkansas and Missouri modeling teams have not allowed validation of the model to be completed or any additional analyses to be conducted. However, a working model has been built and preliminary baseline results are presented in the maps that follow.

The hydrology and physiography map, and the land use/land cover map, were created by the Arkansas modeling team, figures 15 and 16, respectively.

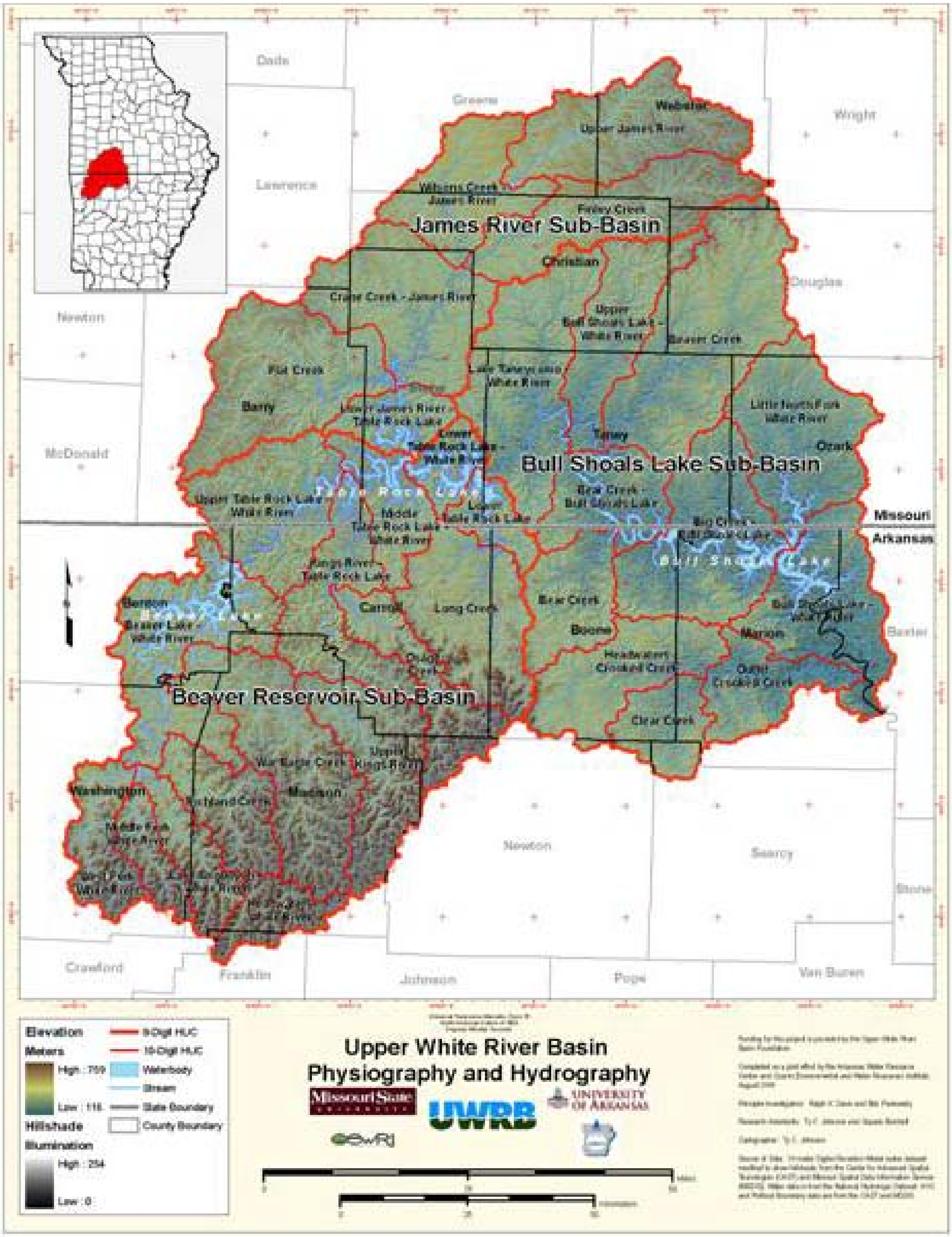

Figure 15. Upper White River Basin physiography and hydrography

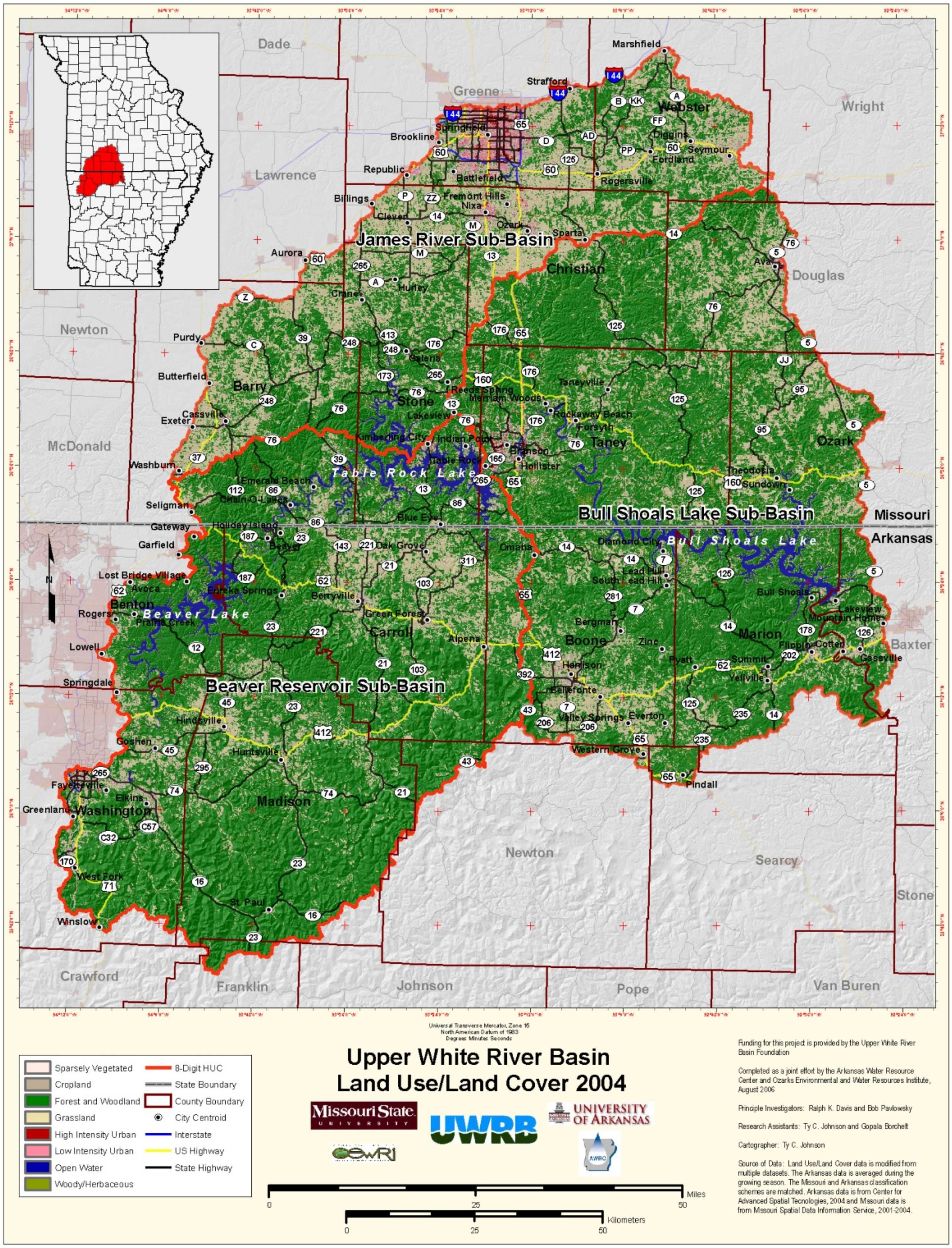

Figure 16. Upper White River Basin land use/land cover

The Upper White River Basin was divided into 24 subbasins (figure 17). The locations of permitted facilities are also shown in figure 17. Figure 18 presents the estimated sediment leaving by subbasin. The sediment loads are based on the assumption that most of the pasture land is in fair to poor condition. This assumption is based on nearby areas but needs to be validated for these subbasins.

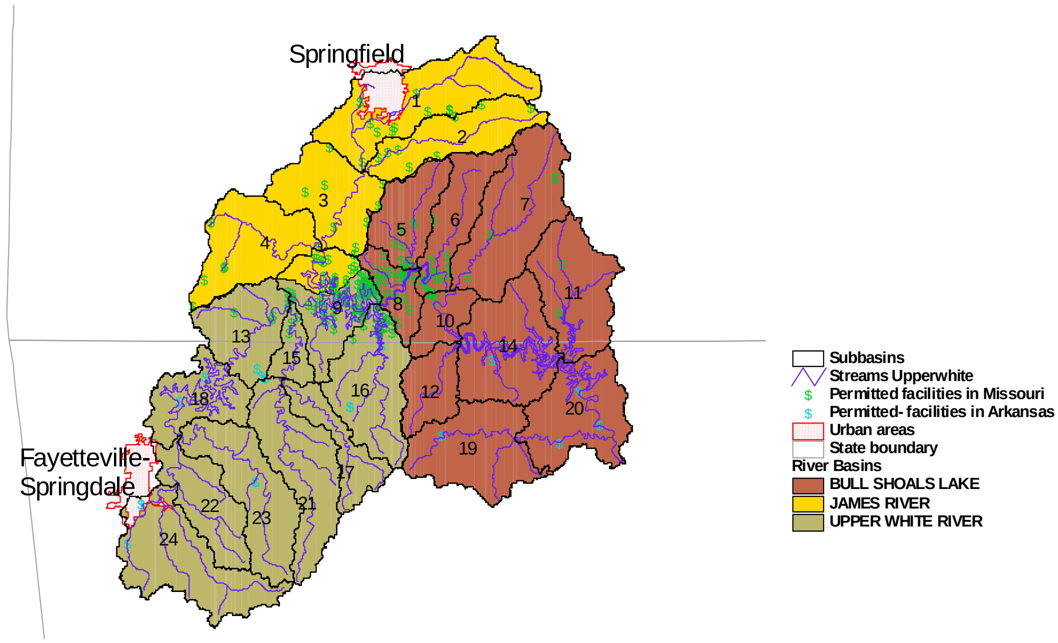

Figure 17. Upper White River permitted facilities

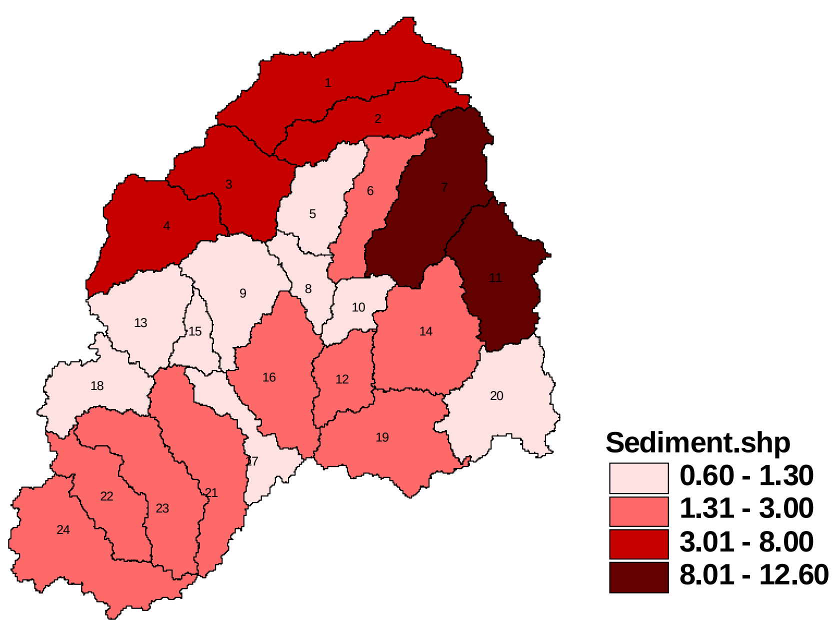

Figure 18. Upper White River sediment yield from nonpoint sources (tons/acre)

Subbasin 7, which contributes some of the highest sediment loads in the watershed, has highly variable sediment loads over time and by land use/land cover (i.e. deciduous forest, mixed forest, cropland producing hay, fair condition pasture, septic fields and poor condition pasture, respectively). The loads are present in figure 19 on a logarithmic scale to capture the extreme variability. Table 19 presents the land use/land cover and the estimated sediment leaving all subbasins by land use. Poor condition pasture contributes almost all of sediment load. Figures 20 and 21 present the estimated phosphorus and nitrogen loadings from non-point sources. Poor condition pasture also contributes much of the nitrogen and phosphorus loads. These initial results have not been validated, thus these results are very preliminary.

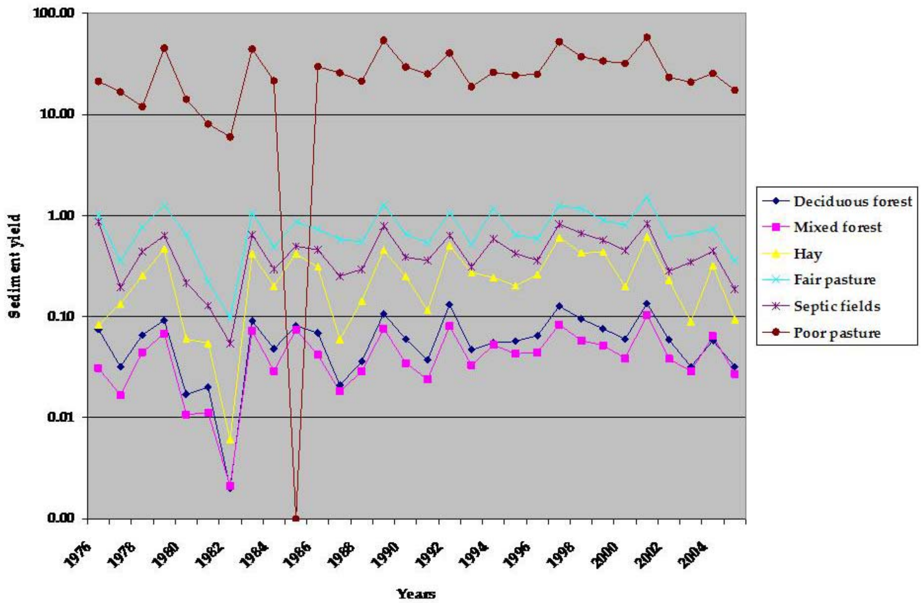

Figure 19. Subbasin 7 sediment delivery by land use/land cover by year

Table 19. Upper White River Land use and sediment delivery from subbasins

Land use	Area sq. km	Area sq. miles	Acres	Percent of area	Total sediment leaving subbasins (english tons)
Forest	9,942.43	3,838.78	2,456,816	58.67%	583
Pasture	5,120.43	1,977.00	1,265,281	30.22%	37,602
Cropland	1,460.29	563.82	360,844	8.62%	187
Septic fields	58.41	22.55	14,434	0.34%	14
Water	363.66	140.41	89,863	2.15%	0
Total watershed	16,945.23	6,542.56	4,187,238	100.00%	38,386

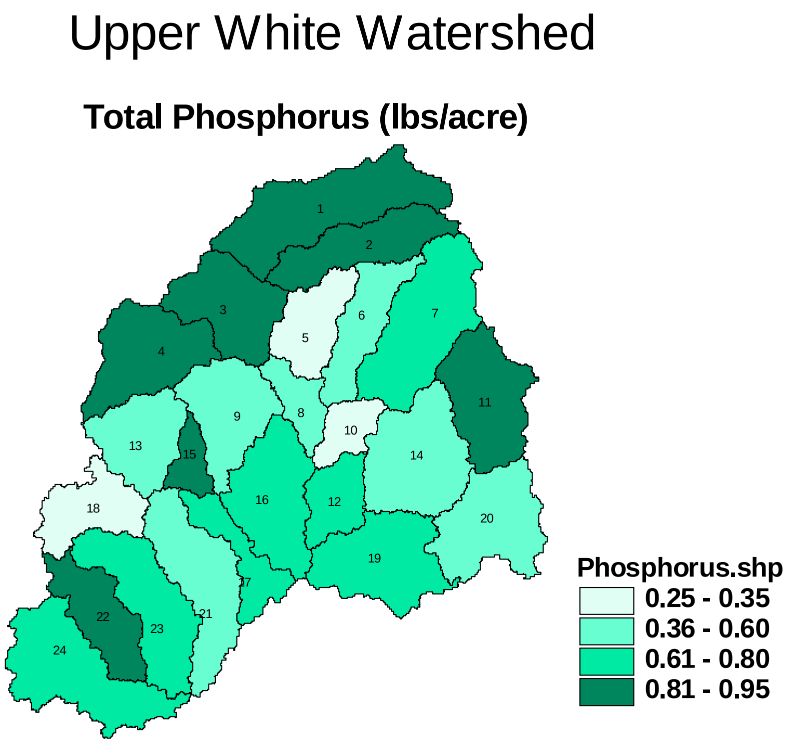

Figure 20. Upper White River phosphorus loading from nonpoint sources (tons/acre)

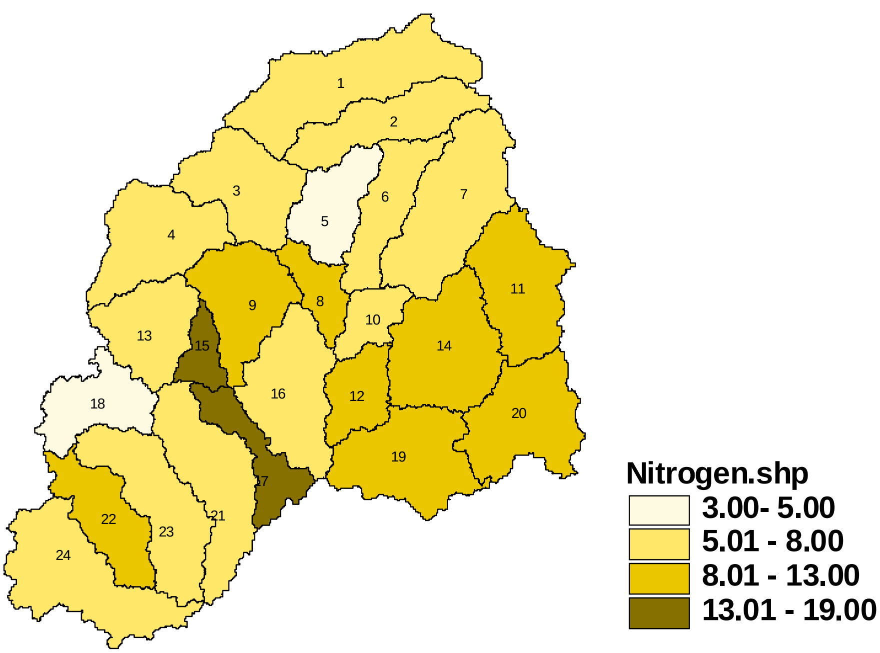

Figure 21. Upper White River nitrogen loading from nonpoint sources (tons/acre)

These preliminary results suggest that pasture management practices may be an effective way to reduce both sediment and nutrient non-point loadings. Technologies that make water availability throughout the pasture may be a passive way to distribute grazing intensity and reduce the percentage of poor condition pasture.

Assessing the effectiveness of alternative grazing systems might best be done by combining SWAT watershed analyses with multi-field grazing assessment using the APEX (Agricultural Policy Evironment eXtender) model. APEX can be used to analyze many alternative grazing systems and their impacts on erosion and runoff. Results from APEX can be fed directly into SWAT for the pasture areas of SWAT subbasins.

Total phosphorus loadings (figure 22) reflect subbasin loads assuming point discharges are at current permitted rates (TP-Rule) and at the projected rate of 0.05 ppm (TP-05).

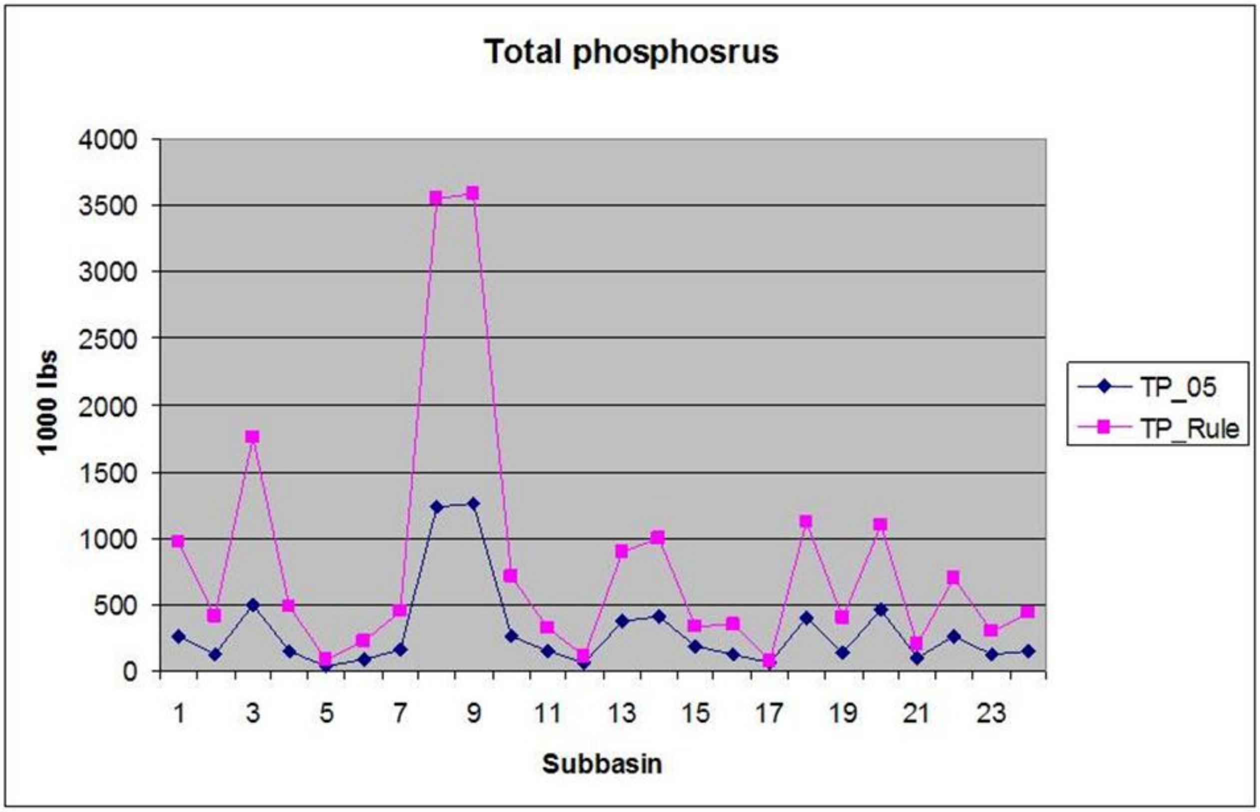

Figure 22. Total subbasin phosphorus loadings with current permitted discharges (TP-Rule) and with a permitted discharge of 0.05 ppm (TP-05)

Economic Impact Assessment

Dr. Dennis Robinson and graduate associate Kyoungmin Nam from CPAC at MU, and Dr. Jennie Popp and graduate associates Nathan Kemper and H. German Rodriguez from the Department of Agricultural Economics and Agribusiness at the University of Arkansas used Impact Analysis for Planning (IMPLAN) model to create input/output analyses of poultry, recreation, and agricultural industry impact in the Upper White River Basin and surrounding areas. They worked together to create the model sectors from the county data purchased from Minnesota IMPLAN Group and 2002 Agricultural Census, the National Agricultural Statistics Service, and the Economic Research Service (ERS) of the USDA. The data was debugged and validated for this application. The IMPLAN model matrix and results were analyzed with mathematical optimization technologies to summarize the multitude of numerical results into conclusions and recommendations.

University of Arkansas Economic Analyses

The Arkansas team prepared an assessment of the importance of the poultry industry to Northwest Arkansas and Eastern Oklahoma and an assessment of the impacts of recreation industry development around and nearby the Beaver Lake reservoir. The watershed draining into Beaver Lake Reservoir accounts for much of the Arkansas portion of the Upper White River Basin. The reservoir is also a primary supplier of drinking water for Northwest Arkansas.

The objectives of "The Economic Power of Poultry in the Ozarks[9]" study were to assess the economic impact of the poultry in the 22-county area of Northwest Arkansas and Eastern Oklahoma and to examine the economic impacts of potential changes in poultry production in the region resulting from phosphorus limits for surface water. The study found that the poultry industry accounted for nearly 50,000 jobs and over $1.3 billion in labor income. It assessed the impacts of imposing surface water quality limits of 0.100 mg/L and 0.037 mg/L of phosphorus in surface water. The 0.100 mg/L and 0.037 mg/L phosphorus limits were estimated to decrease poultry production by 13 and 58 percent, respectively leading to loses of 2,259 and 19,241 jobs and $56.21 and $542.85 million, respectively.

The recreation industry study, "Regional Growth and Beaver Lake: A Study of Recreation Visitors[10]" found that although the 2.4 annual recreation visits generated 600 jobs, $12.9 million in income and $20.9 million in value added revenues to the region, it is not likely to offset the costs of maintaining the quantity and quality of water to supply the growing Northwest Arkansas urban populations.

MU Economic Analyses

The MU team assessed the economic impacts of redistributing poultry litter to reduce potential water quality degradation. Dr. Robinson's presented this analysis entitled "Estimating the Regional Economic Impacts Due to Poultry Litter Distribution Restrictions in the White River Basin of Northwest Arkansas and Southwest Missouri: A Non-Linear Input-Output Analysis" was presented at Mid-Continent Regional Science Association 39th Annual Conference, IMPLAN National User's Conference 7th Biennial Conference, June 5-7, 2008 at Antlers Hilton Colorado Springs, Colorado Springs, Colorado. He notes that Northwest Arkansas and Southwest Missouri have been growing rapidly recently. For example, their populations and employment have been growing at rates between 2 and 4 percent per annum during since 1990 (table 20), much faster than the annual growth rates for Kansas, Oklahoma, and the rest of the Nation. The previous Arkansas studies found that most of this good fortune for the White River Basin area of Arkansas and Missouri can be attributable to the agricultural and recreation sectors. On a regional level, the states of Arkansas, Missouri and Oklahoma have seen far higher growth rates in the poultry sector than the nation as a whole.

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[9] 2006 Journal of Applied Poultry Research volume 15 pages 502 to 510.

[10] Submitted to Tourism Economics

Table 20. Upper White River populations and employment 1980 to 2006

Economic Indicators for the White River Basin Multiregional Input-Output Model Regions

							Annual Averge Growth Rate			
	Name	Abr	1980	1990	2000	2006	1980 to 1990	1990 to 2000	2000 to 2006	1970 to 2006
Population (persons)	Arkansas White River Basin	WR-AR	288,177	330,493	458,899	537,994	1.3%	3.5%	2.5%	3.2%
	Missouri White River Basin	WR-MO	354,833	410,516	516,794	567,603	1.4%	2.4%	1.4%	2.2%
	Rest of Arkansas	RofAR	2,000,561	2,026,093	2,219,498	2,271,117	0.1%	0.9%	0.3%	0.5%
	Rest of Missouri	RofMO	4,567,133	4,718,364	5,089,346	5,270,036	0.3%	0.7%	0.5%	0.6%
	State of Kansas	KS	2,369,039	2,481,349	2,692,890	2,755,817	0.4%	0.8%	0.3%	0.6%
	State of Oklahoma	OK	3,040,758	3,148,825	3,454,058	3,577,536	0.3%	0.9%	0.5%	0.7%
	Rest of the US	RofUS	214,604,218	236,507,174	267,762,823	283,774,716	0.9%	1.2%	0.9%	1.2%
Full and Part-Time Employment (jobs)	Arkansas White River Basin	WR-AR	134,618	186,069	272,269	326,817	3.5%	4.2%	2.9%	5.3%
	Missouri White River Basin	WR-MO	171,346	234,046	321,663	363,115	3.3%	3.4%	1.8%	4.1%
	Rest of Arkansas	RofAR	900,584	1,025,108	1,231,598	1,274,522	1.3%	1.8%	0.5%	1.5%
	Rest of Missouri	RofMO	2,383,068	2,759,315	3,175,557	3,308,222	1.4%	1.4%	0.6%	1.4%
	State of Kansas	KS	1,312,137	1,483,043	1,771,218	1,844,852	1.2%	1.8%	0.6%	1.5%
	State of Oklahoma	OK	1,550,662	1,664,461	2,015,085	2,144,708	0.7%	1.9%	0.9%	1.4%
	Rest of the US	RofUS	107,778,785	132,028,858	157,971,410	169,070,664	2.0%	1.8%	1.0%	2.1%

Source: Regional Economic Information System, U.S. Bureau of Economic Analysis

Vertical integration of the US poultry industry allowed larger numbers of birds to be produced and processed in Northwest Arkansas and Southwest Missouri. The poultry industry growth also generated large quantities of litter that was applied nearby on pasture and crop lands for fertilizer resulting in improved pasture productivity and increased livestock production potential. Some of the nutrients in the feed are not converted into meat, bone and energy by the birds and those nutrients (including phosphorous and nitrogen) end up in the litter.

Poultry litter phosphorous is suspected to be a significant source of water quality degradation. Because soil nutrient management practices historically focused on nitrogen, applications of poultry litter to meet pasture nitrogen needs have resulted in accumulations of phosphorous in the soil. Soil phosphorous can move with erosion, runoff and leaching into nearby springs, streams and lakes. Wider distribution of litter to reduce concentration levels is one potential solution being pursued by numerous states. Some states provide cost share dollars to offset the increased hauling cost.
The purpose of this analysis was to examine the effects of requiring poultry litter be distributed more widely than is presently done. Raising litter delivery costs will potentially reduce viability of the poultry industry in the region. First, this analyses estimates of how much and where recyclable manure being is generated in the US and how much and where it can be used for fertilizer (based on crop phosphorous removal in yield). Potential increases in hauling costs to implement a requirement of wider poultry litter distribution by poultry producers in the White River Basin areas of Arkansas and Missouri were estimated. Second, a multiregional input-output model for the White River Basin and the surrounding areas in Arkansas, Missouri, Kansas and Oklahoma that was constructed using 2002 IMPLAN databases. Third, a nonlinear multiregional input-output methodology for computing the regional economic impacts of restrictive manure management practice requiring wider distribution of recyclable manure was created. The regional economic impact analyses are summarized and a number of conclusions and recommendations for further study are given.

Quantity and Location of Recyclable Manure
The quantity and location of poultry litter to be redistributed was estimated by the following process:

1. Compile county animal production data from the 2002 US Agricultural Census.
2. Use manure phosphorous available for recycling coefficients by type of animal production to estimate manure phosphorus available by county, figure 23,[11]
3. Use EPIC/APEX manure fertilizer parameters for phosphorous percent in zero percent moisture manure by source to convert manure phosphorous by county to 20 percent moisture content manure by source by county (figure 24).
4. Compile county crop production data from the 2002 US Agricultural Census.
5. Use EPIC/APEX crop parameters for phosphorous percent for zero percent moisture yields, standard percent moisture content in yields, and units of measure to calculate pounds of phosphorous in harvested yields of crops by crop by county (figure 25).
6. Subtract 50 percent of estimated crop phosphorous removal by county from phosphorous available from recyclable manure by county to estimate poultry litter to be redistributed outside the county or potential demand for poultry litter from other counties if balance is negative (figure26).

The county-level manure supply and demand values were aggregated geographically into one of seven regions for this analysis:

1. Upper White River, Arkansas counties
2. Upper White River, Missouri counties
3. Remaining Arkansas counties
4. Reminding Missouri counties
5. All Kansas counties
6. All Oklahoma counties
7. All remaining counties of the US.

[11] Van Dyne D. L., and C. B. Gilbertson. 1978. Estimating U.S. livestock and poultry manure and nutrient production. Report No. ESCS-12. United States Department of Agriculture, Economics, Statistics, and Cooperatives Service. Washington, D.C.

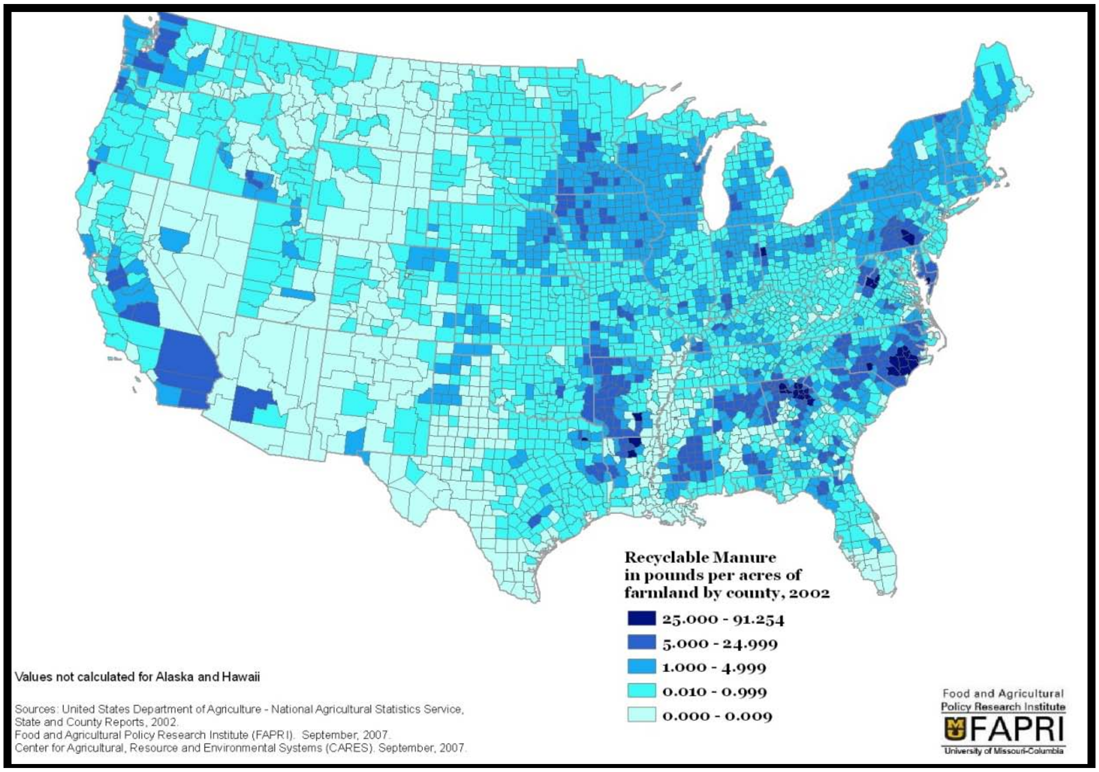

Figure 23. Recyclable manure phosphorus in pounds per acre of farmland

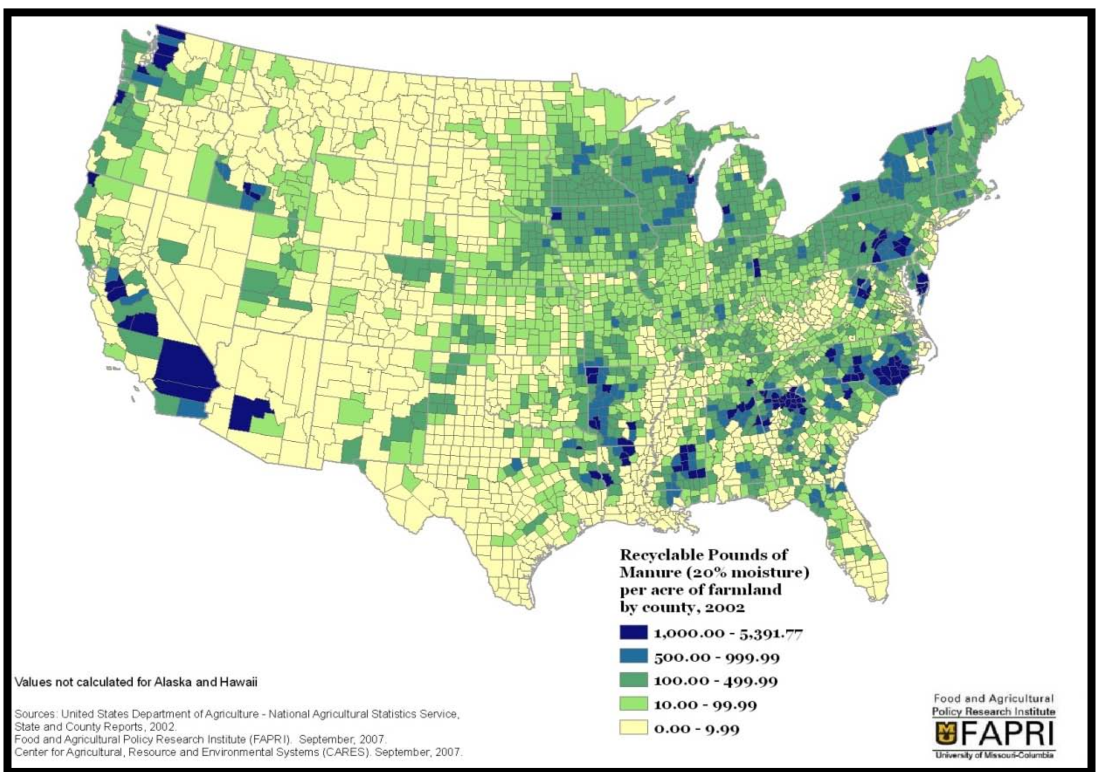

Figure 24. Total recyclable manure (20% moisture) in pounds per acre of farmland

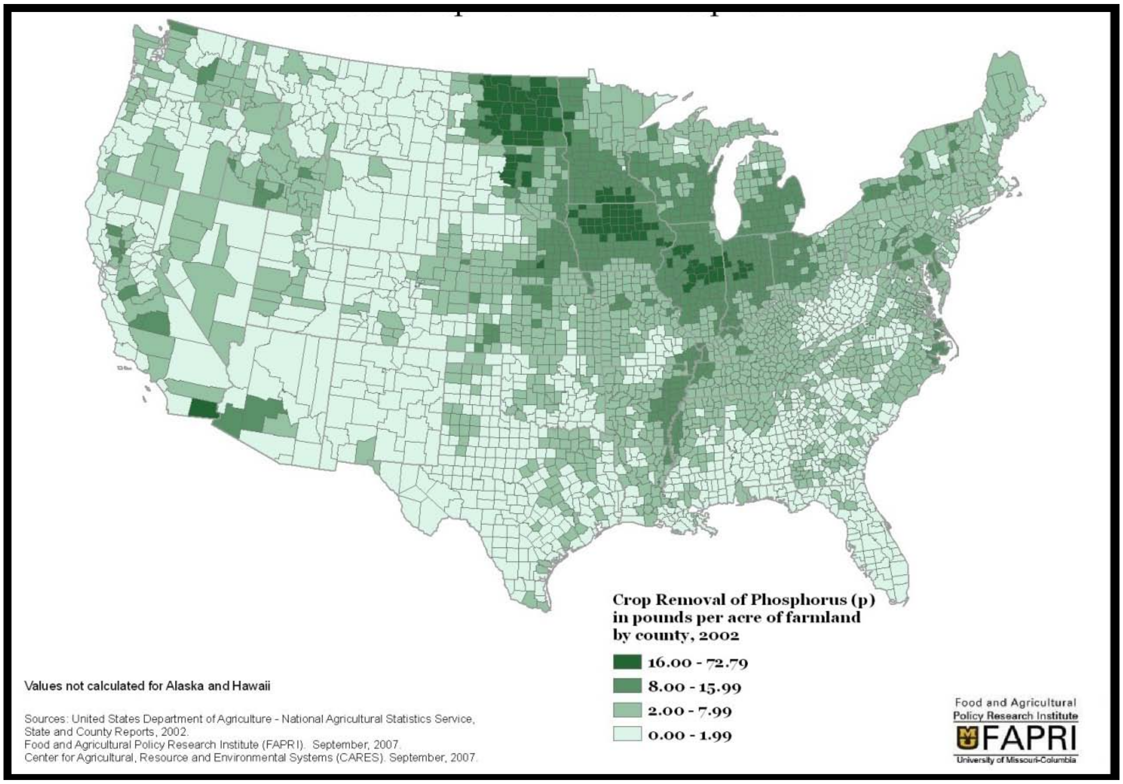

Figure 25. Estimated crop removal of phosphorus in pounds per acre of farmland

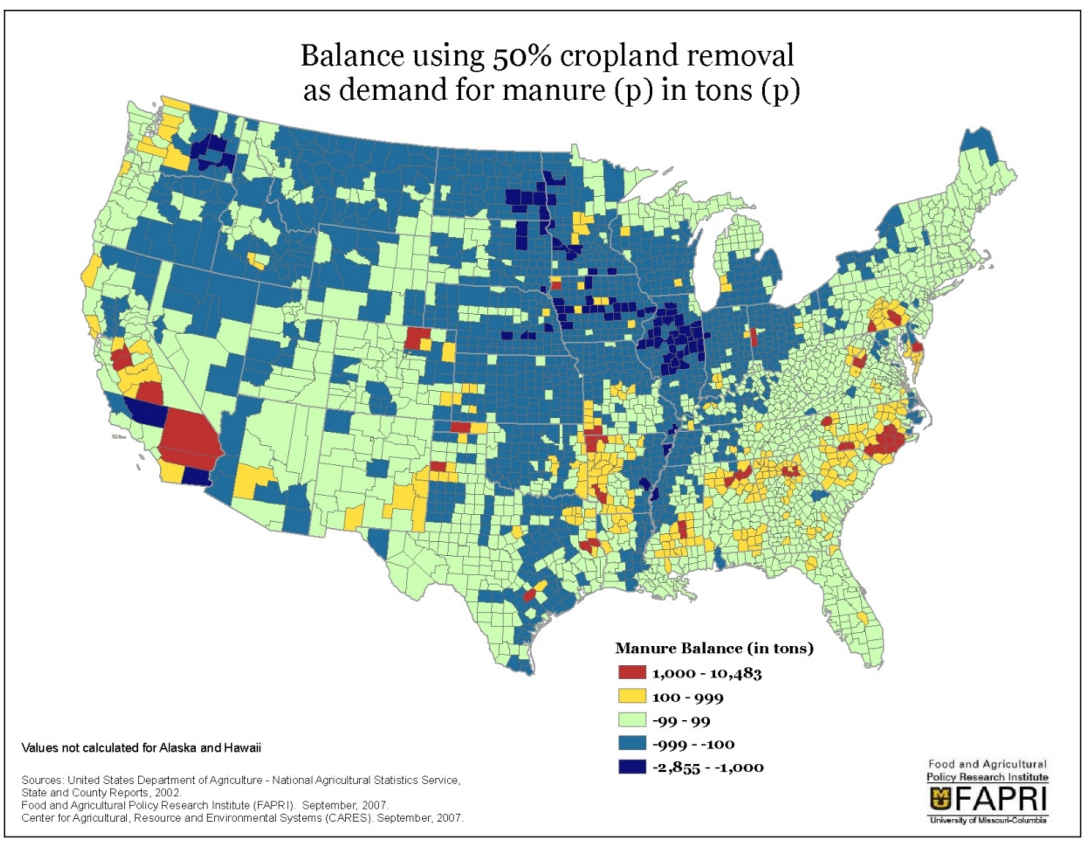

Figure 26. Estimated poultry litter to be transported by county

Table 21 shows the geographically aggregated supply and demand for manure by animal source and by potential geographic distribution. The tons of manure shipped outside the county of origin represents the excess supply of manure that can not be spread within the county under more restrictive litter/manure management practices. The tons of litter/manure deficit represent the amount of manure that can be shipped and spread within phosphorous concentration restrictions. The manure that is spread within the county of origin is the difference between the total manure generated and the amount that has to be shipped outside the county of origin. Based on the recyclable litter/manure that is generated an estimate of the transportation cost of hauling manure from its origin to be spread as fertilizer was computed. Table 22 shows estimated hauling costs that would be incurred if the amount of recyclable manure currently generated were spread evenly over a circular area of varying radii from the manure's origin. These hypothetical circular areas represent the dilemma that poultry producer face if the restrictions on litter distribution are imposed.

Table 21. Aggregated supply and demand for manure by animal source and by potential geographic distribution

Region	Total Recyclable Tons Of Manure Generated (20%moisture)				Balance Using 50% Corp Land Removal as Demand for Manure Phosphorous*		
	TOTAL	Cattle & Milk Cows	Pigs & Hogs	Poultry	Within County of Origin	Outside County of Origin	Manure Deficit
White River: Arkansas	748,117	32,746	11,958	703,414	15,165	732,953	3,236
White River: Missouri	349,455	135,785	3,841	209,829	159,552	189,903	42,902
Rest of Arkansas	1,270,441	47,089	100,850	1,122,502	184,744	1,085,697	1,343,607
Rest of Missouri	1,038,935	336,063	379,742	323,130	727,357	311,578	2,303,170
Kansas	1,080,225	943,125	118,565	18,535	1,006,040	74,185	2,568,443
Oklahoma	863,418	276,727	291,940	294,751	287,653	575,765	894,263
Rest of US	45,884,108	25,984,797	8,152,226	11,747,085	30,200,835	15,683,273	41,298,833
Total US	51,234,700	27,756,332	9,059,122	14,419,246	32,581,345	18,653,355	48,454,455

Table 22. Transportation costs of recyclable manure for varying spreading radii

Region	Total Recyclable Tons Of Manure Generated (20%moisture)			Poultry Litter Hauling Costs at Spreading Radius (miles) in Thousands of 2007 Dollars at $0.15 per Ton-Mile					
	Cattle & Milk Cows	Pigs & Hogs	Poultry	5	10	50	100	150	200
White River: Arkansas	32,746	11,958	703,414	$352	$703	$3,517	$7,034	$10,551	$14,068
White River: Missouri	135,785	3,841	209,829	$105	$210	$1,049	$2,098	$3,147	$4,197
Rest of Arkansas	47,089	100,850	1,122,502	$561	$1,123	$5,613	$11,225	$16,838	$22,450
Rest of Missouri	336,063	379,742	323,130	$162	$323	$1,616	$3,231	$4,847	$6,463
Kansas	943,125	118,565	18,535	$9	$19	$93	$185	$278	$371
Oklahoma	276,727	291,940	294,751	$147	$295	$1,474	$2,948	$4,421	$5,895
Rest of US	25,984,797	8,152,226	11,747,085	$5,874	$11,747	$58,735	$117,471	$176,206	$234,942
Total US	27,756,332	9,059,122	14,419,246	$7,210	$14,419	$72,096	$144,192	$216,289	$288,385

For example, under current litter management practices, and assuming that these practices allow litter to be spread within five miles of the point of production then and that hauling charges for litter are $0.15 per ton-mile, it is estimated that distributing the 703,414 tons of poultry litter generated within the White River Arkansas area will cost $352,000. If the distance that the litter has to be spread increases to 10 miles the hauling costs will increase to $703,000.

The point here is that requiring poultry producers to more widely distribute their litter will mean higher transportation cost to haul the litter and, as a result, higher production costs. A further complication, that will likely increase hauling costs for litter even more, is that as poultry producers look for other places to distribute their litter other producers are also looking. As a result, poultry producers will have to find areas that currently have a deficit manure balances. Since the costs of loading and spreading manure are pretty much the same everywhere, the poultry producer with the lowest manure hauling costs will get to spread his/her litter (of course, up to allowable concentration levels).

In addition to the increased hauling cost, there will usually be some additional handling cost when manure is transported significantly further than five miles from the poultry farm. Local hauling and spreading is accomplished with the litter spreading trucks that are equipped with tires designed to handle off-road travel on pastures and fields. Hauling litter long distances in spreader trucks would result in excess tire wear and would tie up the spreader trucks and operators for many hours transporting versus spreading litter. Current practice is to load the litter in an 18-wheel tractor trailer at the poultry farm, transport it either to the farm where it is to be applied or to a central location near the application area where it is dumped, stored, and then reloaded into spreader trucks for application. This adds an additional $3 to $5 per ton to the cost of wider distribution of poultry litter.

The solution to our litter distribution problem is analogous to the classic linear programming transportation problem. Here we are given supplies of manure that are generated by a number of producers (the excess tons of manure) located in counties of the country. Also we have counties that have manure deficits and can accept manure for fertilizer (representing demands at markets for a single commodity, recyclable manure). The question is: how much recyclable manure should be shipped between each county with excess manure and each county that has a deficit manure balance so as to minimize total transportation costs? We want to

[1] Minimize total transport costs:

$$\sum_i \sum_j c_{ij} X_{ij}$$

Subject to constraints

[2] Supply limit at county i:

$$\sum_j X_{ij} \le a_i \text{ for all } i$$

[3] Demand at county j:

$$\sum_i X_{ij} \ge b_j \text{ for all } j$$

X_{ij} is the amount of recyclable manure shipped from county i (supply) to county j (demand), where $X_{ij} \ge 0$, for all i and j,

a_i is the supply of manure of county i (supply),

b_j is the demand for manure at county j (demand), and

c_{ij} is the hauling cost per ton-mile shipment between i and j.

We implemented a linear programming transportation problem, equations [1] to [3], for our analysis of the distribution of recyclable manure between counties with excess manure within the two White River Basin area (Arkansas and Missouri) and counties elsewhere in the nation with deficit manure balances using the GAMS software (Brooke et al., 1998). Our GAMS analysis generated a set of county-to-county manure tonnage distributions. Based on the county geographic centroids, we computed the distances between the counties that generated the manure and the counties that received manure. Multiplying the tons by the miles for each pair of counties provided ton-mile estimates. Then multiplying the ton-miles by a $0.15 per ton-mile hauling cost derived the county-to-county manure transportation cost estimates. Table 23 presents the tons shipped, ton-miles and transportation costs geographically aggregated to our regions. We computed the increased transportation costs by subtracting the "old" transportation costs from the "new" transportation costs (requiring the restrictive litter management practices). We estimate that the restrictive litter management practices will cost poultry producers in the White River Basin area in Arkansas an additional $17.1 million for

Table 23.Tons and ton-miles shipped and their transportation costs between source and demand for recyclable manure

Regions		Tons	Ton-Miles*		Transport Costs ($000) at $0.15 per Ton-Mile		
Origin	Dest	Shipped	New	Old	New TC	Old TC	Increase
1	1	23,016	235,898	15,344	$35.4	$2.3	$33.1
1	3	544,862	95,971,917	1,816,207	$14,395.8	$272.4	$14,123.4
1	4	95,398	12,954,811	317,993	$1,943.2	$47.7	$1,895.5
1	5	24,196	1,476,228	80,655	$221.4	$12.1	$209.3
1	6	83,661	5,642,445	278,870	$846.4	$41.8	$804.5
2	1	5,955	622,158	19,849	$93.3	$3.0	$90.3
2	2	273,493	8,034,860	486,174	$1,205.2	$72.9	$1,132.3
2	3	81,257	17,299,457	270,855	$2,594.9	$40.6	$2,554.3
2	4	8,299	1,202,635	27,664	$180.4	$4.1	$176.2
2	5	140,002	9,407,075	466,674	$1,411.1	$70.0	$1,341.1
Total		1,280,140	152,847,484	3,780,285	$22,927.1	$567.0	$22,360.1

*** New ton-miles are calculated based on tons of recyclable manure shipped and spread evenly within the county of its origin and tons shipped elsewhere. Old ton-miles based on tons of recyclable manure shipped and spread evenly within a 5-mile radius of its source.**

hauling and will cost poultry producers in the White River Basin area of Missouri an additional $5.3 million for hauling.

The increases in litter hauling charges were greater for those poultry producers in the White River Basin area of Arkansas than those located in the Missouri area. The larger increases in hauling costs were due to longer average trip lengths for the Arkansas producer than for the Missouri producers. Average trip lengths can be calculated by dividing the ton-miles by the tonnages (shown in table 23). The average trip length for the White River Arkansas poultry producers under the restrictive litter management practice is expected to be approximately 150 miles while the corresponding average trip length for White River Missouri producers is about 72 miles. The average length trip under the current litter management practice is about three miles.[12]

White River Basin Multiregional Input-Output Model: Model Construction and Multipliers A White River Basin Multiregional Input-Output (WR-MRIO) Model was compiled using IMPLAN's regional interindustry accounts data for 2002 (Olson and Lindall, 2004) i.e., the model has a base year for 2002.[13] The WR-MRIO Model is geographically configured to have six regions (White River: Arkansas, White River: Missouri, Rest of Arkansas, Rest of Missouri, State of Kansas and State of Oklahoma) and 63 producing sectors (table 24). The industrial aggregations shown in table 24 were chosen to preserve many of the "key" sectors that are related to poultry and meat production.

The WR-MRIO Model consists of three basic accounts—use, make (or by-product), and interregional trade accounts. The "use" accounts show the consumption of commodities by industries and by final users within each region. The "make" accounts present the production of commodities by each region's sectors. The interregional "trade" accounts indicate the distribution of commodities between regions from where they are produced to where they are consumed. The use and make accounts for the WR-MRIO Model were compiled by appropriately aggregating the detailed industrial IMPLAN use and make accounts for the six White River Basin regions. The trade accounts were appropriately aggregated county-level IMPLAN commodity trade accounts.[14]

Jackson (2004) describes the procedures used to compile the WR-MRIO multiregional input-output accounts from IMPLAN social accounts matrix databases.[15]

A multiregional input-output (MRIO) analysis explicitly considers the relationships between industrial sectors and among regions of an economy. The analysis examines how these relationships affect the process of changes throughout the entire economic system. Analogous to standard input-output (IO) analysis, MRIO models

[12] We assumed that poultry producers currently distribute their generated litter supply near where it is generated—within 5 miles. The average trip length for a circular area with a radius of 5 miles is about 3 miles.

[13] However, impact results can be inflated to desired price levels. Monetary impacts reported in this paper are valued in 2007 dollars.

[14] The county-level commodity trade accounts were provided by Minnesota IMPLAN staff.

[15] The method requires one to make all appropriate adjustments to each county's social accounts data and then aggregate to the geographical level specified in the MRIO model. Robinson (2007) explains, in detail, how to compile a multiregional input-output or social accounts matrix from the single-region perspective of the IMPLAN accounts system.

Table 24. Upper White River Basin social accounting matrix producing sectors

1	Oilseed & grain farming	33	Other nonelectrical machinery & equipment
2	Other crop farming	34	Computers & equipment
3	Cattle ranching & farming	35	Electrical machinery & equipment
4	Poultry farming & egg production	36	Appliances
5	Hogs & other animal farming	37	Electronic & controlling equipment
6	Logging & forest products	38	Transportation equipment
7	Commercial fishing, hunting & trapping	39	Furniture & fixtures
8	Agirculture & veterinary services	40	Instruments & testing equipment
9	Oil & gas extraction & support services	41	Miscellaneous manufacturing
10	Other mining	42	Transportation
11	Electrical power & utilities	43	Wholesale & retail trade
12	Construction	44	Printing & publishing
13	Animal feed	45	Software development & recording
14	Flour & grain mlling	46	Radio, TV & motion picture recording
15	Animal slaughtering, except poultry	47	Finance & insurance
16	Meat processed from carcasses	48	Real estate
17	Rendering and meat byproduct processing	49	Rental services
18	Poultry processing	50	Accounting, design & legal services
19	Other food products	51	Admin, management & support services
20	Textiles, apparel & leather goods	52	Research, technical & consulting services
21	Sawmills & lumber products	53	Other business support services
22	Pulp & paper products	54	Educational services
23	Petroleum refining & products	55	Health care services
24	Agricultural chemicals	56	Child care & social services
25	Other chemicals & chemical products	57	Recreation & amusement services
26	Plastics & plastic products	58	Hotels & accommodations
27	Tires & rubber products	59	Food & drinking places
28	Clay, ceramic & glass products	60	Equipment maintenance & repair services
29	Cement, stone & other nonmetallic products	61	Personal services
30	Iron, steel & nonferrous metals	62	Civic orgranizations
31	Metal products	63	Other govt enterprises
32	Farm, lawn & garden machinery		

Note: These sectors are aggregations of the 509 IMPLAN industries

start with a balancing equation between inputs and outputs. However, MRIO models take interregional trading patterns into account. Following the development of Miller and Blair (1985), one can write the MRIO balancing equation between inputs and outputs (taking into account interregional trading patterns) as,

[4]

$$X = TA\,X + Y$$

Given r to be the number of regions in the economic system and n to be the number of industrial sectors, X is an $(rn \times 1)$ vector of industrial and regional output levels, T is an $(rn \times rn)$ matrix of multiregional trading patterns, A is an $(rn \times rn)$ matrix of regional technical coefficients, and Y is an $(rn \times 1)$ vector of industrial and regional final demand purchases (Miller and Blair, 1985).[16]

[16] Multiregional transportation (T) and technological coefficients (A) are treated as a single factor (TA) for modeling convenience. They can be considered separately to be able to separate the effects due to

The works of analysts such as Isard (1951), Moses (1955), Leontief and Strout (1963), Polenske (1970) and others have been important in the historical development of MRIO theory and models. The conventional MRIO model assumes:

1. each industry in each region produces a single output
2. the regional input-output coefficients are fixed regardless of changes in output prices, input costs, tax structures, or shipping costs;
3. neither input cost nor output price will affect an industry's decision on output and input mixes or employment, income, and trade structures; and
4. trade coefficients remain fixed regardless of changes in shipping costs or in purchase prices of inputs in the regions.

The standard solution to the multiregional input-output model is derived by solving for output (X) in equation [4] in terms of final demand (Y) and assuming that the multiregional trading patterns and interindustry technical coefficients are constant.

[5]

$$X = (I - TA)^{-1} Y$$

or

$$\Delta X = (I - TA)^{-1} \Delta Y$$

The $(I - A)^{-1}$ matrix (called the Leontief inverse matrix) provides the direct, indirect, and induced (if the households are endogenized) requirements that will occur if each of the industries experience a one dollar change in final demand.

Column multipliers for each industrial sectors are calculated by summing the elements of each of the columns of the $(I - TA)^{-1}$ matrix. However, multiregional input-output models have added features not available to their single-region counterparts. We derive interregional impacts or even interregional column multipliers from the MRIO models. Figure 3 illustrates the types of column multipliers that MRIO model can provided.

Impacted Region	Regional Impact Source: Region A	Regional Impact Source: Region B	Regional Impact Source: Region C
Region A	Region A Impact on Region A	Region B Impact on Region A	Region C Impact on Region A
Region B	Region A Impact on Region B	Region B Impact on Region B	Region C Impact on Region B
Region C	Region A Impact on Region C	Region B Impact on Region C	Region C Impact on Region C
Total	Σ	Σ	Σ

Figure 27. Multiregional input-output multipliers

By partitioning the multiregional Leontief inverse matrix according to its regional configuration (the hypothetical model in figure 3 has three regions)—six in the case of the WR-MRIO model. All we have to do is sum the columns of each partition sub-matrix. The interpretation is as follows the sub-matrix partition formed by the intersection of Regions A and B provide the interregional column multipliers that represent Region A's impact on Region B. This was done with the WR-MRIO Model for each of the six regions and the resulting interregional column output multipliers are given in appendix C tables C-1 through C-6. Taking the White River Basin area in Missouri (appendix table C-2) as an example, we can see that a dollar change in demand for poultry and eggs (sector 4) will have a 1.4 cent impact on the White River: Arkansas region, a $1.57 impact on the White River: Missouri region, a 3.6 cent impact in the Rest of Arkansas, a 21 cent impact in the Rest of Missouri, a 5.9 cent impact on the State of Kansas, and a 3.8 cent impact of the State of Oklahoma. In total, the one dollar change in demand for poultry and eggs will have a $1.93

changes in trading patterns from those related to changes in the technical production relationships.

impact in the four-state area of Arkansas, Missouri, Kansas, and Oklahoma.

A More General Multiregional Input-Output Model Solution Nothing in the standard multiregional input-output model, or its solution, accounts for the economic impacts that changes in system efficiencies would generate. System efficiencies can arise from a number of sources, for example, environmental regulation changes that require poultry litter used for crop fertilization to be spread further away from its source in order to reduce phosphorous concentrations in the soil. Hauling the poultry litter further from the poultry farms raises its transportation costs (discussed above), thus raising production costs for poultry producers and making their poultry less economically attractive. The increases in transportation costs incident to the new environmental requirements may create a kind of "substitution effect" that can be detrimental to poultry producers (especially if existing poultry producers have "narrow" profit margins). This substitution effect plays a crucial role in determining the regional technical and trade relationships, industrial output, income and employment levels, and even market shares. Unfortunately, standard input-output methodology fails to capture or account for these kinds of substitution effects.

To render the input-output model more flexible, many analysts have investigated the possibility of varying the regional technical coefficients and trading patterns. Rose (1984) reviewed twelve methods of accounting for technological change in an input-output framework.[17] These procedures include such ad hoc changes in technical coefficients, mechanical devices like the RAS procedure, and explicitly modeling production functions. Following the work of Sandberg (1973), Hudson and Jorgenson (1974) and their KLEM model, Liew and Liew (1985), Liew (2000), Liew and Robinson (2001), and West and Jackson (2004) have developed nonlinear, equilibrium input-output approaches that determine both price and quantity for each commodity in all regions.[18] In these models, regional technical and trade coefficients are endogenous on production costs such as transportation fees, wage rates, and the service price for capital. This is accomplished by couching the MRIO system in terms consistent with neoclassical theory of the firm. The nonlinear MRIO model is derived from the duality between production and price frontiers. The price frontiers are solved and expressed in terms of input elasticities, wage rates, the service price of capital, transportation costs, tax rates, technical progress parameters, and quantities of commodities. These equilibrium prices then determine the equilibrium multiregional input-output technical, trade, and primary input coefficients. As a consequence, changes in such costs as transporting commodities induces price changes which, in turn, alters the purchasing patterns of commodities throughout the economic system.

One way to approach the nonlinear MRIO model is to maximize system wide profits subject to a technical production requirement and a consumption balancing constraint. A nonlinear input-output model solution has at least three analytical advantages. First, it permits an analysis that focuses just on those impacts related to changes in transportation costs associated with the environmental regulations regarding the distribution of poultry litter.[19] Second, this solution relaxes

[17] See the discussions by Arrow (1951), Koopmans (1951), and Samuelson (1951) on the reasons for the possibility of technical substitution in Leontief models.

[18] West and Jackson (2004) suggest that these types of nonlinear input-output models are preferable to the more complex and time consuming process of constructing models such as computable general equilibrium (CGE) models.

[19] Note that similar equations can be developed for changes in labor and capital costs.

the "fixity" of the multiregional technical coefficients. Third, even though the steps of the analytical procedure for calculating the impacts of this model proceed in a particular order, they were developed via a solution to a system of simultaneous equations.

Regional Economic Impacts of Poultry Litter Distribution Management Practice Restrictions

We estimated above in table 23 that the restrictive litter management practices will cost poultry producers in the White River Basin area in Arkansas an additional $17.1 million and will cost poultry producers in the White River Basin area of Missouri an additional $5.3 million. These litter transportation costs are also increases in production costs for the poultry producers. Using the nonlinear input-output model shown above, we were able to compute the regional economic impacts of the increased hauling costs due to the litter management practices. First we computed the relative price effects of the increased litter management restrictions using the transportation cost increases. Second, we used the relative price changes and the increased hauling costs to derive changes in the WR-MRIO Model's interregional technical coefficients. Third, we calculated the regional industrial output (i.e., business sales) changes via the general multiregional input solution, equation [6], using the changes in the interregional technical coefficients. Fourth, the regional industrial output changes were converted into employment (full and part-time jobs), employment compensation (wages and salaries), proprietors' income (of small business owners), other property-type income (rents, dividends, interest and other unearned income), and indirect business taxes (sales and commercial property taxes, licenses, fees, etc.) using appropriate ratios for every industry in each region. Finally, the monetary values were inflated using 2007/2002 industry-specific price deflators.

Table 25 presents the final demand changes and output impacts (summarized by region) that are expected to result from the increased litter hauling costs. The substitution and final demand output impacts (noted in equation [6] above) are shown in addition to total output impacts. It is interesting to note that a majority of the final demand output impacts occur outside the White River Basin areas of Arkansas and Missouri while a majority of the substitution output impacts occur within the White River Basin. The final demand output impact is larger in every region than the substitution output impact, except for the White River Arkansas region.

Table 25. Final demand changes and output impacts by region due increased litter hauling costs

			Output Impacts		
	Region	Final Demand Change	Substitution Effect	Final Demand Effect	Total
1	White River: Akansas	-$2,463	-$14,009	-$5,320	-$19,330
2	White River: Missouri	-$5,421	-$4,207	-$10,566	-$14,774
3	Rest of Arkansas	-$3,152	$1,248	-$7,052	-$5,804
4	Rest of Missouri	-$10,449	-$7,331	-$24,113	-$31,443
5	Kansas	-$2,436	-$668	-$6,231	-$6,900
6	Oklahoma	-$4,524	-$915	-$10,640	-$11,555
	Four State Total	-$28,445	-$25,883	-$63,923	-$89,805

* All monetary values in thousands of 2007 dollars and employment is in full and part-time jobs

Table 26 summarizes the economic impacts by region. In total, the proposed litter management restrictions are expected to cause a drop in output of almost $90 million, a loss of about 700 full and part-time jobs, and a reduction in $23.2 million in worker income and $3.2 million in proprietors' income (other losses include $14.7 million in rents, dividends and interest and $4 million in indirect business taxes). A majority of these impacts are expected to occur outside the White River Basin areas in Arkansas and Missouri. In fact, two-thirds of the output and proprietors' income impacts, 70 percent of the employment impacts, and 75 percent of employee compensation impacts are expected to be experienced outside the White River Basin. Geographically, the Rest of Missouri region will be hit the hardest (accounting for more than one-third of the output and job losses and nearly 45 percent of the worker income losses).

Table 26. Economic impacts by region

	Region	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
1	White River: Akansas	-$19,330	-111	-$3,173	-$775	-$3,234	-$460
2	White River: Missouri	-$14,774	-108	-$2,883	-$324	-$2,110	-$410
3	Rest of Arkansas	-$5,804	-54	-$1,641	-$203	-$791	-$272
4	Rest of Missouri	-$31,443	-263	-$10,268	-$1,071	-$5,510	-$1,829
5	Kansas	-$6,900	-62	-$2,003	-$272	-$1,186	-$404
6	Oklahoma	-$11,555	-110	-$3,213	-$599	-$1,905	-$632
	Four State Total	-$89,805	-708	-$23,180	-$3,244	-$14,736	-$4,006

* All monetary values in thousands of 2007 dollars and employment is in full and part-time jobs

Table 27 summarizes the economic impacts by industry. The sectors most heavily impacted by the litter management restrictions are poultry and eggs; wholesale and retail; finance, insurance and real estate; transportation; business services; personal services; and poultry processing.

Table 27. Economic impacts by industry.

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$330.4	-8	-$8.4	-$20.1	-$109.1	-$9.5
Cattle ranching & farming	-$140.4	-2	-$6.3	-$6.8	-$4.4	-$4.4
Poultry & eggs	-$13,384.4	-51	-$881.2	-$596.2	-$3,244.8	-$68.3
Hogs & other animals	-$10.1	-1	-$1.0	$0.0	-$0.6	-$0.2
Other agriculture	-$345.3	-7	-$108.0	-$51.5	-$8.3	-$7.7
Mining	-$133.6	-1	-$21.1	-$16.0	-$31.3	-$9.8
Utilities	-$1,529.4	-3	-$241.6	-$37.2	-$534.7	-$138.9
Construction	-$859.6	-8	-$251.6	-$65.7	-$27.7	-$4.0
Animal feed	-$4,451.6	-7	-$413.7	-$10.2	-$226.9	-$37.7
Meat processing	-$291.6	-1	-$37.5	-$0.9	-$8.1	-$2.6
Poultry processing	-$8,829.8	-54	-$1,608.8	-$68.4	-$2.5	-$75.9
Other Manufacturing	-$414.8	-1	-$30.1	-$0.8	-$17.3	-$3.4
Transportation	-$10,555.9	-69	-$3,135.6	-$356.7	-$1,004.8	-$255.6
Wholesale & retail trade	-$14,432.6	-190	-$5,596.8	-$602.2	-$2,229.2	-$2,245.5
Communications	-$3,599.6	-18	-$975.4	-$250.7	-$713.4	-$164.4
Finance, Insurance & Real Estate	-$12,660.3	-67	-$2,338.0	-$383.4	-$4,413.2	-$735.8
Business services	-$8,668.6	-84	-$3,790.6	-$385.2	-$1,523.6	-$117.3
Personal & other services	-$9,167.5	-137	-$3,734.3	-$391.9	-$635.9	-$125.2
Total	-$89,805.4	-708	-$23,180.0	-$3,243.9	-$14,735.8	-$4,006.2

Appendix C tables C-7 through C-12 show the industrial impacts for the six regions in our analysis. Here we focus on the industrial impacts for the White River Arkansas and White River Missouri regions. Although a first glance at the two tables will indicate a similar distribution of impacts in the two areas there are several notable points. First, the absolute magnitudes of the impacts in these two regions are quite similar, even though the increases in litter hauling charges to poultry producers in the White River Arkansas area are three times higher than in the White River Missouri region. This indicates that the economic impacts of the litter management restrictions are relative more onerous in the White River Missouri region than in the White River Arkansas area. Second, the largest two impacts in the White River Arkansas region (in terms of industrial output) occurs in poultry and eggs sector (the sector directly impacted by the litter management restrictions) and the animal feed sector (a "backward" sector) while the two largest impacts in the White River Missouri region is in the poultry processing sector (a "forward" linkage sector) and the poultry and eggs sector (the directly impacted sector). The economic impacts in the other four regions tended occur in the service sectors rather than production sectors of each regional economy (appendix tables C-9 to C-12).

MU Economic Analysis Conclusions and Recommendations

A litter management proposal that required poultry producers to redistribute their poultry litter to reduce soil phosphorous concentrations was evaluated. The regional economic cost of implementing that litter management proposal was estimated to be $17.1 million for poultry producers in the White River Arkansas area and $5.3 million for producers in the White River Missouri area. The increased hauling cost will add to the economic pressures poultry producers are experiencing with rising fuel cost to heat poultry houses and increased feed ingredient costs. The increased hauling costs would be expected to result in a loss of $9.8 million in business sales for the White River Arkansas poultry producers and $3.1 million for the White River Missouri producers. The proposed litter management to require wider litter distribution will result in reductions in sales, employment, and income for poultry producers and for the wider economy of Northwest Arkansas and Southwest Missouri.

Stakeholder Cooperation and Input

Successful implementation of any water quality initiative must include stakeholder acceptance that it will produce results worth the efforts and resources they must supply. This project initiated cooperative efforts with the Arkansas Water Resources Center, University of Arkansas and Upper White River Basin Foundation to minimize duplication of efforts and to capture potential synergies. Coordination began with meetings of the Missouri and Arkansas analysts and the local organizations to develop the proposals. Once the proposals were funded a coordinating committee was established.

Coordinating Committee

The coordinating committee included Missouri members from the Watershed Committee of the Ozarks, the James River Basin Partnership, the Upper White River Basin Foundation, Table Rock Lake Water Quality, Inc, Missouri Fertilizer Control, and South Missouri Water Quality Project. It also included Arkansas members from the Beaver Water District and the Kings river Watershed Group. In addition to the members from existing organizations, it had at least three poultry industry representatives and five commodity organization representatives. The MODNR and the USDA NRCS members assisted the committee.

Analysts from the University of Missouri Extension, FAPRI–MU, CPAC, Department of Fisheries and Wildlife Sciences, Watershed Planning Center, College of Veterinary Medicine, Southwest Research Center, and Department of Soil Science as well as analysts from Missouri State University (MSU) participated in Missouri part of the Upper White River Basin project. Analysts from the University of Arkansas Water Resources Center, Department of Agricultural Economics and Agribusiness, and Department of Biological and Agricultural Engineering conducted the analyses on the Arkansas part of the project.

The government agency staff and the local stakeholder group members of the coordinating committee are presented in appendix A, table A-1. Appendix A, table A-2 lists the analytical staff from MU, University of Arkansas, and Missouri State University that conducted the analyses.

Upper White River Symposium/workshop

The Upper White River Symposium was held April 6-7, 2006 at the Radisson Hotel in Branson, Missouri. The program built on the previous forums hosted by the Upper White River Basin Foundation and used preliminary results from this project. Many of the invitees were attendees of previous forums. The invitees were selected by a process designed to capture different points of view.

This Symposium offered information on topics and issues identified by the Delegates in previous forums using preliminary results from this project and from other completed and ongoing projects. The Symposium focused the development of 2-3 projects that the cooperators could collectively undertake to improve water quality in the Upper White River Basin. All sessions were open to the public; however, only invitees were allowed to participate in the process. Invitees were allowed to seek information from all present. In practice, the only participants excluded were the presenters who provided information when requested.

The symposium was split into three sessions, one the afternoon of April 6 and the other two the morning of April 7. The symposium sessions are summarized below. The first session focused on "Monitoring and Evaluation."

Session 1 was by Dr. Bob Pavlowsky from the Ozarks Environmental and Water Resources Institutes at MSU made the first presentation entitled "Nutrient Trends in the Upper White River Basin." The objectives of his study were to:

- monitor water quality to establish a baseline from which to measure changes in total nitrogen (TN), total phosphorus (TP), and water chemistry based on 19 existing USGS gage sites (Monthly samples were taken from March 2005 to February 2006),
- create an environmental GIS database that cut across state and county lines and meshed with University of Arkansas databases and
- analyze water quality trends.

The second presentation by Dr. Ralph Davis of the Arkansas Water Resources center at the University of Arkansas was entitled "Kings River & Beaver Lake Watershed." Dr. Davis described the data collection and processing projects conducted in the Beaver Reservoir part of the Upper White River Basin.

The third presentation by Dr. Dan Obrecht from MU summarized the results of Table Rock Lake monitoring entitled "Upper White River Monitoring by the MU Limnology Lab." Their monitoring began in 1992 and continues today. Their monitoring includes TN, TP, Algal Chlorophyll, Secchi disc transparency, suspended solids, turbidity, conductivity, alkalinity and other water chemistry. He presented data on spatial variability of phosphorus in Table Rock Lake in 2005 (figure 28) and the changes in the phosphorus concentration in the Upper White River as it flows into and out of Table Rock Lake (figure 29).

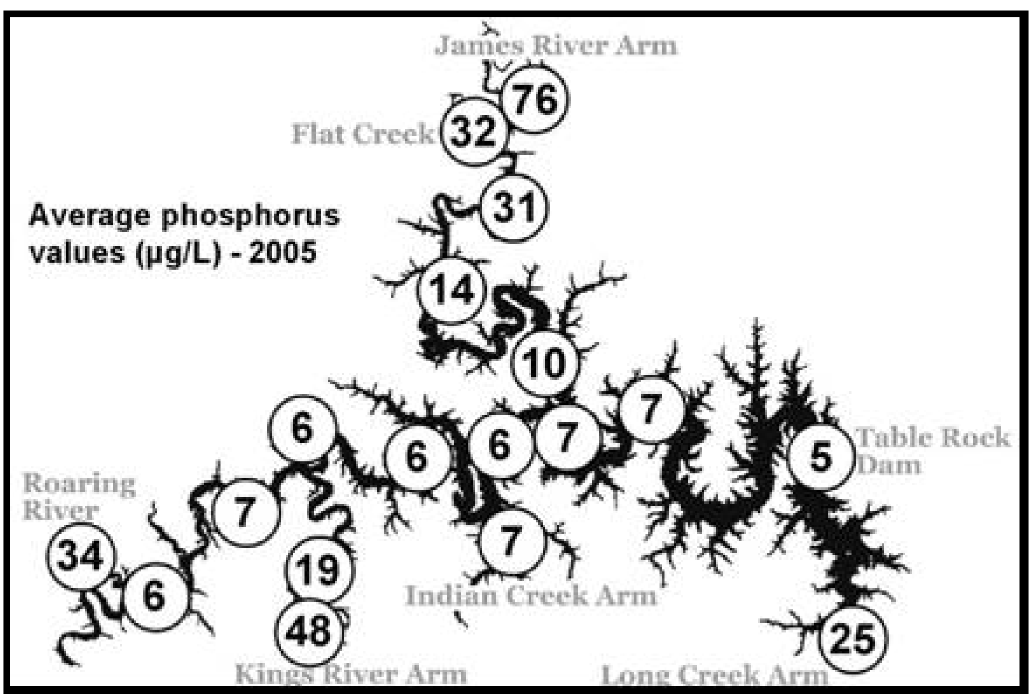

Figure 28. Spatial Variability of Phosphorus in Table Rock Lake, 2005

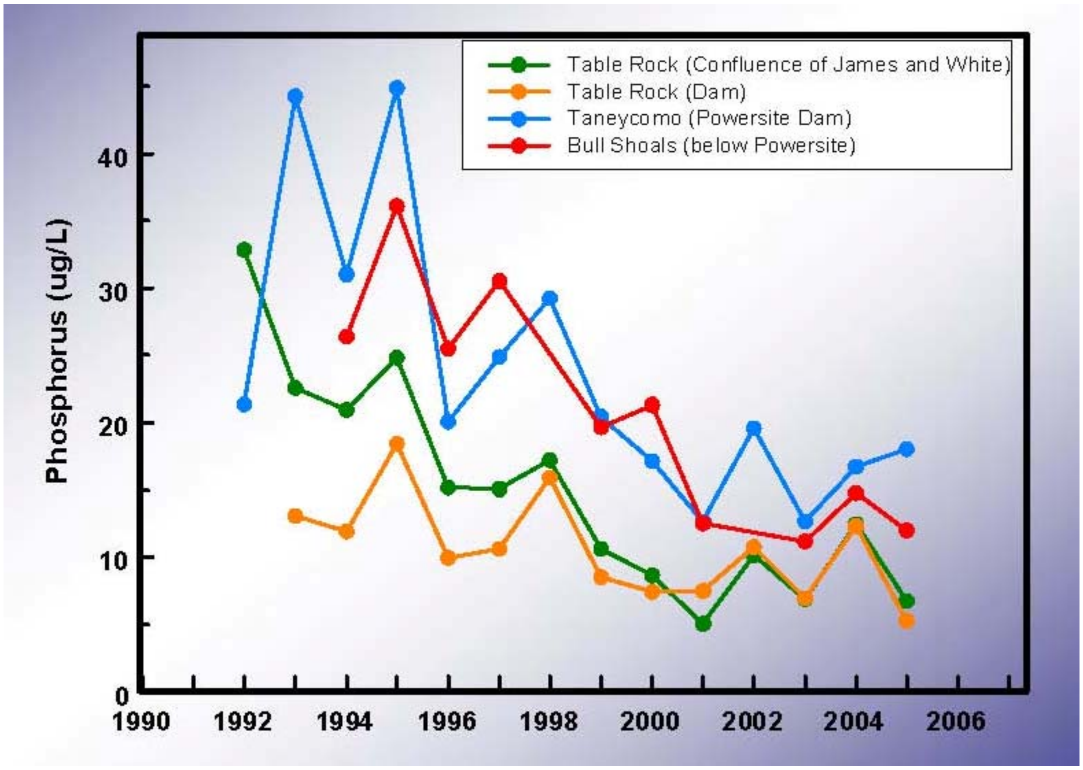

Figure 29. Changes in Upper White River Phosphorus Concentration as it flows into and out of Table Rock Lake, 1992-2006

The fourth presentation of the Monitoring and Evaluation session focused modeling as a tool to evaluate alternative measures that might improve Upper White River Basin water quality. Dr. Indrajeet Chaubey from the University of Arkansas Department of Biological and Agricultural Engineering presentation was entitled "Modeling Approaches to Evaluate Watershed and Water Quality Processes." Dr. Chaubey gave examples of the SWAT model's potential use in the Beaver Reservoir watershed. He identified five reasons models are needed to address water quality issues. They are:

1. to predict future events,
2. to predict watershed response at points where measured data are not available,
3. to predict response from a number of watershed management scenarios for which data collection will be extremely expensive or time consuming,
4. to determine the likelihood of water quality improvement before expensive best management practices (BMPs) are installed, and
5. because Total Maximum Daily Load (TMDL) thresholds are based on mathematical/computer modeling.

Following each session, the participants were assigned to one of three discussion groups. Each group contained a mixture of stakeholders expected to represent many points of view. Each group had one or more trained facilitators. The members were then charged with identifying future efforts needed to maintain and enhance Upper White River monitoring and evaluation. Each group identified a number of potential efforts and then narrowed the list to 2 to 6. At that point they were asked to examine each of the selected ideas with a facilitated instrument designed to address the potential feasibility of the idea, identify who would carry out the effort and who would pay for it, and its likely effectiveness to improve water quality. There were 12 worksheets that were partially completed for the Monitoring and Evaluation session. The worksheets are summarized below.

A. Data process – maintain exiting collection sites, standardize across watersheds, common definitions, public accessible data that can be integrated
B. Develop site specific water quality monitoring of BMPs for agricultural improvements and construction sites
C. Identify locations and install continuous quantity and water quality gages
D. Identify hot spots: Prioritize sub-watersheds using existing data, physiographic characteristics, population trends, agricultural trends, identify hot spots within these sub-watersheds --Provide solutions
E. Better cause and effect of land use & water quality and how that effects economics/environment/economies
F. Water quantity and quality issues
G. Identify indicators to determine water quality thus making water quality issues more understandable to the public and local governments
H. Long term monitoring plan: develop protocol; analyze historical data to establish baseline; and implement long-term monitoring stations
I. Develop consistent methods and analysis of the data to obtain meaningful results.
J. Modeling for predicting data at un-monitored points.
K. Identify a goal for water quality: anti-degradation or improvement
L. Understand the role of sedimentation and remobilization in P cycling in river-lake transition zones. What is the P cycle over an entire year (cold and hot seasons) over time? How do lake bed sediment concentrations act over time with re-suspension of sediment and Phosphorus? What is the relationship between how much P the lakes can handle compared to the age of the lakes. River algae growth and indicator of nutrient enrichment.

Figures 30-35 are examples of completed worksheets from the groups. The first five are nearly complete. Note worksheet 4 just has Xs instead of numbers for who pays by percent. If all Xs are assumed equal, the XX is equivalent to 40 % and X is equivalent to 20%. The most important function of the worksheets is to help the group understand the impacts and costs of the projects/efforts suggested. Note figure 35 presents a great idea, but it is too broad to address. The other six projects were also less well defined and the worksheets were only partially filled out due to the difficult of completing them and time available.

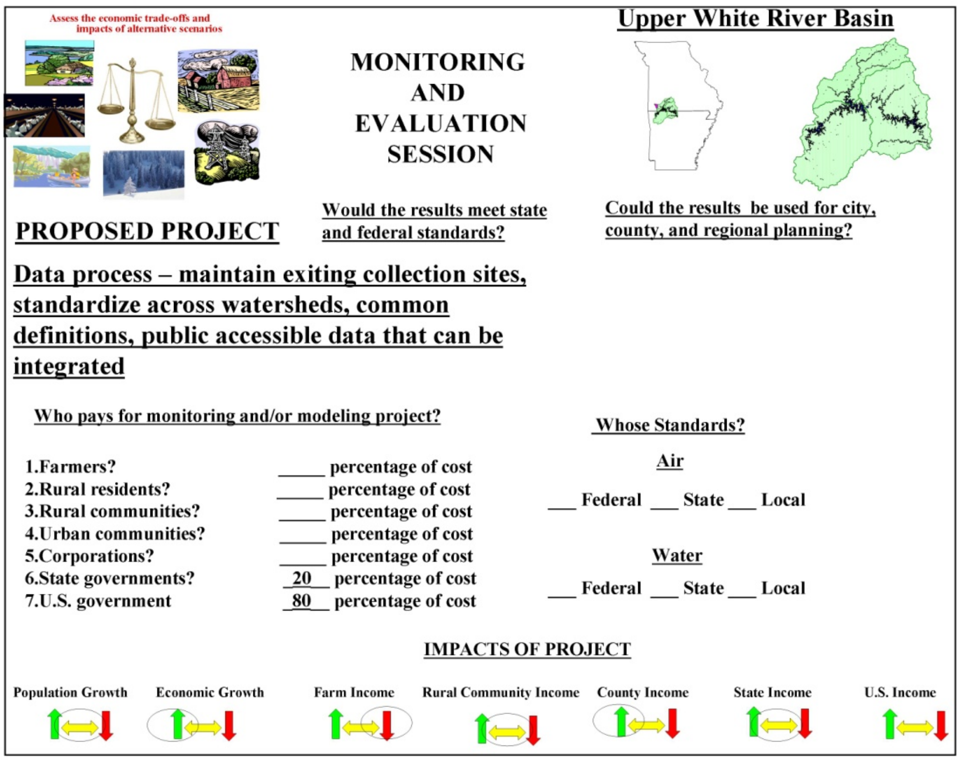

Figure 30. Data process – maintain exiting collection sites, standardize across watersheds, common definitions, public accessible data that can be integrated

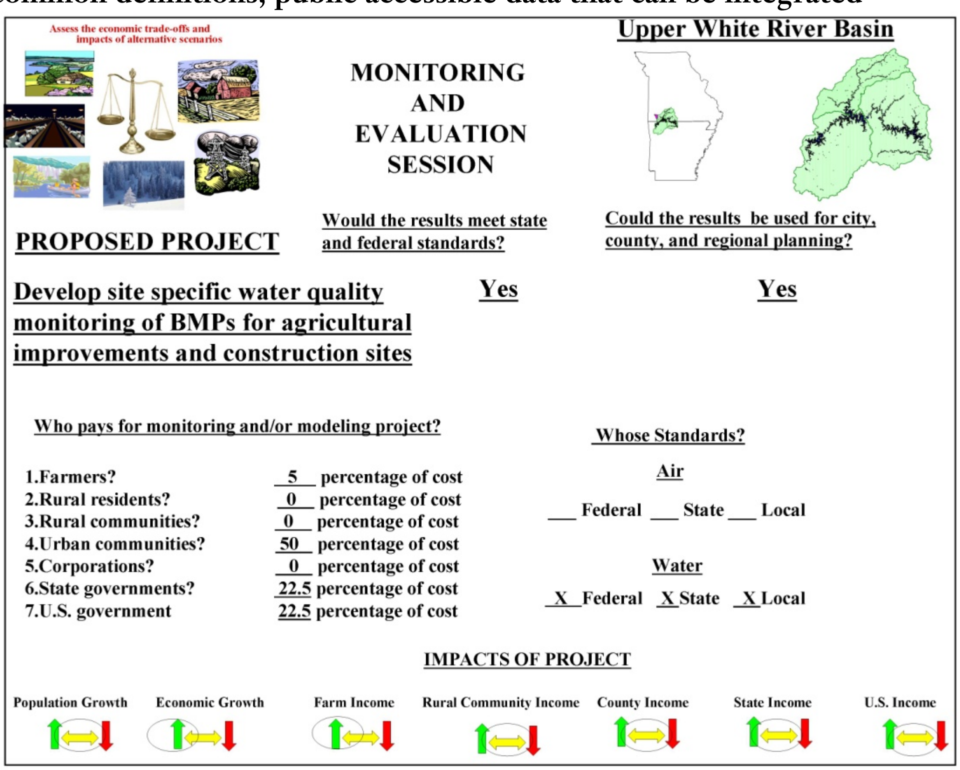

Figure 31. Develop site specific water quality monitoring of BMPs for agricultural improvements and construction sites

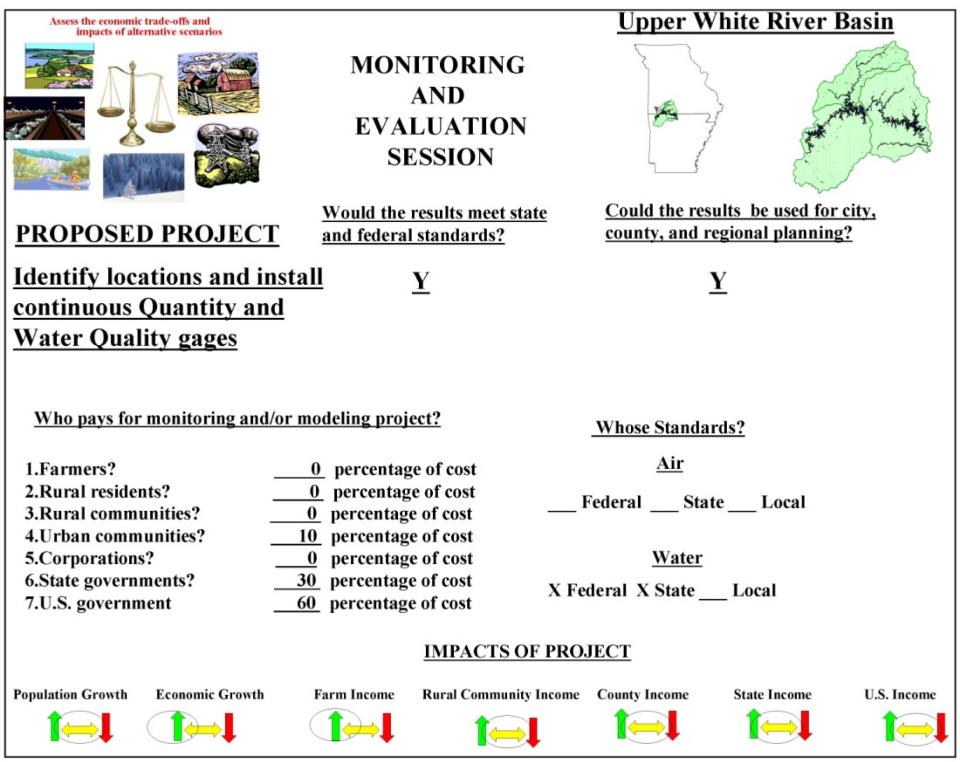

Figure 32. Identify locations and install continuous quantity and water quality gages

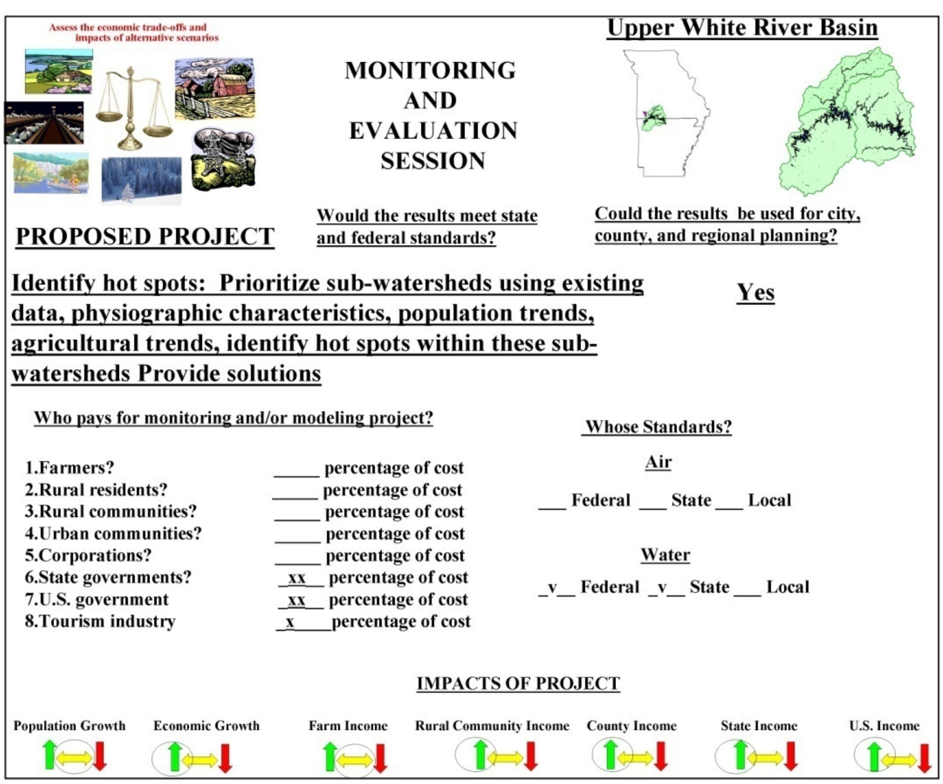

Figure 33. Identify hot spots

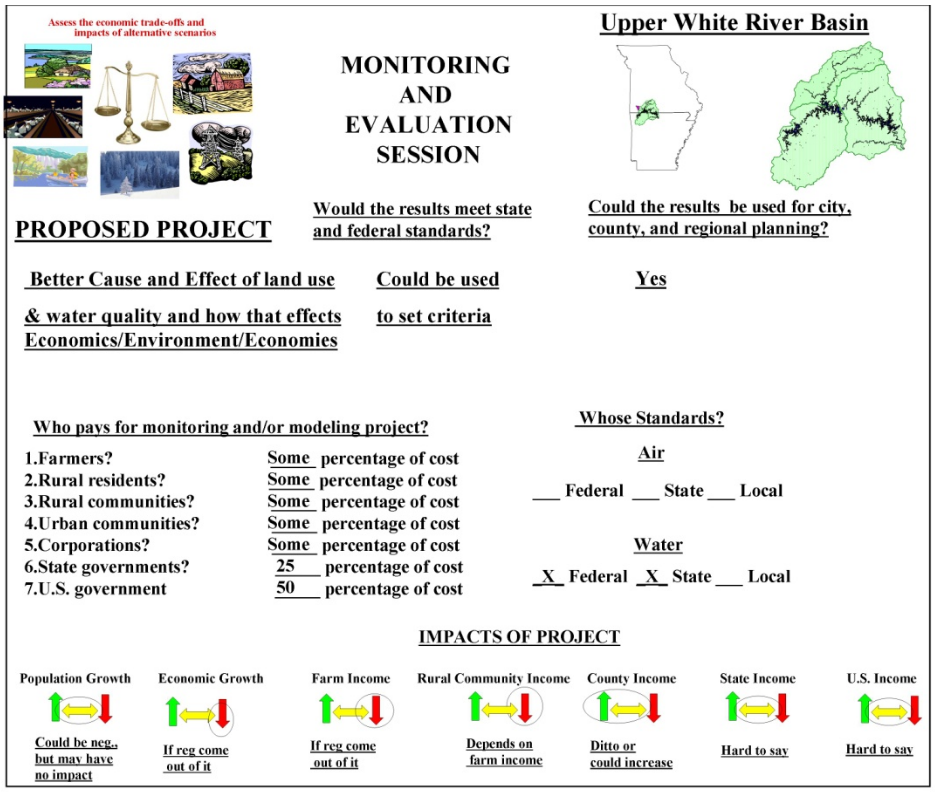

Figure 34. Better Cause and Effect of land use & water quality and how that effects Economics/Environment/Economies

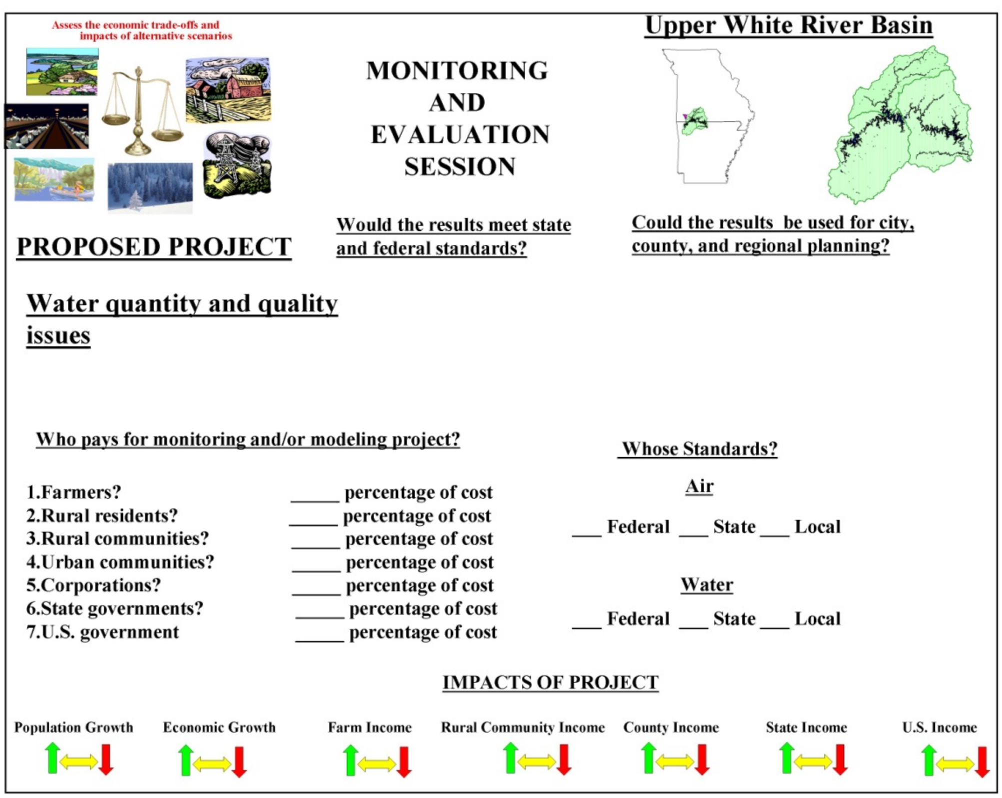

Figure 35. Water quantity and quality issues

Session 2 The second session focused on "Waste and Health Issues." The first speaker was Dr. Claire Baffaut from FAPRI–MU with "Bacterial loads from cattle grazing versus human population." The human population density was based on the 2000 Population Census is shown in figure 36.

The estimated daily loading of bacteria in the Upper White River Basin from failing septic systems and from cattle manure are shown in figures 37 and 38, respectively.

The second speaker was Mr. Jay Hua from the EPA Region 7 office. He addressed the potential "Health Impact of Bacteria Loads." Common health effects include upset stomach, diarrhea, ear infections, and rashes. The bacteria are commonly excreted directly into water or washed into the water with fecal material. During whole body contact recreation they may be accidentally ingested with water.

Most bacteria are not a threat to human health. Indicator organisms are used as surrogates for actual pathogens of concern because the technology and expertise required to test for pathogens is limited and it is very expensive to identify only the bacteria that are pathogens. The presence of more plentiful organisms such as *E. coli*, fecal coliform, and enterococci are used to estimate the likelihood of accidentally ingesting pathogens.

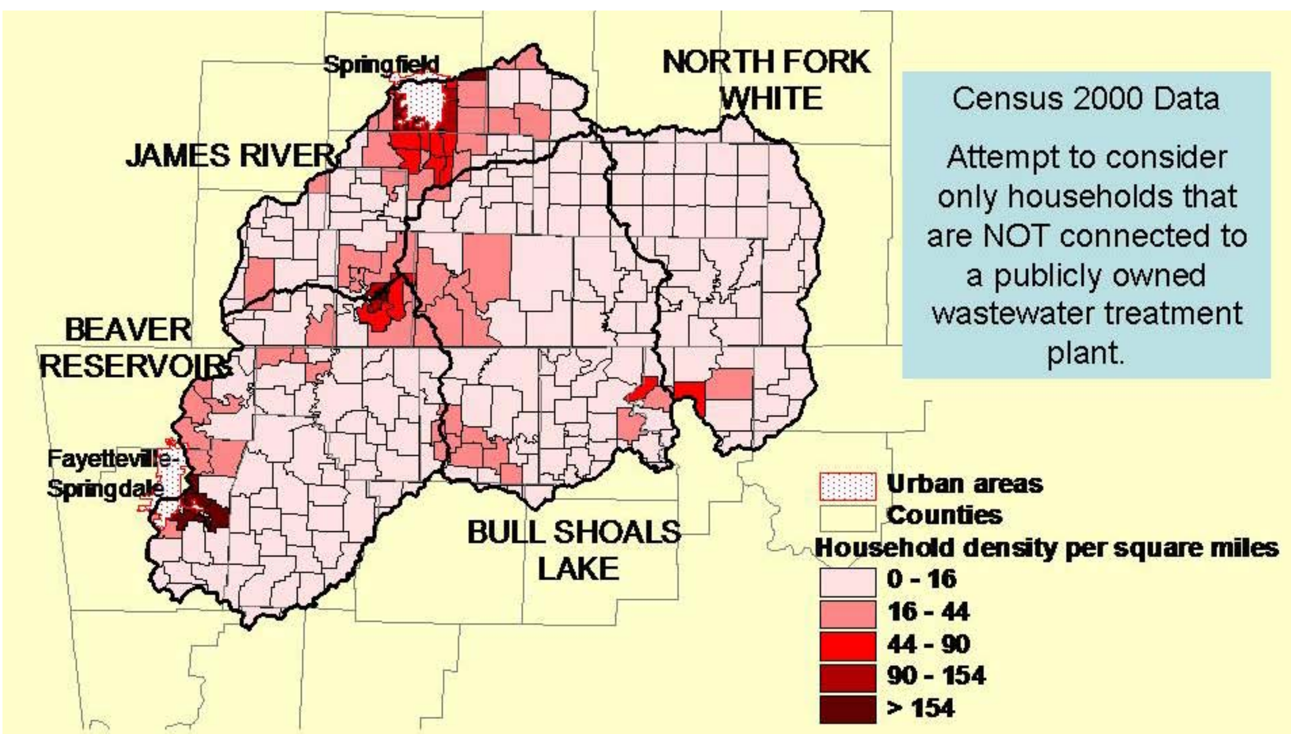

Figure 36. Population densities in the Upper White River Basin, 2000

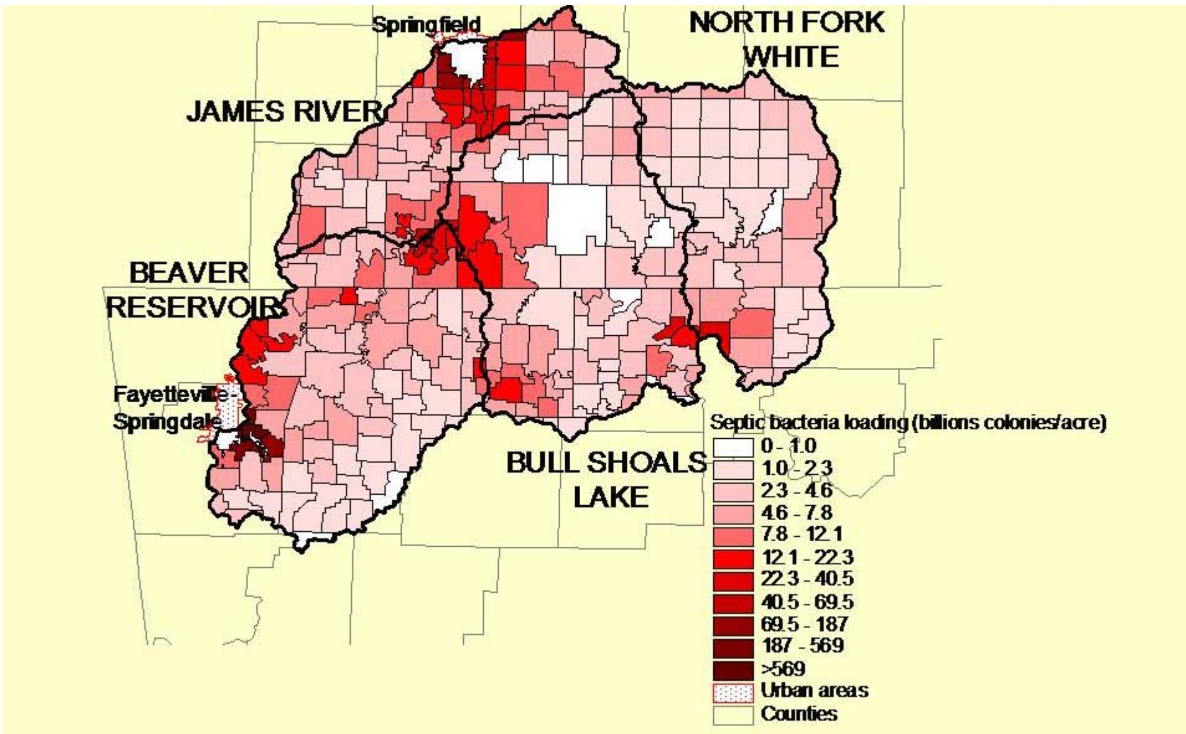

Figure 37. Estimated daily bacteria loading from failing septic systems in the Upper White River Basin

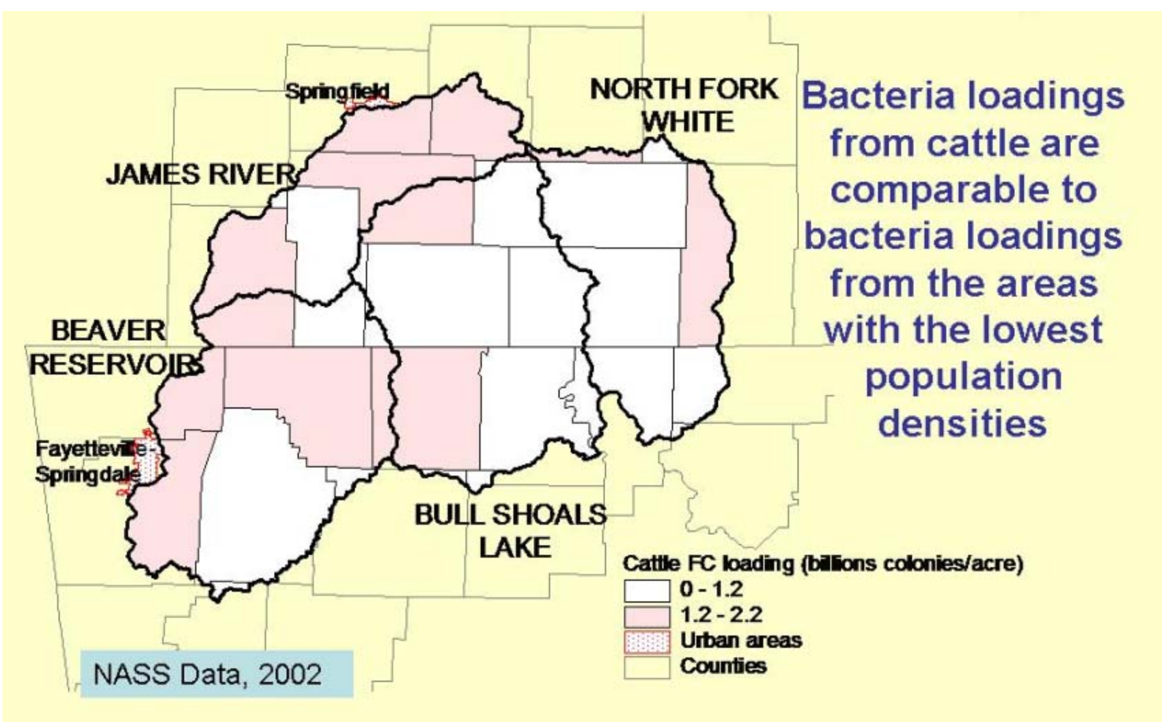

Figure 38. Estimated daily bacteria loading from grazing cattle manure in the Upper White River Basin

Research may lead to better ways to identify health threats such as identifying the source of the bacteria which would allow a better assessment of risk because some animal sources are less likely to contain pathogens than others. Human sources have been shown to be more likely to be the sources of pathogens that effect human health because few pathogens can be transmitted from animals to humans.

Recreational water quality studies in 1970s established exposure response relationships between enterococci and *E.coli and* gastrointestinal illness. These studies served as basis for current recreational water guidelines recommended by the EPA in freshwaters (*E. coli* or enterococci) and in marine waters (enterococci). The EPA's criteria have two components, single sample maximum and a geometric mean. The single sample maximum criteria allow users to evaluate single samples for beach management monitoring and closure decisions, and to assess the attainment of recreational use designation. Geometric means are used to assess medium and long term health risk and also to assess the attainment of recreational use designation.

Table 28 presents current the EPA *E. coli* criteria recommendations and the associate health risk expressed as illness per thousand people bathing in the water.

The third speaker, David Casaletto, addressed problems around Table Rock Lake arising from increasing population and development in the Table Rock Lake watershed. Most of the watershed has a rural population that uses onsite wastewater treatment systems (OWTS) to treat wastewater. These systems are often not suitable to the thin existing soils in the region.

Table 28. Current U.S. EPA *E. coli* Criteria Recommendations

Illiness rate (number ill per 1000 people)	Multi-sample Geometric mean density	Single sample maximum allowable density designated beach area	moderate use	light use	infrequent use
	(colonies per 100 ml)				
8	126	236	299	409	576
9	**161**	**301**	**382**	**523**	**736**
10	**206**	**385**	**489**	**668**	**940**

(shaded) **Current Missouri standards**

Mr. Casaletto showed pictures to illustrate the kinds of failing and inappropriately constructed systems they found. Figure 39 is a picture of a failing lagoon system and figure 40 is a picture of a failing septic system. Both drain into Table Rock Lake[20].

Figure 39. Failing lagoon system

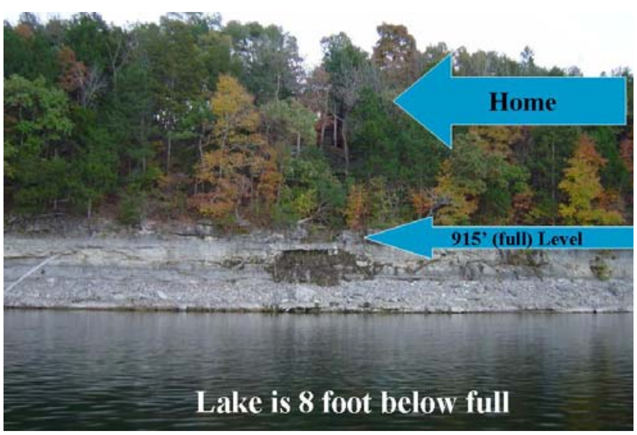

Figure 40. Failing septic system

[20]http://www.trlwq.org/pdfs/DemoProjectExecutiveSummary.pdf

Table Rock Lake Water Quality, Inc. was established by local stakeholders to address these issues. This organization initiated the Table Rock Lake National Demonstration Project to test different types of advanced technology for OWTS. The Demonstration Project also utilized the EPA management models for proper maintenance of OWTS.

The project goals were to:

1. Install and test different types of advanced wastewater treatment technologies to evaluate effectiveness in the unique geological setting around Table Rock Lake. A number of decentralized treatment technologies including advanced OWTS (systems with pre-treatment components before dispersal into soil) were commercially available. The focus of the Demonstration Project was to compare technology and test performance in treating wastewater and phosphorus removal using FAST, RetroFAST, ZABEL or ZABEL SCAT treatment systems in the Table Rock Lake area.
2. Develop a management program following the EPA's recommended management models for OWTS. A responsible maintenance entity (RME) was needed to remove maintenance responsibilities from real estate developers or homeowners.
3. Identify legal impediments to widespread adoption of advanced OWTS by changing the regulatory and wastewater industry's perceptions of these systems and gaining their acceptance in Missouri. In the past advanced OWTS technologies have not been widely accepted as feasible or practical and most contractors in the area were unfamiliar with such systems.

The project outlined six tasks to accomplish. Task 1 was to create a soil map and establish performance criteria. The soil index map for Stone County shows that septic systems have very limited potential for functioning well in most Stone County soils (figure 41).

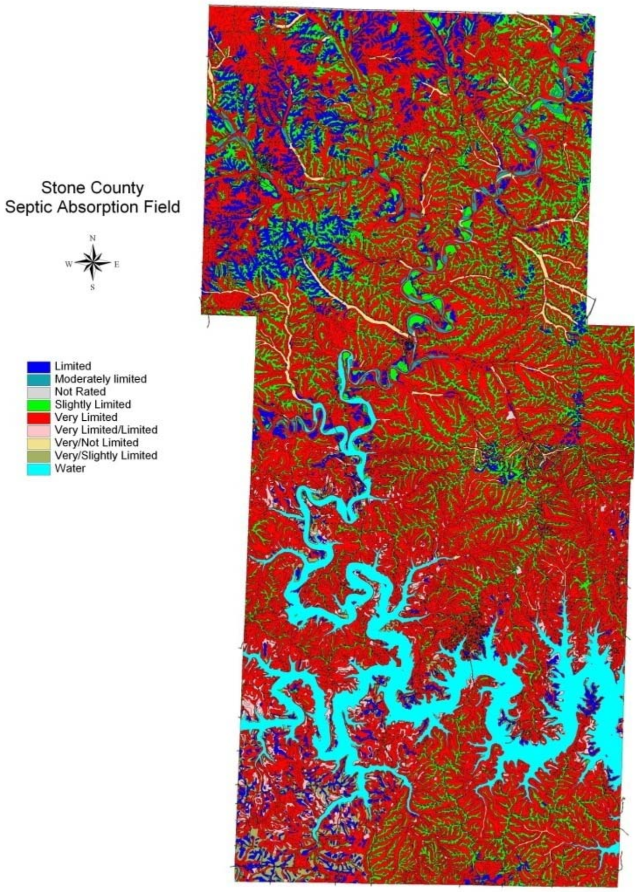

Figure 41. Stone County Soil Index

Task 2 was to review existing ordinances to determine acceptability of alternative systems. Task 3 was to install and maintain advanced onsite wastewater treatment systems to demonstrate feasibility. Tasks 4, 5 and 6 were to collect and analyze field data, conduct laboratory testing, and share the information with local stakeholders.
Twenty-five sites were installed or remediated through this demonstration project. Criteria were established for acceptance into the project and different types of advanced OWTS were installed that would effectively pre-treat wastewater before dispersal into a surface stream or soil. Monitoring systems were installed on four sites to measure treatment success. Samples were taken from septic tank effluent (raw sewage), treatment effluent (pre-treated, filtered liquids) and sub-surface liquids (after passing by drip irrigation through the soil). Analysis of samples produced evidence of successful treatment.

The major results from their Demonstration Project were:
1) acceptance by State/County regulatory agencies and installers
2) installation and remediation of over 25 OWTS in the Table Rock Lake region and influencing numerous installers and homeowners to seek advanced OWTS options
3) formation of Ozarks Clean Water Company (OCWC) as a RME to remove maintenance responsibilities from developers and homeowners in cluster systems (subdivisions & apartment complexes that use a central OWTS)
4) changes in the wastewater ordinance by local regulatory agency, the Stone County Health Department, to require renewable operating permits for advanced OWTS (U.S. EPA management level 3), and
5) demonstration that phosphorus removal can be effectively achieved through OWTS and drip irrigation in imported soil around Table Rock Lake.

Figures 42-46 are pictures of the installation of a new drip system that uses effluent to irrigate the owner’s lawn. The figures show the replacement tank, the filtration system, the effluent line to the field, the drip lines, and absorption/evaporation field.

Figure 42. OWTS Tank


Figure 43. OWTS Filter


Figure 44. Drain Line to Drip Irrigated Field


Figure 45. Drip Irrigation Installation


Figure 46. Absorption/Evaporation Field

Data from this project will provide scientific evidence for the acceptance of advanced OWTS as standard systems. Project partners and participants gained applied knowledge of advanced OWTS and alternative treatment technology. Education and outreach through numerous local, statewide and national meetings focused attention on the potential water quality implications of failing wastewater systems and successful remediation systems in the Table Rock Lake Watershed. The Demonstration Project includes changed OWTS installation practices in southwest Missouri. It led to the formation of OCWC which will continue to grow and provide service to benefit residents of Missouri particularly residents of the Table Rock Lake watershed. This project helped change public perception of the role of OWTS in rural communities and may serve as a national model for other lake communities.

The session again split into three groups with trained facilitators. This time their charge was to identify future efforts needed to address septic, sewer, and animal waste issues related to human health in the Upper White River watershed.

Each group identified a number of potential efforts and then selected a few to examine further. The combined list of efforts identified by the three groups were:

- stakeholder education on proper siting, regulation, installation and maintenance of on-site systems (county health departments, general public, county officials, pumpers, etc.)
- improve education about resources available and cooperation agreements for BMPs to address animal waste, and educate producers.
- design education campaign on septic systems (expand to specific stakeholder groups)
- voluntary well sampling program for bacteria will provide baseline scientific data/info and basis for improved on-site systems
- DNA source tracking to identify the key sources of bacteria loading
- public policy to optimize regulatory mechanisms for long-term on-site sewage deposit – economic component study.

Figures 47-52 are the completed worksheets from the groups. The first worksheet reflects some of the knowledge gained from the forum presentations. The second and third efforts compliment the first and might be combined with the first to create a new program thrust for MODNR and the Missouri Department of Conservation (MDC). The fourth and fifth proposed efforts might be combined with other monitoring efforts identified in the previous section. The last worksheet is an idea that was not completely addressed due to the time available and the broad nature of the proposed effort.

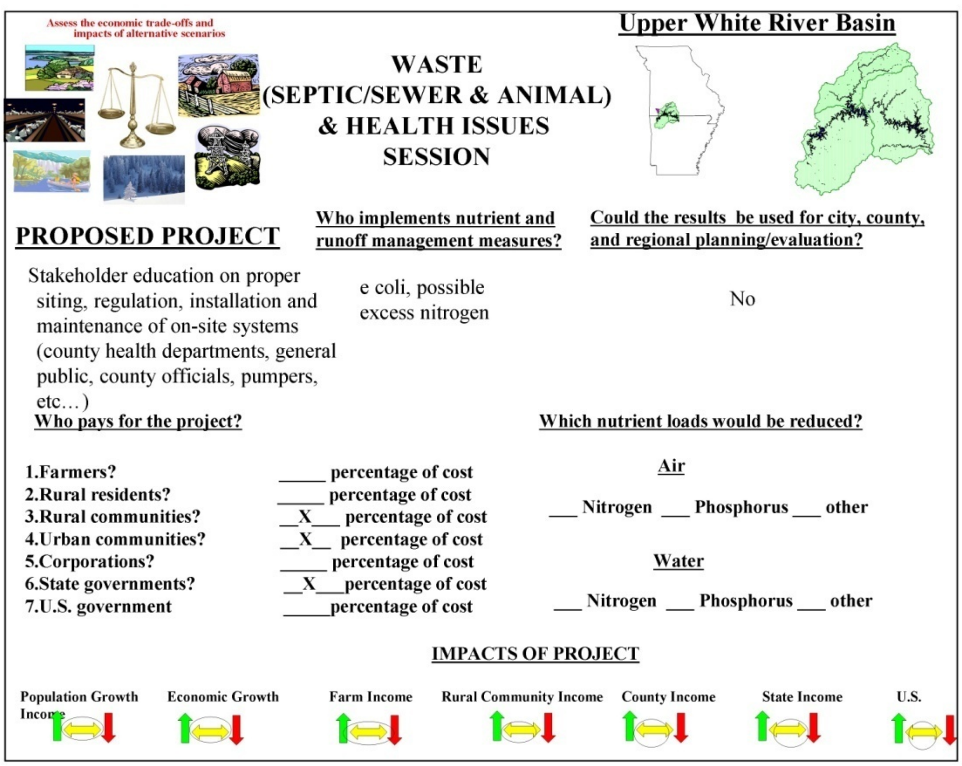

Figure 47. Stakeholder education on proper siting, regulation, installation and maintenance of on-site systems

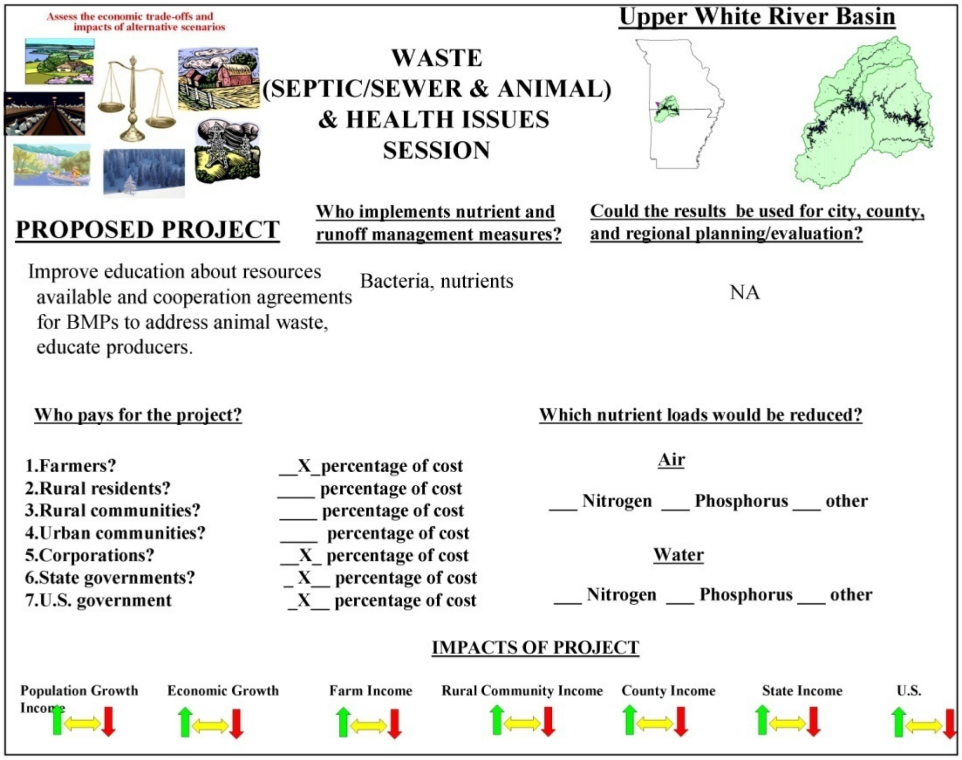

Figure 48. Improve education about resources available and cooperation agreements for BMPs to address animal waste, educate producers.

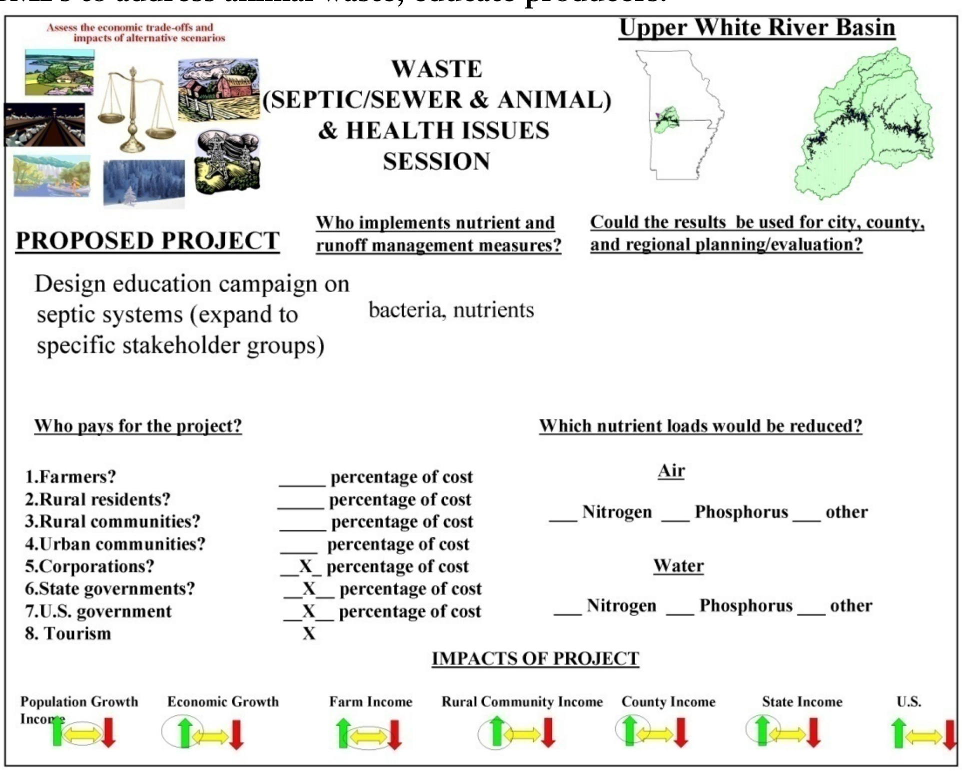

Figure 49. Design education campaign on septic systems

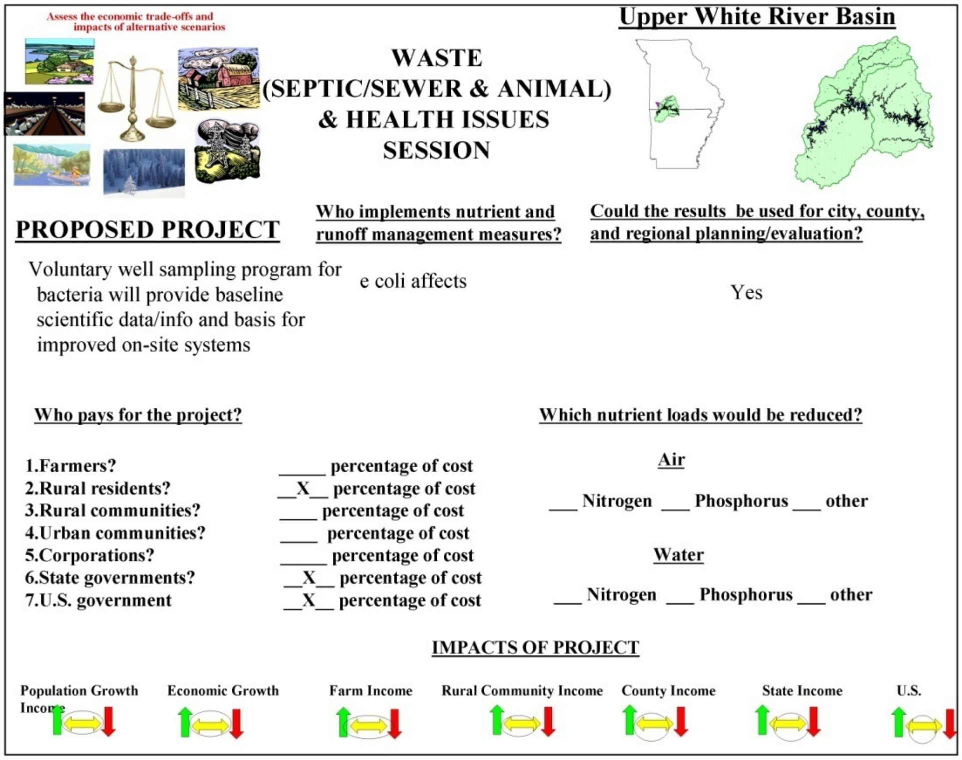

Figure 50. Voluntary well sampling program for bacteria will provide baseline scientific data/info and basis for improved on-site systems

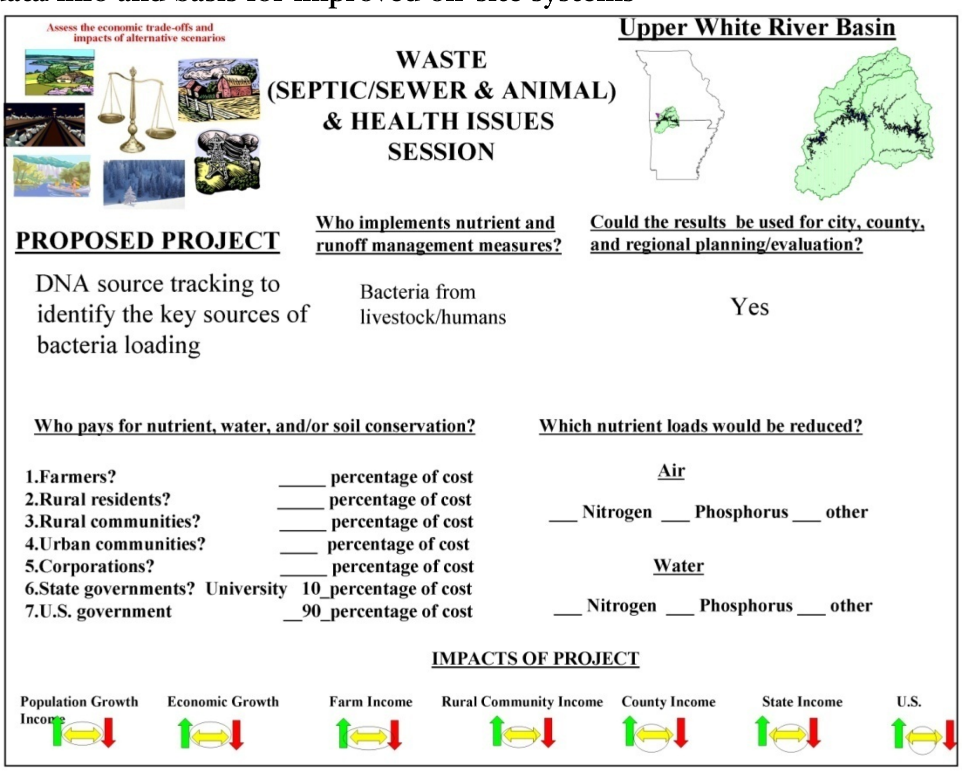

Figure 51. DNA source tracking

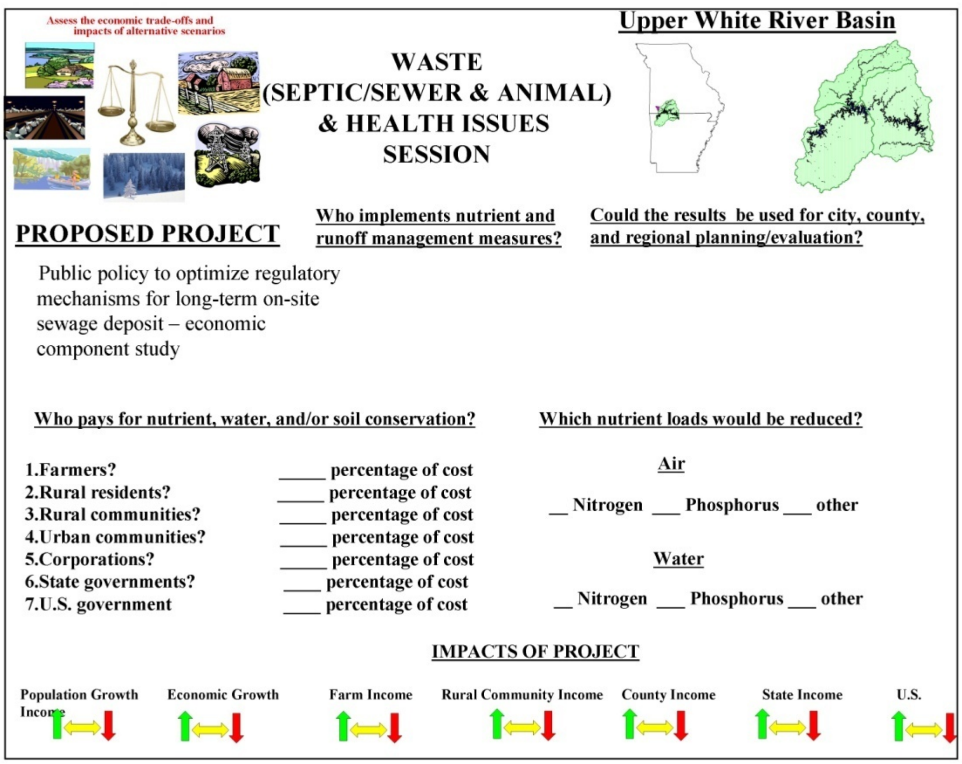

Figure 52. Public policy to optimize regulatory mechanisms for long-term on-site sewage deposit economic component study

The final forum session focused on "Nutrients and Runoff." The first presentation of this session was by Dr. Dennis Robinson from CPAC at MU with input from Dr. Jennie Popp from the Department of Agricultural Economics and Agribusiness at the University of Arkansas entitled "Economic Impact of Poultry and Cattle Industries in Missouri Counties and the Upper White River Basin." His presentation was in response to issues related to poultry litter application in White River area of SW Missouri and NW Arkansas, Confined Animal Feeding Operations (CAFO) rules and county health ordinances, farm conservation practices support by Missouri Sales tax revenues, and the production of Agri-forestry products in south central Missouri. The economic impact of animal and crop agriculture and related industries on the Upper White River Watershed counties was assessed using input/output modeling.

Five measures of importance were examined: (1) gross business sales (2) net value added to communities (3) labor income in thousands of dollars plus (4) employment (full- and part-time jobs), and (5) percentage of total of each measure for the region. Gross business sales and employment dependence on agricultural related activities by county for counties within or adjacent to the Upper White River Basin are shown in tables 29 and 30. Figure 53 illustrates the difficulty in balancing economic and environmental issues.

This presentation was followed by a presentation entitled "Fertilizer Use in Southern Missouri" by Joseph Slater from the Fertilizer/Ag Lime Control Service at MU. Fertilizers are regulated by each state. The first fertilizer law was enacted in 1876 in Connecticut. Missouri's fertilizer law was enacted in 1893. First fertilizers were organic in nature: Fish meal, bone meal, manure, etc. Today all fertilizers are sold by grade i.e. guaranteed analysis N-P-K. Manure and similar products that are not graded have no guaranteed nutrient value and are not considered fertilizers. Organic products that are graded are classified as fertilizers.

Table 29. Missouri White River Basin area counties showing greatest business sales dependence on agricultural related activities.

County	All Agriculture	Animal Agriculture Total	Animal Agriculture Farm	Animal Agriculture Process	Crop Agriculture Total	Crop Agriculture Farm	Crop Agriculture Process	Other Agriculture
McDonald	67.9%	61.9%	5.3%	56.7%	4.5%	0.1%	4.4%	1.4%
Barry	36.5%	24.7%	0.7%	24.0%	11.6%	0.4%	11.3%	0.1%
Ozark	22.0%	13.1%	13.1%	0.0%	8.9%	1.5%	7.5%	0.0%
Douglas	15.6%	12.0%	9.6%	2.4%	3.6%	0.5%	3.0%	0.0%
Dallas	14.5%	13.0%	12.6%	0.3%	1.6%	1.6%	0.0%	0.0%
Polk	12.4%	8.3%	8.2%	0.1%	3.9%	1.7%	2.1%	0.3%
Webster	10.4%	7.6%	7.5%	0.1%	2.1%	0.8%	1.3%	0.7%
Greene	10.1%	1.6%	0.0%	1.6%	8.4%	0.0%	8.4%	0.1%
Taney	4.0%	1.5%	0.1%	1.3%	2.5%	0.0%	1.5%	0.0%
Christian	3.7%	3.0%	1.3%	1.7%	0.6%	0.4%	0.3%	0.1%
Stone	2.0%	1.6%	1.6%	0.0%	0.3%	0.0%	0.3%	0.0%

Percentage of total value. Results generated using 2002 IMPLAN database for each county.

Table 30. Missouri White River Basin area counties showing greatest employment dependence on agricultural related activities.

County	All Agriculture	Animal Agriculture			Crop Agriculture			Other Agriculture
		Total	Farm	Process	Total	Farm	Process	
McDonald	54.6%	52.4%	13.3%	39.1%	1.4%	0.1%	1.3%	0.8%
Ozark	28.9%	25.1%	25.1%	0.0%	3.8%	2.1%	1.7%	0.0%
Douglas	28.3%	25.9%	22.3%	3.5%	2.4%	1.1%	1.3%	0.0%
Barry	23.7%	17.7%	0.7%	17.0%	5.9%	0.5%	5.4%	0.1%
Dallas	21.5%	19.1%	18.9%	0.2%	2.3%	2.3%	0.0%	0.0%
Webster	17.6%	15.2%	15.0%	0.2%	2.2%	1.5%	0.6%	0.2%
Polk	14.4%	11.7%	11.5%	0.1%	2.6%	2.1%	0.5%	0.1%
Christian	5.5%	4.4%	3.5%	0.9%	1.0%	0.9%	0.1%	0.1%
Stone	5.4%	5.1%	5.1%	0.0%	0.3%	0.2%	0.1%	0.0%
Greene	5.1%	1.2%	0.0%	1.1%	3.8%	0.1%	3.6%	0.2%
Taney	2.0%	1.0%	0.4%	0.6%	1.0%	0.1%	0.7%	0.0%

Percentage of total value. Results generated using 2002 IMPLAN database for each county.

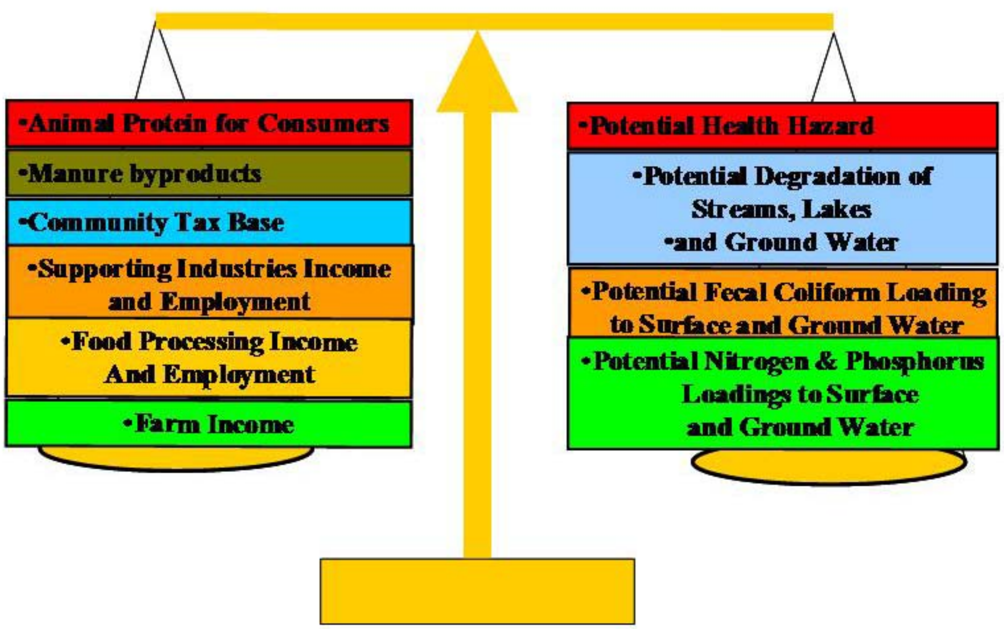

Figure 53. Balancing economic and environmental issues in the Upper White River Basin

Missouri now sells about two million tons of fertilizer per year statewide (figure 54). Southwest Missouri counties (Barry, Barton, Christian, Dade, Greene, Jasper, Lawrence, McDonald, Newton, and Stone) have fertilizer sales of about 140,000 tons, figure 55. The neighboring counties (Bates, Benton, Cedar, Dallas, Henry, Hickory, Polk, St. Clair, Taney, Vernon, and Webster) have fertilizer sales of 180,000 tons (figure 56).

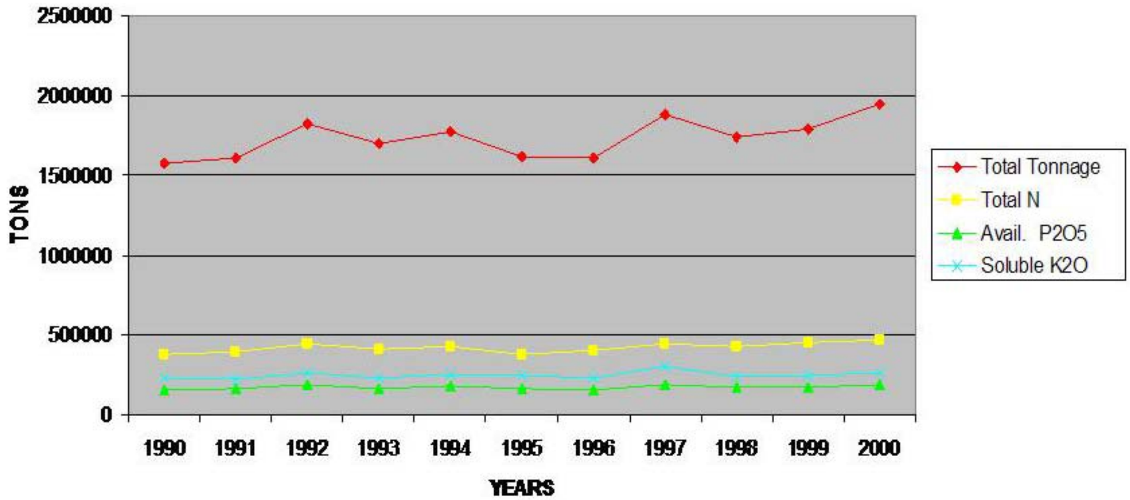

Figure 54. Missouri fertilizer sales, 1990-2000

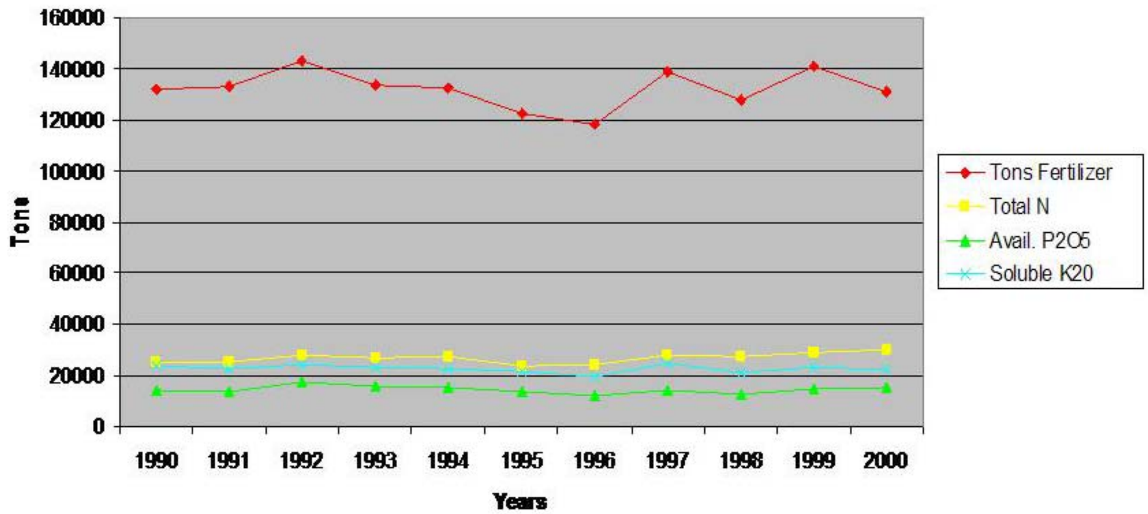

Figure 55. Southwest Missouri fertilizer sales, 1990-2000

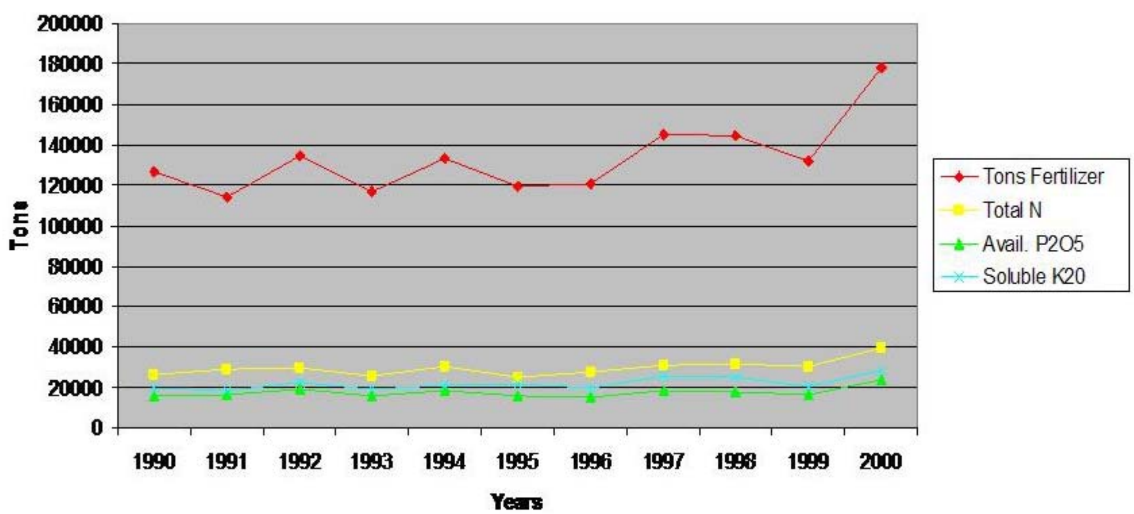

Figure 56. Fertilizer sales for counties bordering Southwest Missouri counties, 1990-2000

Fertilizer needs are higher for harvested cropland than most other land uses. Figure 57 shows harvested cropland by county for Missouri as a percentage of total land area.

Most of the farmland in southwest Missouri and the Upper White River Basin is pasture land (figure 58). Phosphorus balance (application versus crop use) is a key issue in Southwest Missouri and the Upper White River Basin. Considerable phosphorus is available in the manure of animals raised in the region and much of the manure, primarily poultry, is able to be recycled for its nutrient value. Figure 59 presents the estimated manure phosphorus that could be recycled for the state.

The speaker concluded that commercial fertilizer use in Southwest Missouri appears to be stable or decreasing. Fertilizer use in the bordering counties appears to be increasing which could increase demand for manure in those counties and in other areas of Missouri.

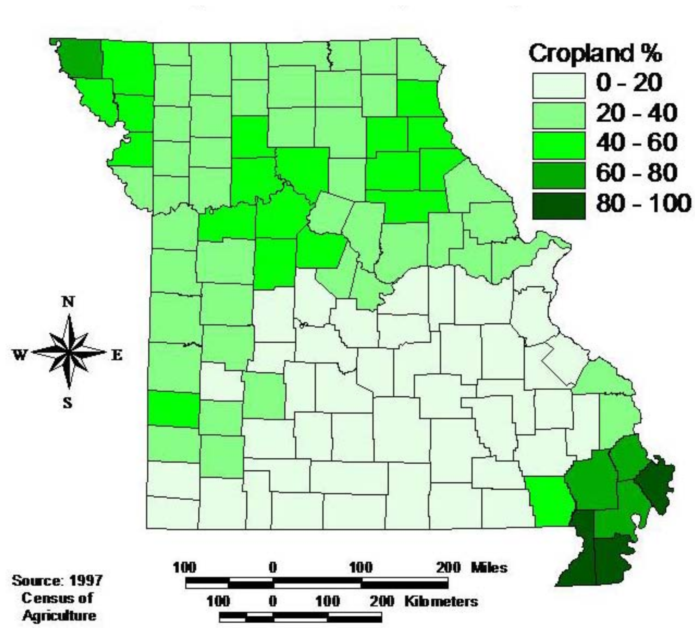

Figure 57. Harvested cropland as a percent of county land area, 1997

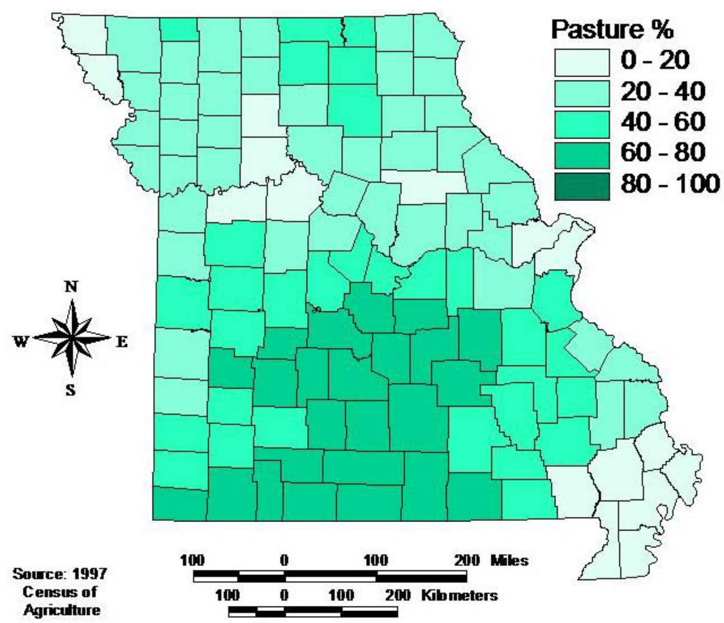

Figure 58. Pasture as a percentage of farmland by county for Missouri, 1997

A handout was produced by Dr. D. Todd Farrand using Fertilizer/Ag Lime Control Service data, 1997 Agricultural Census data, and 2000 Population Census data.

Participants were given copies for use in their discussions. Figures 60-66 are a subset of the information in the handout. Figure 60 presents phosphorus sales for the Upper White River Basin counties from 1990 to 2005.

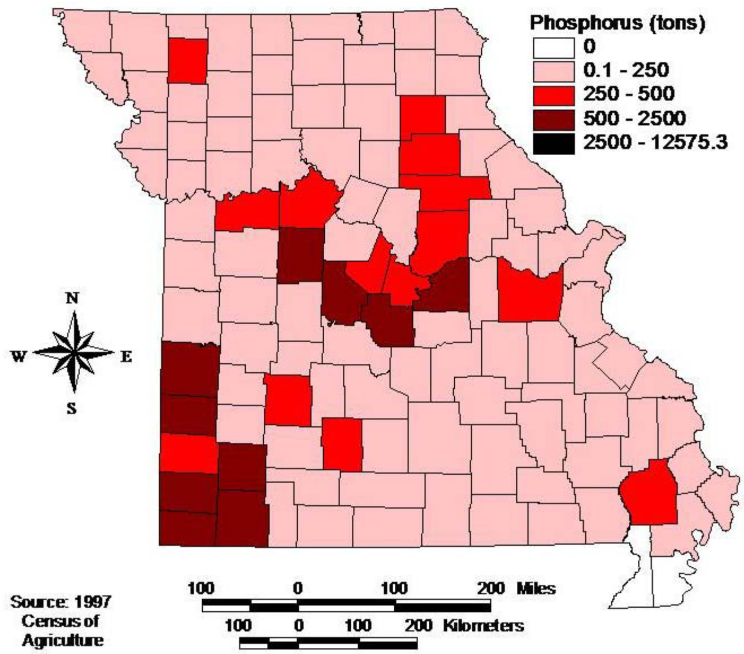

Figure 59. Estimated manure phosphorus by county for Missouri, 1997

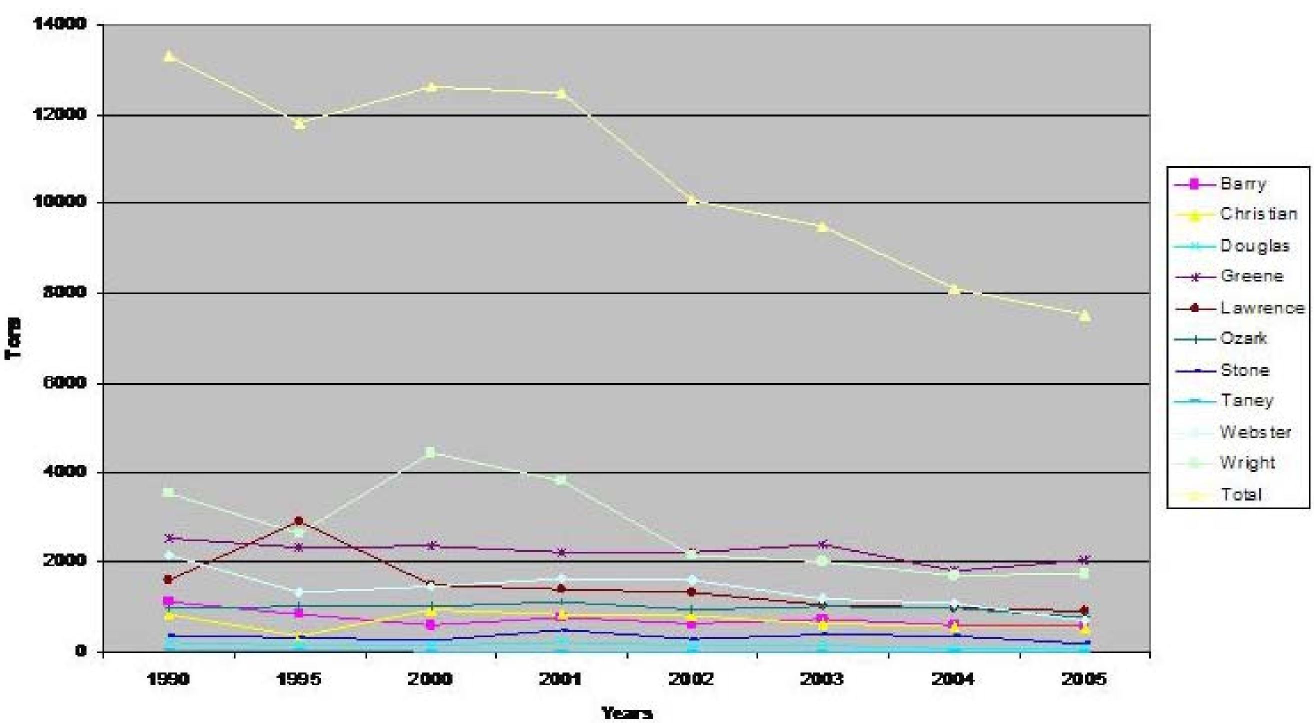

Figure 60. Fertilizer phosphate sales in the Upper White River Basin Counties

Figure 61 presents Upper White River commercial phosphorus sales spatially for 2005. Figures 62 and 63 present the estimated recyclable manure phosphorus less the crop removal of phosphorus.

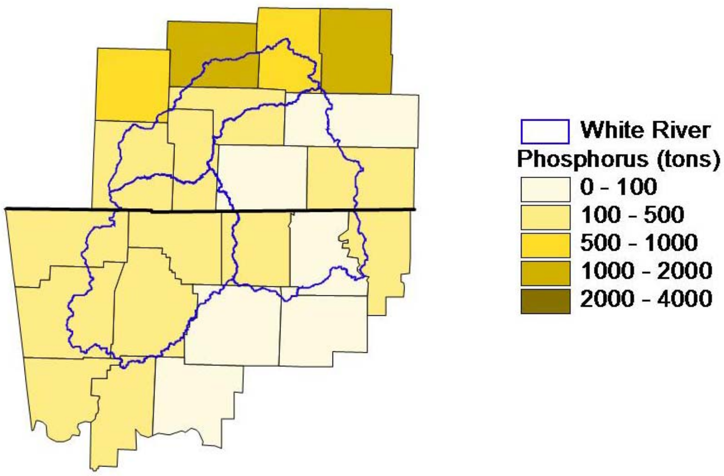

Figure 61. Upper White River commercial phosphorus sales, 2005

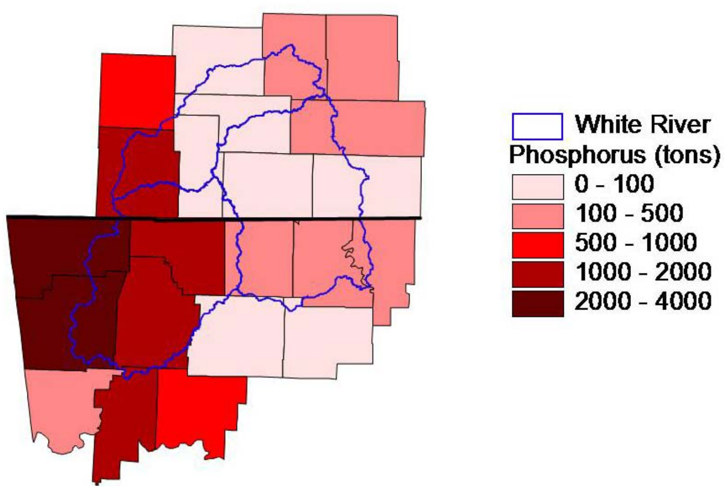

Figure 62. Upper White River recyclable livestock manure phosphorus, 1997

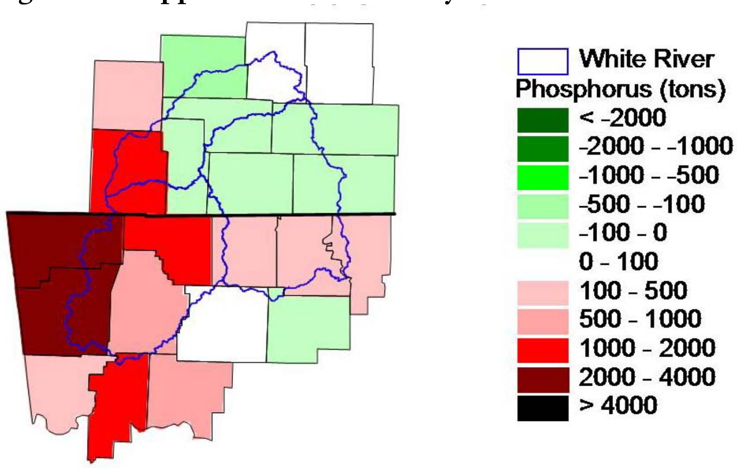

Figure 63. Upper White River recyclable manure phosphorus less crop removal, 1997

Figure 64 shows the human population density in the Upper White River Basin. The potential phosphorus balance when human waste and commercial phosphorus applications are added is shown in figure 65.

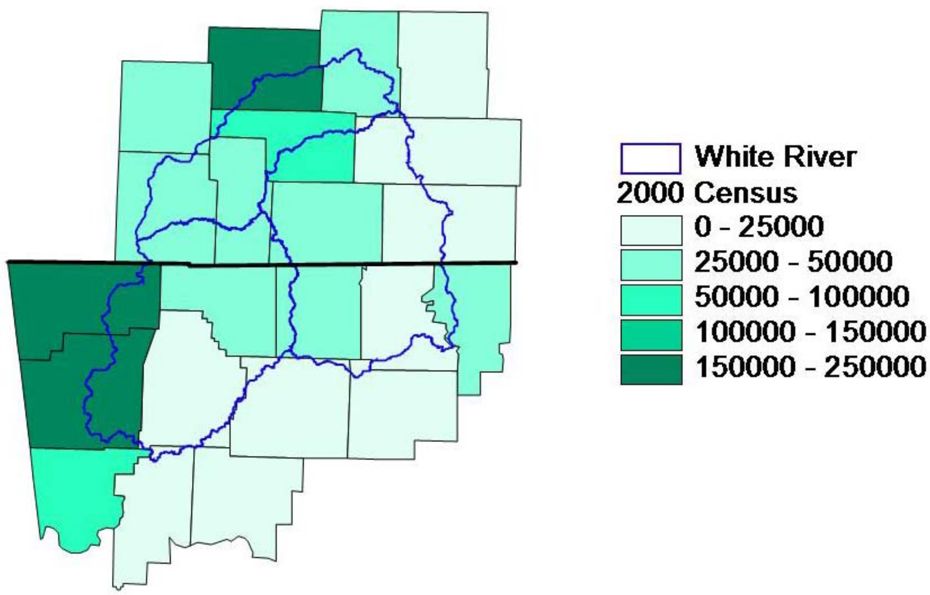

Figure 64. Upper White River population density 2000

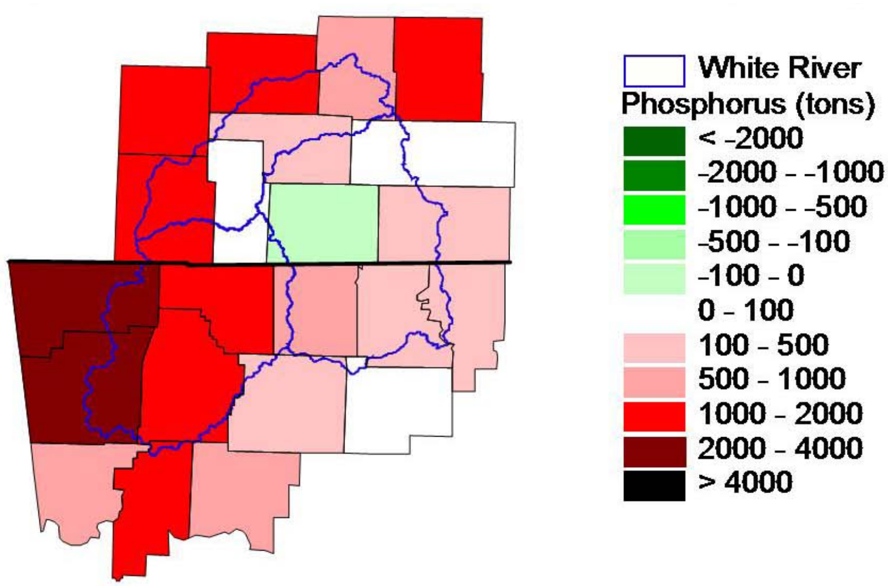

Figure 65. Upper White River manure P + commercial P + Human P - crop P

Figure 66 shows the percentage of the total of recyclable livestock manure phosphorus, human waste phosphorus, and commercial phosphorus attributable to poultry.

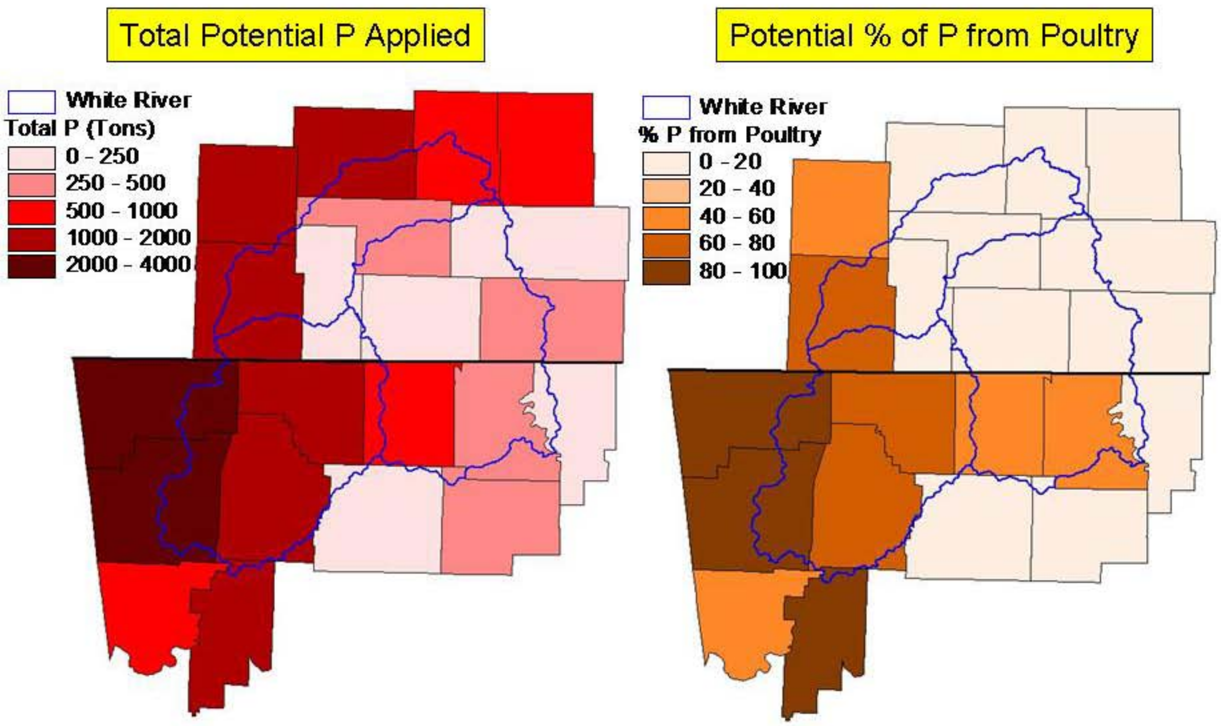

Figure 66. Potential from poultry as a percentage of all sources

The handout illustrated nutrients come from many sources i.e. farms, urban homes and businesses, poultry, livestock and humans. Commercial fertilizer is applied on farmland, lawns, parks, and public facilities.
Potential excessive phosphorus from poultry exists for some but not all counties in the Upper White River Basin with many having the potential to use poultry manure phosphorus instead of commercial phosphorus. Some recent poultry manure organic fertilizer products recommended for lawns and gardens were shown to participants.

The final speaker of the session was Holly Neill from the James River Basin Partnership (JRBP) related the current "Nutrient Management in Southwest Missouri" project objectives and accomplishments. The project objectives were to:

- Create a greater understanding of poultry nutrient management in Southwest Missouri.
- Promote the use of litter as a nutrient source in an environmentally conscious way.
- Educate landowners about benefits of nutrient management planning.
- Increase JRBP interaction with agriculture community.

The project was partially funded by the EPA region 7 through the MODNR for the 2003 to 2006 period. The project began by developing an understanding of current public perception of poultry litter use as a source of needed nutrients. About 40 percent of respondents already used poultry litter mostly in dry form. Availability and convenience in getting the litter were the biggest barriers to its use as fertilizer. Farmers were interested in learning more about poultry litter as a substitute for commercial fertilizer. Respondents preferred information brochures as the method of acquiring knowledge, but 40 percent were also interested in attending educational programs. One of the first efforts of the project was to examine the land to the suitability for poultry litter application.

They then disseminated information to agencies and organizations that assist poultry producers in Southwest Missouri, and helped livestock producers locate poultry manure sources by working directly with major poultry companies. USDA-NRCS officials verified the information.

The project set up full day workshops that included a mapping session, a soil testing demonstration, a water quality information session, information on poultry and litter production and manure management, and a session on how to implement a nutrient management plan. Evening workshops were held on water quality, poultry and litter production, manure management, and soil testing. Over 50 percent attendees of full day workshops proceeded to establish a nutrient management plan for their farm. Nutrient management workshop participants that proceeded with plan received $50.00 incentive and 100 percent of soil and litter test cost. JRBP staff and partners wrote comprehensive nutrient management plans (CNMP) for participants. The partners were MU Extension, USDA-NRCS, the Elk River Watershed Improvement Association, the Shoal Creek Watershed Improvement Group, Poultry Company Representatives and a MSU contractor. They completed 57 Comprehensive Nutrient Management Plans (CNMPs) covering 6,976 acres. Time constraints of partner nutrient management planners prevented 18 CNMPs from being completed by project. Seventy percent of the plans were written for landowners in the Elk and Spring Watersheds. Phosphorous was not recommended for 45 percent of total acres (3,139 acres).

The session members were again split into three groups with trained facilitators. This time their charge was to identify future efforts needed to address nutrient and runoff issues related to water quality in the Upper White River watershed. Again, each group identified a number of potential efforts and then narrowed the list to four.

The combined list of efforts identified by the three was:

1. urban nutrient management, education for all stakeholders, public and private sector
2. develop and promote model business plan for export of poultry litter out of watershed.
3. form a cross functional group to look at areas with excess of poultry litter and determine user options
4. innovations including education and sustainability
5. on-site pelleting.

Figures 67-70 are the completed worksheets from the groups.

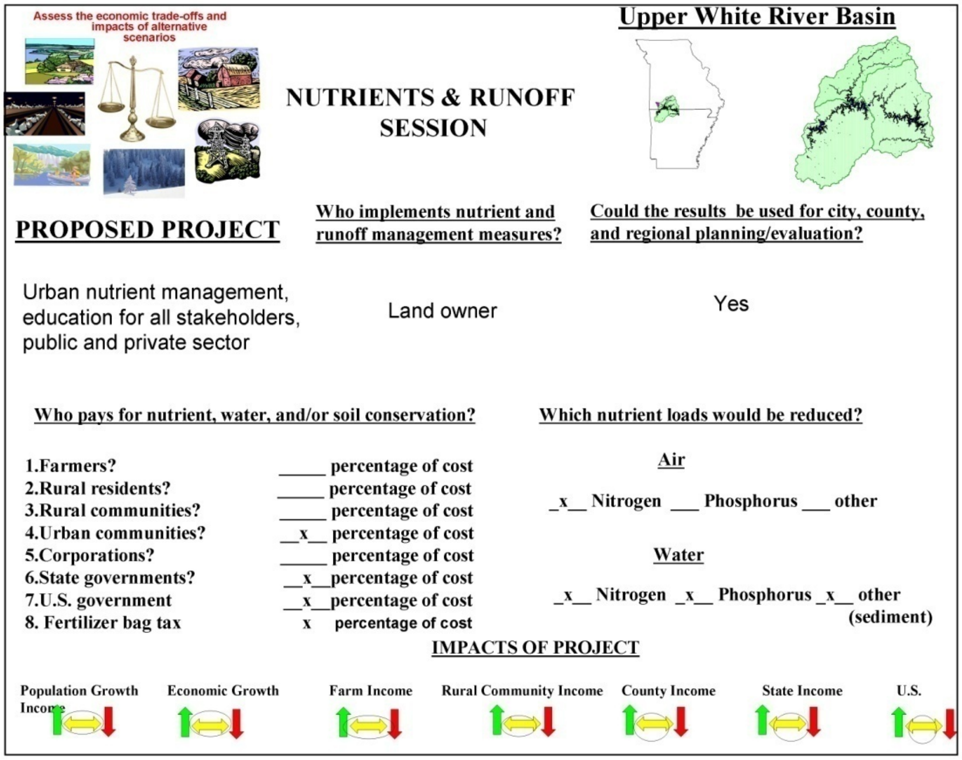

Figure 67. Urban nutrient management, education for all stakeholders, public and private sector

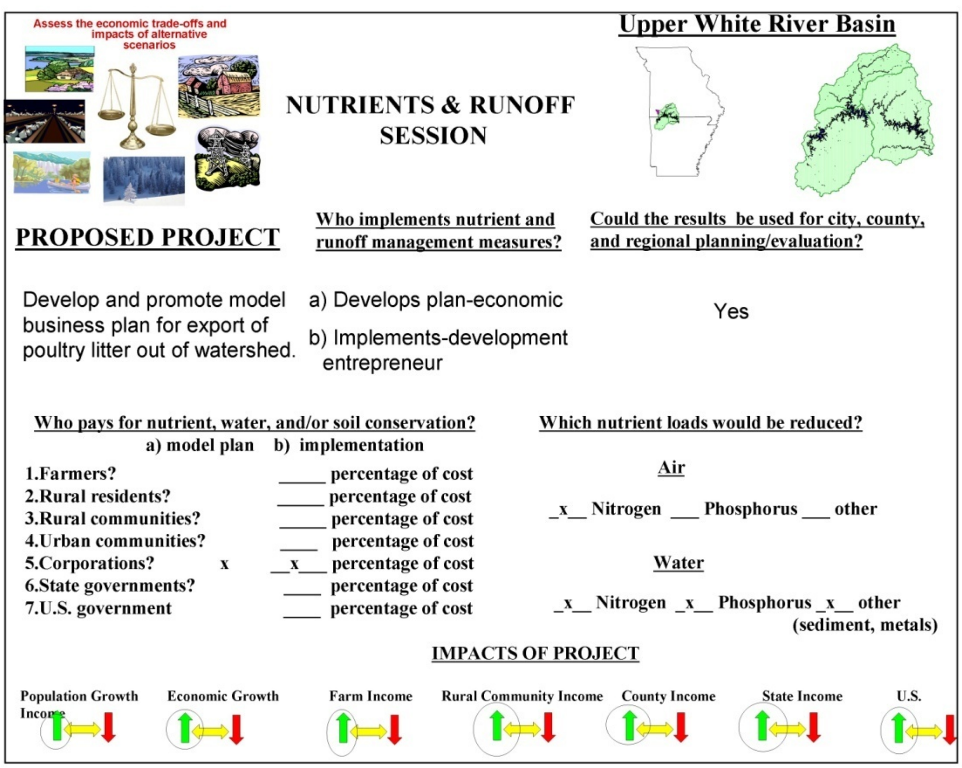

Figure 68. Develop and promote model business plan for export of poultry litter out of watershed.

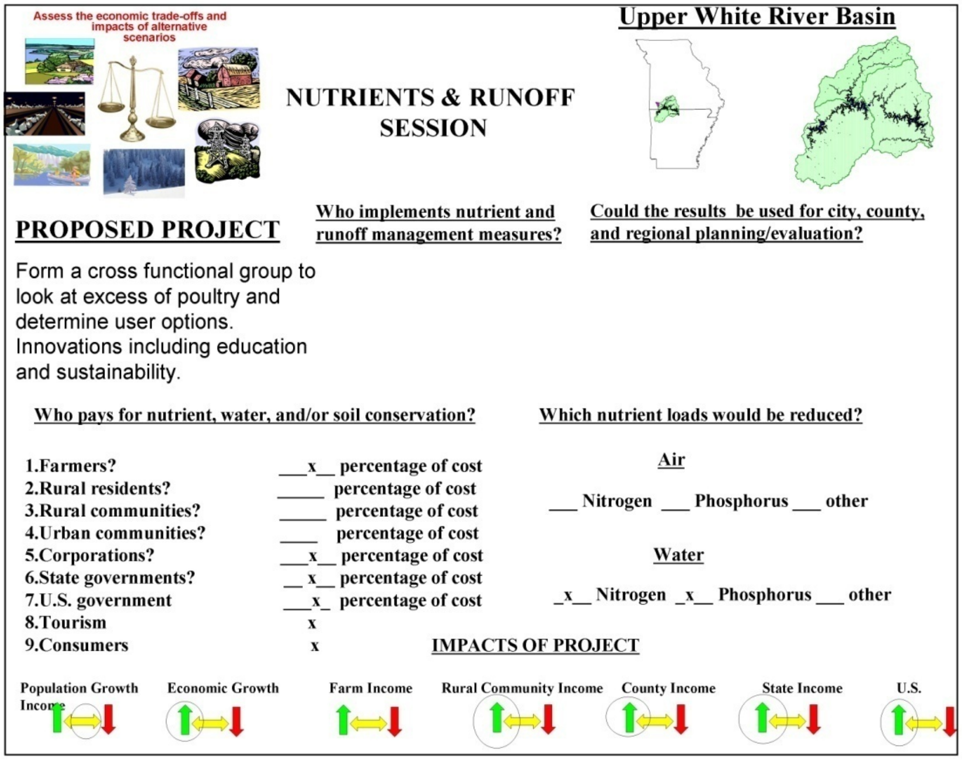

Figure 69. Form a cross functional group to look at excess of poultry and determine user options

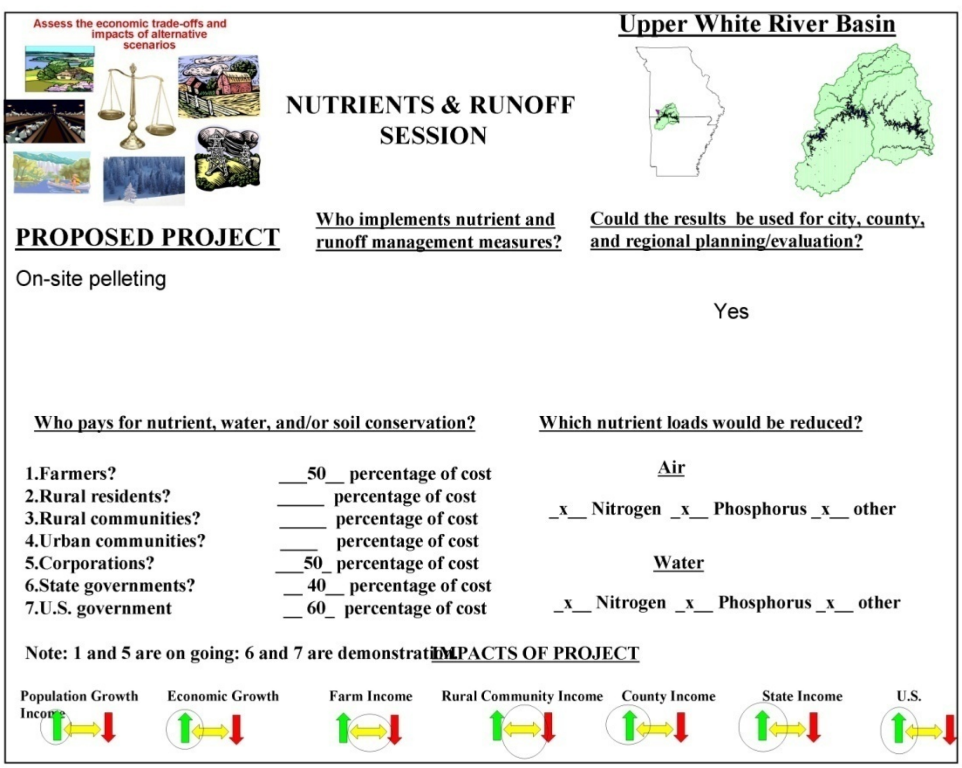

Figure 70. On-site pelleting

Upper White River Symposium/workshop Summary

The coordinating committee summarized the 22 identified efforts into the following Monitoring & Evaluation Top Three Thrusts:

1) Data collection processes
   a) maintain existing collection sites,
   b) voluntary well monitoring
   c) standardize processes across watersheds,
   d) establish common definitions
   e) maintain publicly accessible data that can be integrated across watersheds
2) Identify hot spots
   a) prioritize sub-watersheds using
      i) existing data,
      ii) physiographic characteristics,
      iii) population trends,
      iv) agricultural trends,
   b) identify hot spots within these sub-watersheds
   c) identify potential solutions and sources of support
3) Develop site specific water quality
   a) monitoring of BMPs
   b) agricultural improvements,
   c) construction sites
   d) other BMP applications

Waste (Septic/Sewer & Animal) & Health Issues Top Three Thrusts

1. Stakeholder education (county health departments, general public, county officials, pumpers, etc…)
   a) on proper siting, regulation, installation and maintenance of on-site systems
   b) Improve education about resources available and cooperation agreements for BMPs to address animal waste, educate producers
   c) Design education campaign on septic systems
2. DNA source tracking to identify the key sources of bacteria loading
3. Public policy to optimize regulatory mechanisms for long-term, on-site sewage deposition – economic component study

Nutrients & Runoff Issues Top Three Thrusts

1. Urban nutrient management
   a) education for all stakeholders in public and private sectors
2. Marketing poultry litter
   a) develop and promote model business plan for export of poultry litter out of watershed
   b) form a cross functional group to look at areas with excess poultry litter
   c) determine user options
   d) encourage innovations including education and sustainability
3. On-site pelleting

Upper White River Symposium/workshop Follow-up

Committee members were asked to develop potential proposals that addressed one or more of these thrusts. Wendi Rogers from FAPRI–MU prepared a draft proposal that addressed monitoring to assess concentrations of *E. coli*, antibiotics, and endocrine disruptors. The proposal was circulated amongst the cooperators, but has not yet been pursued further.

No other proposals were circulated. However, all three monitoring and evaluation thrusts are being pursued by local organizations and/or MODNR and the EPA. Region 7 of EPA has just published an RFP entitled “Identifying Critical Areas and Targeting Best Management Practices (BMPs) for Water Quality in Region 7 Priority Watersheds” which includes the James River Basin.

Waste (Septic/Sewer & Animal) & Health Issue thrusts are being pursued locally. The only clear connection to this project is the assessment by FAPRI–MU of the impact of nutrient management and septic pumping for the James River Basin that was a cooperative effort of the South Missouri Water Quality Project, the James River Basin Partnership and the Upper White River Basin Foundation.

"Nutrients & Runoff Issue" thrusts were addressed by more than one analysis. The cooperative efforts of the South Missouri Water Quality Project, the James River Basin Partnership, and the Upper White River Basin Foundation address urban nutrient management and septic pumping projects in the James River Basin. The impacts of their efforts were estimated by FAPRI–MU's Dr. Claire Baffaut using the SWAT model of the James River Basin. A regional indicator of the success this project in cooperation with many others in Southwest Missouri is reflected by the change in phosphorus use in that region shown previously in figure 60. In the last five years, the region reduced commercial phosphorus purchases from 12,629 tons to 7,530 tons, a decrease of 5,099 tons or a 40.38 percent. At a rate of $0.25 per pound for phosphorus that is a savings to the producers in that area of $2,549,500.

The increased awareness of environmental issues to protect water quality in that area and the training for agency personnel and producers by state and regional specialists encourages producers to take soil tests and make decisions based on plant food requirements, cost savings, and environmental responsibility. The cooperative efforts of all stakeholders are responsible for this change and of course the increasing price of phosphate probably contributed. However, if the change was only driven by increasing fertilizer price the nitrogen sales in figure 71 should have the same proportionate drop in sales. It doesn't. FAPRI–MU prepared an analysis of the potential supply and demand for recyclable manure phosphorus in the region in and around the Upper White River Basin to begin addressing "Nutrients & Runoff" issue number 2, marketing poultry litter.

This project assessed the regional economic cost of more widely distributing poultry litter. The additional hauling cost based on a least cost method of transporting poultry litter to reduce soil phosphorus build-up was estimated to be $17.1 million for poultry producers in the White River Arkansas area and $5.3 million for producers in the White River Missouri area. That assessment assumed that 50 percent of the cropland phosphorus market could be replaced through manure application.

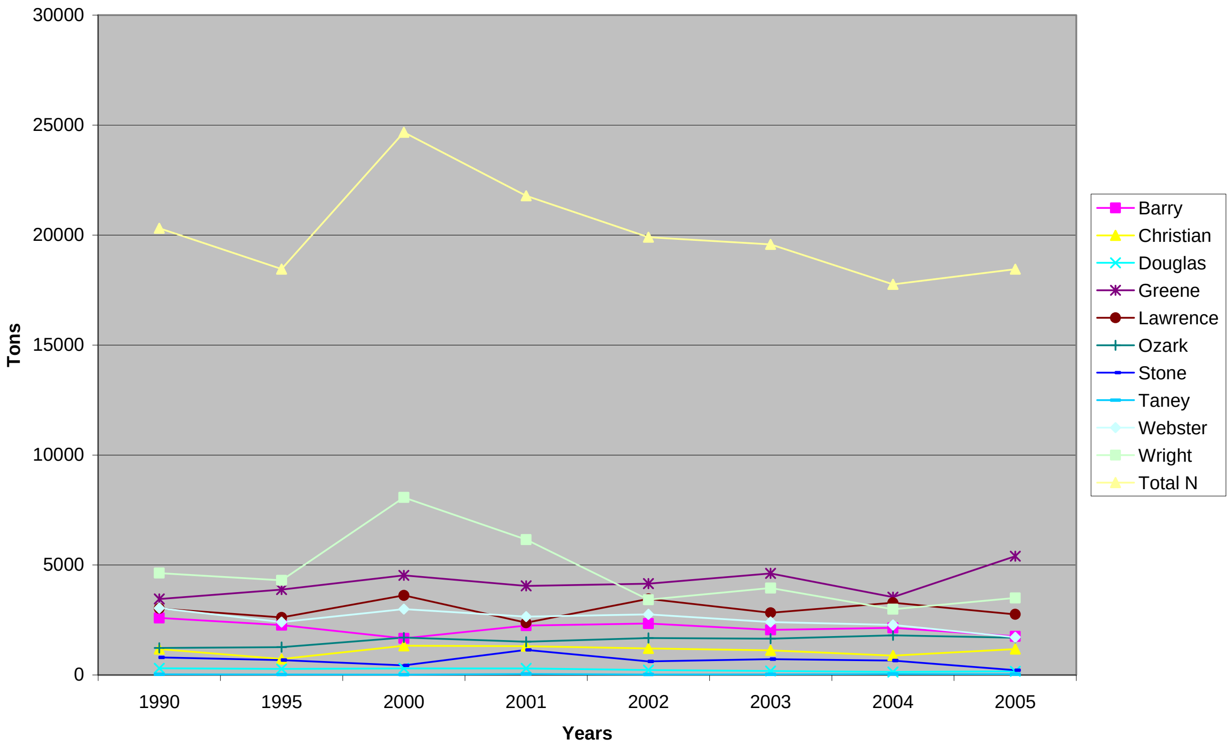

Figure 71. Nitrogen sales in Southwest Missouri

An alternative method to the least cost transportation model of estimating the hauling cost to attain a geographic balance of phosphorus removed with excess recyclable manure phosphorus (P) was developed. It used Carroll county Arkansas as the centroid of the area to be balanced. The resulting county level manure phosphorus ton-mile map is shown in figure 72. Ton-miles are based on the estimated tons of excess or deficit of recyclable manure P in each county multiplied by the estimated distance in miles from the county centroid of a county with excess manure to counties deficit in manure P. This analysis assumes that all encompassed counties meet the same balance criteria. This map also shows that there may be some multi-county areas that could be targeted for marketing poultry litter because of the size of the potential market and the distance from poultry litter sources.

Currently, about 30 percent of the harvested crop removal of P for the entire country can be met with manure P. Negative ton-miles reflect counties that can absorb some of the excess manure P from nearby counties, the amount of manure P that can be used, and the reduction in number of miles below the distance from the center of Carroll county Arkansas to the most distant county from Carroll county Arkansas.

At $0.15 per ton-mile[21], the total cost of manure hauling is estimated to be $27.8 million dollars per year. This estimate is not an optimum, but is less complex to calculate. Both methods assume that there will be competition from manure P sources in the counties encompassed. Therefore, the appropriate cost for the region is not just the cost for hauling manure from the Upper White River Basin, but also the cost of hauling manure from all encompassed counties until the entire

[21] The ton-mile charge was adjusted upward from a rate of $0.11 in 2002 to $0.15 to represent an approximation of the rate for 2007/2008.

encompassed area has a phosphorus balance where only half of the potential harvested crop removal is replaced. The estimated hauling cost varies from just over $30.00 per ton to $0.00 for locally spread manure.

Estimated local loading and spreading costs vary from $6.00 to $8.00 per ton depending on local hauling distances. Loading costs are estimated to be $5.00 per ton. Storage costs would be appropriate in some scenarios, but were not estimated at this time. Total hauling, handling and spreading cost per ton vary from $11.00 to $13.00 per ton. Poultry litter cost at the poultry farm varies from $5 to $20 per ton.

The increase in energy costs and fertilizer costs has raised the value of manure fertilizers and raised hauling costs. Trucking of poultry litter as a backhaul to corn production areas in the same trucks that deliver corn to poultry feed mills has helped facilitate poultry litter sales by reducing hauling cost per ton-mile. If hauling costs for the Upper White River Basin are combined with the above estimated initial loading at the poultry farm, loading and spreading at the destination, and the cost of litter from the farmer; the delivered and spread costs vary from $16.00 to $68.00 per ton.

Farmers are currently willing to pay $35.00 to $40.00 per ton delivered and spread. A key variable in this system that has not yet been quantified is the storage costs from poultry house cleanout to land application.

On-site pelleting New technologies to process poultry litter into pelted, pearlized, bailed, and compressed tablets make hauling and spreading more manageable, but they had cost. On-site compression was examined by Dr. Yuyi Lin from MU. However, a prototype machine that could be transported from farm to farm on a flat bed truck is not yet funded. Current estimated cost of this machine is approximately $60,000. The compressed poultry litter is twice as dense, there is little surface area exposed to generate odor when dry, and can be made from poultry litter that has about 20 percent moisture without drying or adding binders.

Oracle Pellet Systems announced in March 2008 that has started selling mobile pelleting plants. Their plant sells for $125,000 and can pellet 650-850 lbs per hour. These technologies may change the perception of poultry litter as a nutrient source or a bio-energy source.

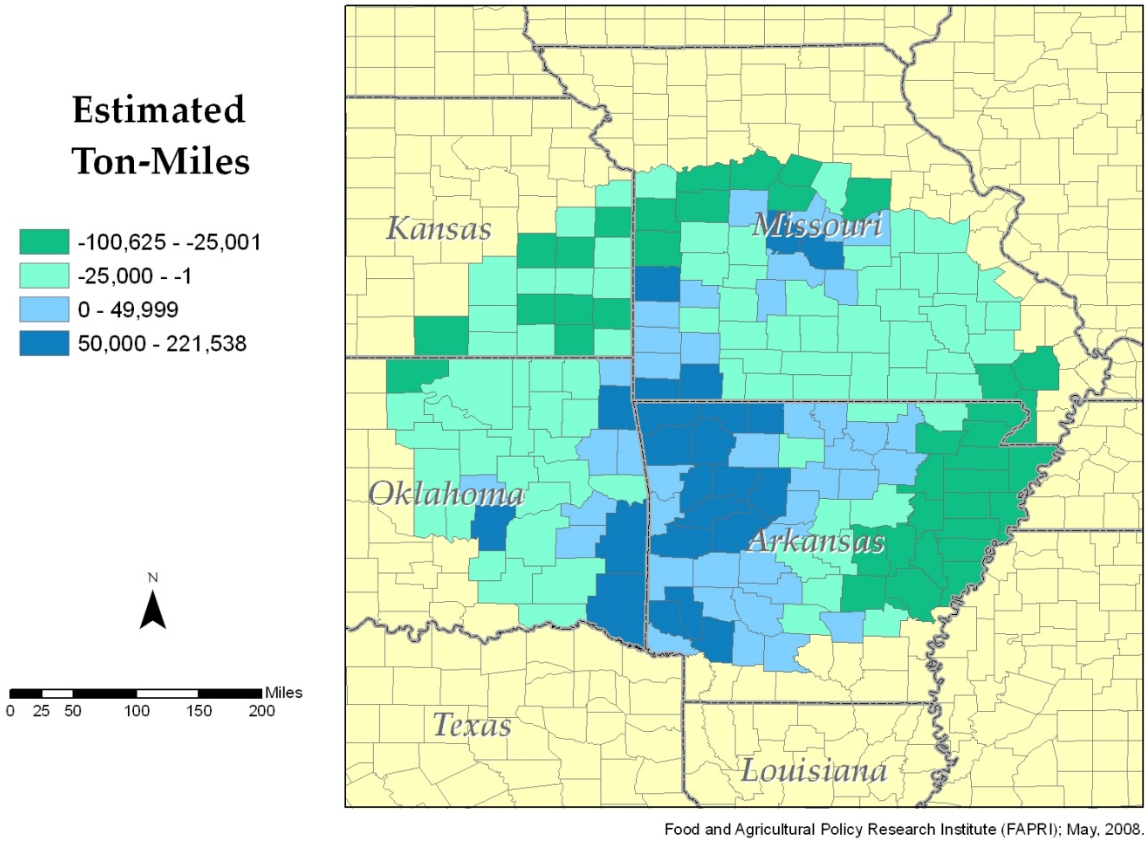

Figure 72. Estimated ton-miles by county to balance manure P and 50 percent of harvested crop removal

Reports and Presentations

Upper White River Watershed Integrated Economic and Environmental Management Project Related Publications

Baffaut, C. Upper Shoal Creek Watershed Bacteria Total Maximum Daily Load. FAPRI-UMC Report 304-03. 2003.

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Benson, V.W., Integrating Energy, Environmental, and Economic Issues. Presented to Missouri Special Senate Committee on Fuel, Waste and the Environment, Jefferson City. March 30, 2006.
Benson, V.W., Using History and Science to Pursue Economic and Environmental Balance. Presented at the 2006 AWAG Watershed Conference: "Clean Water – Stronger Communities", Building Livable Communities Through Watershed Protection, U. Of A. Continuing Education Center & Radisson Hotel, Fayetteville, Arkansas, November 2-4, 2006,
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Appendix A

Table A-1. National and State Government, Local Organization, Commodity Organization, and Private Industry Cooperators

Steve Bauguess	Missouri Department of Natural Resources
Trish Rielly	Missouri Department of Natural Resources
Floyd Gilzow	Missouri Department of Natural Resources
Holly Neill	James River Basin Partnership, Missouri
Steve Stewart	Upper White River Foundation, Missouri
David Casaletto	Table Rock Lake Water Quality, Inc., Missouri
Steve Hefner	USDA, Natural Resources Conservation Service
Montie Hawks	USDA, Natural Resources Conservation Service
Loring Bullard	Watershed Committee of Ozarks, Missouri
Dave White	Watershed Committee of Ozarks, Missouri
Page Shurgar	Kings river Watershed Group, Arkansas
Bob Morgan	Beaver Water District, Arkansas
Brent Bryant	Missouri Cattlemen's Association
David R. Drennan	Missouri Dairy Association
Brian Brookshire	Missouri Forest Products Association
John Bryan	Poultry Federation, Missouri
Don Nikodim	Missouri Pork Association
Tim Alsup	Cargill Inc., Missouri
Preston Keller	Tyson Foods, Arkansas
Art Burnett	Willow Brook Foods, Missouri
Lynn Nutt	Willow Brook Foods, Missouri
Stacy Burks	Missouri Senator Bond's Staff
Don Lucietta	Missouri Congressman Blunt's Office
Philip Moore	Arkansas Congressman Boozman's Office
Rep. Marilyn Ruestman	Missouri State Representative 131rst District
Sen. Doyle Childers	Missouri State Senator 29th District

Table A-2. University Cooperators

Verel Benson	U. of Missouri, FAPRI
Claire Baffaut	U. of Missouri, FAPRI
Todd Farrand	U. of Missouri, FAPRI
Wendi Rogers	U. of Missouri, FAPRI
Joe Trujillo	U. of Missouri, FAPRI
Walaiporn Intarapapong	U. of Missouri, FAPRI
Willi Meyers	U. of Missouri, FAPRI
Jack Jones	U. of Missouri, Dept. of Fisheries and Wildlife Sciences
Joseph Slater	U. of Missouri, Fertilizer/Aglime Central
William Kurtz	U. of Missouri, Watershed Planning Center
Robert Broz	U. of Missouri, Watershed Planning Center
Andy Carson	U. of Missouri, College of Veterinary Medicine
Richard Crawford	U. of Missouri, Southwest Research Center
Steve Anderson	U. of Missouri, Dept. Soil Science
Dennis Robinson	U. of Missouri, CPAC
Kyoungmin Nam	U of Missouri, CPAC
Drew Holt	U. of Missouri, Extension
Bob Pavlowsky	Missouri State University
Jennie Popp	U. of Ark., Dept. of Ag. Economics & Agribusiness
Ralph Davis	U. of Ark., Water Resources Center
Dr. Indrajeet Chaubey	U. of Ark., Dept. of Biological & Agricultural Engineering
Dr. Marty Matlock	U. of Ark., Dept. of Biological & Agricultural Engineering
Chad Cooper	U. of Ark., Dept. of Biological & Agricultural Engineering Brian
K. Schaffer	U. of Ark., Dept. of Biological & Agricultural Engineering
H. German Rodriguez	U. of Ark., Dept. of Ag. Economics & Agribusiness
Nathan Kemper	U. of Ark., Dept. of Ag. Economics & Agribusiness

Appendix B

Table B-1. Springs in the James River Basin with information on discharge.

PRIMARY NAME	FLOW	MINFLOW	MAXFLOW	MEANFLOW	SUBBASIN
MOUNTAINDALE SPRING	1-10 cfs	0.8200	5.4600	2.9300	1
BELL SPRING	10-100 gpm	0.0300	0.0300	0.0300	1
	1 ptpm – 1 gpm	-	-	0.0011	1
	100 gpm – 1 cfs	-	-	0.4352	1
	1-10 gpm	-	-	0.0065	1
RUMFELT SPRING	1-10 cfs	1.6700	1.6700	1.6700	1
DOUBLE SPRING (2)	1-10 gpm	0.0200	0.0200	0.0200	2
CAMPGROUND SPRING	10-100 gpm	0.0223	0.0223	0.0223	2
PRUITT SPRING	10-100 gpm	0.1500	0.1500	0.1500	2
LINDSEY SPRING	1-10 gpm	0.0111	0.0111	0.0111	2
ROLLAND SPRING	1-10 gpm	0.1111	0.1111	0.1111	2
SEQUIOTA SPRING	10-100 cfs	0.9280	17.0200	8.9740	3
HUNT SPRING	10-100 gpm	0.1900	0.1900	0.1900	3
BLUE SPRING	1-10 cfs	1.5700	3.3300	2.1600	3
INDIAN SPRING	10-100 gpm	0.2000	0.2000	0.2000	3
WELCH SPRING	10-100 gpm	0.1800	0.1800	0.1800	3
CAMP CORA SPRING	100 gpm – 1 cfs	0.8000	1.0800	0.9400	3
WINOKA SPRING	1-10 cfs	0.2300	6.0000	2.0260	3
WARD SPRING HOUSE	1-10 cfs	1.0200	1.7300	1.3750	3
CALCITE ROOT CAVE SP	10-100 gpm	0.1671	0.1671	0.1671	3
WALNUT HILL SPRING	10-100 gpm	0.0334	0.0334	0.0334	3
STUTZMAN SPRING	10-100 gpm	0.1000	0.1000	0.1000	3
KELLY (MENTOR) SPRING	100 gpm – 1 cfs	0.3119	0.3119	0.3119	3
MOSS CAVE (SAMUEL’S WELL)	100 gpm – 1 cfs	0.6684	0.6684	0.6684	3
WARD SPRING	1-10 cfs	1.7327	1.7327	1.7327	3
SPOUT SPRING	1-10 gpm	-	-	0.0065	5
WASSON SPRING	10-100 gpm	0.0800	0.1700	0.1250	5
	100 gpm – 1 cfs	0.5200	0.5200	0.5200	6
BROWN SPRING (2)	1-10 cfs	5.1200	11.0000	8.3533	7
MONTAGUE	1-10 cfs	2.7100	2.8100	2.7600	8
CRYSTAL SPRING	1-10 cfs	1.6800	11.0000	6.3400	10
REEDS SPRING	100 gpm – 1 cfs	0.1000	0.4500	0.3000	12

MC MURTY SPRING	100 gpm – 1 cfs	0.1200	0.4400	0.2800	15
MOUNT SINAI SPRING	100 gpm – 1 cfs	0.4400	0.4400	0.4400	18
YOUNG SPRING	100 gpm – 1 cfs	0.1100	0.3700	0.2400	18
LASLEY (OLLIE) SPRING	1-10 cfs	1.8000	1.8000	1.8000	19
	1-10 cfs	-	-	3.0000	19
TODD SPRINGS	1-10 cfs	3.1400	3.1400	3.1400	20
	100 gpm – 1 cfs	-	-	0.4352	20
	100 gpm – 1 cfs	-	-	0.4352	20
MACKEY SPRING #1	10-100 gpm	0.0668	0.0668	0.0668	21
MACKEY SPRING #2	10-100 gpm	0.2228	0.2228	0.2228	21
VALLEY SPRING	10-100 gpm	0.1560	0.1560	0.1560	21
MC GRAW SPRING	10-100 gpm	0.0440	0.0445	0.0445	22
MILL STREET SPRING	100 gpm – 1 cfs	0.5010	0.5013	0.5013	22
WALLIS SPRING	10-100 gpm	0.1000	0.1003	0.1003	22
PRIMARY NAME	FLOW	MINFLOW	MAXFLOW	MEANFLOW	SUBBASIN
BONAR SPRING	10-100 gpm	0.1003	0.1003	0.1003	22
HOPKINS SPRING	10-100 gpm	0.0340	0.0344	0.0344	22
CREIGHTON NATURAL BR	100 gpm – 1 cfs	0.6684	0.6684	0.6684	22
JONES SPRING	1-10 cfs	1.2000	12.0000	2.5000	22
HALL SPRING	100 gpm – 1 cfs	0.4456	0.4456	0.4456	22
BONE BREAK SPRING	100 gpm – 1 cfs	0.7100	0.7100	0.7100	22
HUFF SPRING	10-100 gpm	0.2228	0.2228	0.2228	22
DUGAL SPRING	10-100 gpm	0.1000	0.1003	0.1003	22
TOOMBS CAVE	10-100 gpm	0.0223	0.0223	0.0223	22
GOWER SPRING	10-100 gpm	0.1330	0.1337	0.1337	22
CEMETARY CAVE SPRING	10-100 gpm	0.1140	0.1140	0.1140	22
COUNTRY CLUB CAVE SP	10-100 gpm	0.0780	0.0780	0.0780	22
DITCH CAVE SPRING	10-100 gpm	0.0446	0.0446	0.0446	22
ROSE SPRING	10-100 gpm	0.0560	0.0340	0.0450	22
ROYAL CAVE SPRING	10-100 gpm	0.0560	0.0560	0.0560	22
TAYLOR SPRING	10-100 gpm	0.0334	0.0334	0.0334	22
TAWSEMTHA SPRING	10-100 gpm	0.0500	0.0500	0.0500	22
ASHFORD (ROYAL) SPRING	10-100 gpm	0.0557	0.0557	0.0557	22
DITCH SPRING	1-10 gpm	0.0045	0.0045	0.0045	22

FAUNA SPRING	10-100 gpm	0.1671	0.1671	0.1671	22
JONES BRANCH SPRING	1-10 gpm	0.0223	0.0223	0.0223	22
KERSHNER CEMETERY SPRING	10-100 gpm	0.0891	0.0891	0.0891	22
LITTLE YOSEMITE SPRING	100 gpm – 1 cfs	0.3342	0.3342	0.3342	22
OLD INDIAN SPRING	10-100 gpm	0.2005	0.2005	0.2005	22
BROAD CREEK SPRING	10-100 cfs	18.7000	18.7000	18.7000	22
CAVIN CAVE SPRING	1-10 cfs	5.8600	5.8600	5.8600	22
CAVIN SPRING	1-10 cfs	2.1700	2.1700	2.1700	22
COLLETT SPRING	1-10 gpm	0.0222	0.0222	0.0222	22
KENSINGTON SPRING #2	100 gpm – 1 cfs	0.5000	0.5000	0.5000	22
TREASURE SPRING	1-10 cfs	3.0600	3.0600	3.0600	22
WILKERSON SPRING	1-10 gpm	0.0200	0.0200	0.0200	22
	10-100 cfs	0.9280	17.0200	8.9740	23
ROUNDTREE SPRING	10-100 gpm	0.0900	0.1300	0.1100	24
SHERROD SPRING	100 gpm – 1 cfs	0.2300	0.4600	0.3375	24
RADER SPRING	10-100 cfs	10.5000	36.3000	18.4000	24

Appendix C

Table C-1. Interregional Column Multipliers for White River: Arkansas

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	1.3426	0.0084	0.0307	0.1359	0.0248	0.0634	1.6057
2	Other crop farming	1.3075	0.0082	0.0283	0.1146	0.0191	0.0587	1.5364
3	Cattle ranching & farming	1.6004	0.0097	0.0386	0.1808	0.0469	0.0871	1.9636
4	Poultry farming & egg production	1.5231	0.0138	0.0517	0.2054	0.0370	0.0608	1.8918
5	Hogs & other animal farming	1.4469	0.0105	0.0414	0.1918	0.0463	0.0653	1.8021
6	Logging & forest products	1.3361	0.0089	0.2559	0.0989	0.0189	0.0701	1.7888
7	Commercial fishing, hunting & trapping	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
8	Agirculture & veterinary services	1.6512	0.0209	0.0491	0.2685	0.0280	0.1187	2.1363
9	Oil & gas extraction & support services	1.5982	0.0147	0.0470	0.1830	0.0255	0.0939	1.9623
10	Other mining	1.4383	0.0138	0.0432	0.1311	0.0221	0.0894	1.7380
11	Electrical power & utilities	1.2053	0.0083	0.0315	0.0756	0.0189	0.1026	1.4421
12	Construction	1.6041	0.0293	0.0672	0.2184	0.0322	0.1161	2.0673
13	Animal feed	1.4703	0.0122	0.0387	0.2023	0.0647	0.0725	1.8607
14	Flour & grain mlling	1.5421	0.0110	0.0415	0.2647	0.0698	0.0738	2.0029
15	Animal slaughtering, except poultry	2.0750	0.0139	0.0538	0.2137	0.0661	0.1322	2.5548
16	Meat processed from carcasses	1.5781	0.0150	0.0569	0.2391	0.2565	0.1367	2.2824
17	Rendering and meat byproduct processing	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
18	Poultry processing	1.8465	0.0370	0.1555	0.2098	0.0260	0.1059	2.3807
19	Other food products	1.5635	0.0207	0.0515	0.1735	0.0462	0.0984	1.9537
20	Textiles, apparel & leather goods	1.4174	0.0125	0.0357	0.1253	0.0149	0.0630	1.6687
21	Sawmills & lumber products	1.5907	0.0188	0.1876	0.2584	0.0223	0.0898	2.1677
22	Pulp & paper products	1.4549	0.0155	0.1031	0.1408	0.0181	0.0844	1.8168
23	Petroleum refining & products	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
24	Agricultural chemicals	1.4129	0.0101	0.0429	0.1268	0.0264	0.1240	1.7432
25	Other chemicals & chemical products	1.4447	0.0121	0.0375	0.1638	0.0296	0.0939	1.7816
26	Plastics & plastic products	1.4092	0.0127	0.0445	0.1385	0.0224	0.0750	1.7022
27	Tires & rubber products	1.4394	0.0165	0.0511	0.1458	0.0200	0.0784	1.7512
28	Clay, ceramic & glass products	1.5013	0.0170	0.0481	0.1674	0.0234	0.0904	1.8477
29	Cement, stone & other nonmetallic products	1.5291	0.0191	0.0571	0.1749	0.0495	0.1069	1.9365
30	Iron, steel & nonferrous metals	1.4480	0.0167	0.0551	0.1850	0.0258	0.0882	1.8188
31	Metal products	1.4564	0.0180	0.0703	0.1613	0.0226	0.0845	1.8131
32	Farm, lawn & garden machinery	1.4400	0.0148	0.0604	0.1533	0.0245	0.0865	1.7794
33	Other nonelectrical machinery & equipment	1.5177	0.0174	0.0561	0.1725	0.0291	0.1023	1.8951
34	Computers & equipment	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
35	Electrical machinery & equipment	1.4618	0.0148	0.0386	0.1636	0.0200	0.0720	1.7708
36	Appliances	1.4609	0.0159	0.0507	0.1637	0.0207	0.0710	1.7829
37	Electronic & controlling equipment	1.4428	0.0175	0.0488	0.1492	0.0191	0.0742	1.7516
38	Transportation equipment	1.4063	0.0156	0.0524	0.1554	0.0265	0.0793	1.7354
39	Furniture & fixtures	1.5231	0.0197	0.0763	0.2023	0.0237	0.0882	1.9333
40	Instruments & testing equipment	1.5189	0.0202	0.0393	0.1655	0.0213	0.0831	1.8484
41	Miscellaneous manufacturing	1.5051	0.0190	0.0590	0.1872	0.0264	0.0870	1.8836
42	Transportation	1.7300	0.0248	0.0519	0.2313	0.0277	0.1096	2.1753
43	Wholesale & retail trade	1.5049	0.0200	0.0339	0.1648	0.0170	0.0710	1.8115
44	Printing & publishing	1.4790	0.0121	0.0610	0.1696	0.0201	0.0931	1.8349
45	Software development & recording	1.5447	0.0188	0.0457	0.2130	0.0273	0.1027	1.9522
46	Radio, TV & motion picture recording	1.4817	0.0123	0.0325	0.2582	0.0213	0.0781	1.8842
47	Finance & insurance	1.5461	0.0128	0.0298	0.1610	0.0153	0.0727	1.8377
48	Real estate	1.2122	0.0051	0.0147	0.0997	0.0084	0.0273	1.3674
49	Rental services	1.4866	0.0137	0.0337	0.1769	0.0178	0.1018	1.8305
50	Accounting, design & legal services	1.6474	0.0219	0.0452	0.1930	0.0207	0.0964	2.0247
51	Admin, management & support services	1.5320	0.0180	0.0425	0.2538	0.0230	0.0824	1.9518
52	Research, technical & consulting services	1.5855	0.0189	0.0445	0.1797	0.0206	0.0957	1.9449
53	Other business support services	1.6599	0.0191	0.0452	0.2084	0.0231	0.1055	2.0612
54	Educational services	1.6795	0.0191	0.0444	0.2170	0.0224	0.1048	2.0872
55	Health care services	1.6489	0.0196	0.0463	0.1871	0.0222	0.0978	2.0218
56	Child care & social services	1.6521	0.0186	0.0488	0.1941	0.0252	0.1029	2.0416
57	Recreation & amusement services	1.6405	0.0179	0.0446	0.2057	0.0213	0.0943	2.0243
58	Hotels & accommodations	1.4127	0.0137	0.0313	0.1268	0.0139	0.0597	1.6580
59	Food & drinking places	1.6269	0.0231	0.0581	0.2131	0.0444	0.1020	2.0676
60	Equipment maintenance & repair services	1.5454	0.0159	0.0454	0.1926	0.0243	0.0910	1.9146
61	Personal services	1.6534	0.0162	0.0489	0.2149	0.0239	0.0993	2.0567
62	Civic orgranizations	1.7053	0.0195	0.0472	0.2269	0.0241	0.1196	2.1425
63	Other govt enterprises	1.3693	0.0099	0.0334	0.1006	0.0165	0.0570	1.5867

Table C-2. Interregional Column Multipliers for White River: Missouri

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	0.0034	1.3356	0.0304	0.0637	0.0319	0.0267	1.4917
2	Other crop farming	0.0034	1.2597	0.0207	0.0517	0.0226	0.0227	1.3807
3	Cattle ranching & farming	0.0108	1.5673	0.0632	0.1548	0.1250	0.1072	2.0283
4	Poultry farming & egg production	0.0139	1.5719	0.0366	0.2114	0.0590	0.0387	1.9314
5	Hogs & other animal farming	0.0111	1.5817	0.0648	0.1839	0.0688	0.0464	1.9566
6	Logging & forest products	0.0106	1.6682	0.1088	0.1681	0.0324	0.0511	2.0393
7	Commercial fishing, hunting & trapping	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000
8	Agirculture & veterinary services	0.0132	1.8332	0.0162	0.1725	0.0620	0.0617	2.1588
9	Oil & gas extraction & support services	0.0277	1.6296	0.0136	0.1779	0.0438	0.0566	1.9492
10	Other mining	0.0168	1.5176	0.0163	0.1353	0.0400	0.0406	1.7667
11	Electrical power & utilities	0.0036	1.2399	0.0086	0.0514	0.0212	0.0308	1.3556
12	Construction	0.0152	1.7392	0.0218	0.1727	0.0602	0.0624	2.0715
13	Animal feed	0.0154	1.5522	0.0507	0.1864	0.0839	0.0568	1.9453
14	Flour & grain mlling	0.0127	1.6431	0.0645	0.1264	0.0984	0.0480	1.9930
15	Animal slaughtering, except poultry	0.0168	1.6871	0.0402	0.2954	0.2682	0.2415	2.5493
16	Meat processed from carcasses	0.0222	1.5605	0.0216	0.2050	0.1920	0.0962	2.0976
17	Rendering and meat byproduct processing	0.0175	1.4059	0.0540	0.1220	0.0684	0.0878	1.7557
18	Poultry processing	0.0726	1.7201	0.0735	0.3022	0.0515	0.1146	2.3345
19	Other food products	0.0180	1.7315	0.0264	0.2450	0.1870	0.1798	2.3876
20	Textiles, apparel & leather goods	0.0150	1.5774	0.0121	0.1507	0.0366	0.0409	1.8328
21	Sawmills & lumber products	0.0140	1.7161	0.0575	0.3396	0.0447	0.0480	2.2199
22	Pulp & paper products	0.0173	1.4737	0.0427	0.1335	0.0349	0.0546	1.7568
23	Petroleum refining & products	0.0205	1.5595	0.0473	0.1680	0.0811	0.1077	1.9842
24	Agricultural chemicals	0.0161	1.4449	0.0317	0.1176	0.0363	0.0447	1.6914
25	Other chemicals & chemical products	0.0178	1.4793	0.0167	0.1382	0.0436	0.0445	1.7401
26	Plastics & plastic products	0.0139	1.4665	0.0153	0.1212	0.0416	0.0429	1.7015
27	Tires & rubber products	0.0230	1.4948	0.0378	0.1450	0.0356	0.0438	1.7801
28	Clay, ceramic & glass products	0.0211	1.6433	0.0221	0.1896	0.0484	0.0662	1.9908
29	Cement, stone & other nonmetallic products	0.0165	1.5645	0.0354	0.1613	0.0706	0.0658	1.9142
30	Iron, steel & nonferrous metals	0.0138	1.4596	0.0244	0.1425	0.0442	0.0624	1.7470
31	Metal products	0.0138	1.4946	0.0195	0.1437	0.0428	0.0500	1.7644
32	Farm, lawn & garden machinery	0.0158	1.5055	0.0164	0.1445	0.0433	0.0447	1.7701
33	Other nonelectrical machinery & equipment	0.0162	1.4751	0.0165	0.1527	0.0477	0.0481	1.7564
34	Computers & equipment	0.0109	1.4522	0.0077	0.1041	0.0313	0.0300	1.6361
35	Electrical machinery & equipment	0.0162	1.5278	0.0113	0.1339	0.0385	0.0399	1.7677
36	Appliances	0.0183	1.5383	0.0179	0.1536	0.0437	0.0430	1.8149
37	Electronic & controlling equipment	0.0161	1.4904	0.0149	0.1504	0.0370	0.0408	1.7495
38	Transportation equipment	0.0142	1.4542	0.0177	0.1445	0.0483	0.0446	1.7235
39	Furniture & fixtures	0.0126	1.5515	0.0195	0.1746	0.0392	0.0455	1.8429
40	Instruments & testing equipment	0.0167	1.5823	0.0129	0.1625	0.0413	0.0463	1.8621
41	Miscellaneous manufacturing	0.0150	1.6236	0.0174	0.1683	0.0499	0.0509	1.9252
42	Transportation	0.0159	1.8427	0.0153	0.1847	0.0561	0.0533	2.1680
43	Wholesale & retail trade	0.0147	1.6272	0.0100	0.1289	0.0355	0.0386	1.8549
44	Printing & publishing	0.0130	1.6230	0.0185	0.1433	0.0454	0.0459	1.8890
45	Software development & recording	0.0114	1.7216	0.0129	0.1472	0.0604	0.0539	2.0075
46	Radio, TV & motion picture recording	0.0068	1.6685	0.0097	0.1358	0.0664	0.0448	1.9320
47	Finance & insurance	0.0077	1.7213	0.0081	0.1495	0.0441	0.0387	1.9694
48	Real estate	0.0030	1.3350	0.0046	0.0447	0.0182	0.0191	1.4247
49	Rental services	0.0090	1.6170	0.0093	0.0988	0.0357	0.0421	1.8119
50	Accounting, design & legal services	0.0117	1.7712	0.0119	0.1353	0.0450	0.0509	2.0260
51	Admin, management & support services	0.0098	1.7616	0.0121	0.1360	0.0532	0.0473	2.0200
52	Research, technical & consulting services	0.0094	1.6229	0.0102	0.1121	0.0393	0.0445	1.8385
53	Other business support services	0.0154	1.7946	0.0132	0.1520	0.0505	0.0577	2.0833
54	Educational services	0.0103	1.8823	0.0126	0.1278	0.0488	0.0537	2.1356
55	Health care services	0.0136	1.7892	0.0132	0.1413	0.0474	0.0554	2.0600
56	Child care & social services	0.0152	1.8048	0.0154	0.1540	0.0521	0.0588	2.1003
57	Recreation & amusement services	0.0125	1.7646	0.0123	0.1330	0.0420	0.0467	2.0111
58	Hotels & accommodations	0.0093	1.5261	0.0088	0.0937	0.0285	0.0357	1.7020
59	Food & drinking places	0.0139	1.7914	0.0183	0.1558	0.0579	0.0648	2.1022
60	Equipment maintenance & repair services	0.0135	1.6608	0.0140	0.1331	0.0489	0.0535	1.9238
61	Personal services	0.0134	1.8356	0.0146	0.1476	0.0492	0.0582	2.1186
62	Civic orgranizations	0.0119	1.8843	0.0143	0.1633	0.0568	0.0600	2.1907
63	Other govt enterprises	0.0049	1.4223	0.0097	0.0767	0.0326	0.0327	1.5788

Table C-3. Interregional Column Multipliers for Rest of Arkansas

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	0.0061	0.0021	1.4819	0.0436	0.0103	0.0446	1.5886
2	Other crop farming	0.0063	0.0028	1.4654	0.0412	0.0106	0.0465	1.5727
3	Cattle ranching & farming	0.0113	0.0267	1.6002	0.1158	0.0291	0.1957	1.9789
4	Poultry farming & egg production	0.0224	0.0061	1.7093	0.0728	0.0199	0.0518	1.8822
5	Hogs & other animal farming	0.0163	0.0153	1.6407	0.1142	0.0291	0.1248	1.9404
6	Logging & forest products	0.0081	0.0034	1.9188	0.0363	0.0123	0.0428	2.0216
7	Commercial fishing, hunting & trapping	0.0055	0.0028	1.4497	0.0420	0.0183	0.0554	1.5738
8	Agirculture & veterinary services	0.0126	0.0046	1.8442	0.0594	0.0105	0.0677	1.9988
9	Oil & gas extraction & support services	0.0121	0.0019	1.4313	0.0288	0.0064	0.0942	1.5746
10	Other mining	0.0127	0.0033	1.5197	0.0366	0.0079	0.0528	1.6331
11	Electrical power & utilities	0.0050	0.0015	1.3402	0.0215	0.0049	0.0438	1.4169
12	Construction	0.0134	0.0057	1.7386	0.0532	0.0114	0.0639	1.8862
13	Animal feed	0.0208	0.0054	1.7008	0.0813	0.0295	0.0545	1.8923
14	Flour & grain mlling	0.0130	0.0028	1.6206	0.0917	0.0280	0.0524	1.8085
15	Animal slaughtering, except poultry	0.0208	0.0302	1.8301	0.0854	0.0312	0.1983	2.1960
16	Meat processed from carcasses	0.0270	0.0093	1.7148	0.0759	0.0873	0.0986	2.0129
17	Rendering and meat byproduct processing	0.0199	0.0060	1.6701	0.0482	0.0184	0.0485	1.8112
18	Poultry processing	0.0871	0.0147	1.8610	0.0877	0.0136	0.0708	2.1348
19	Other food products	0.0258	0.0071	1.5761	0.0630	0.0170	0.0650	1.7540
20	Textiles, apparel & leather goods	0.0142	0.0024	1.4907	0.0363	0.0068	0.0353	1.5858
21	Sawmills & lumber products	0.0128	0.0050	2.0842	0.0409	0.0095	0.0487	2.2011
22	Pulp & paper products	0.0173	0.0030	1.6557	0.0420	0.0093	0.0476	1.7750
23	Petroleum refining & products	0.0097	0.0017	1.3939	0.0344	0.0105	0.1396	1.5898
24	Agricultural chemicals	0.0139	0.0023	1.4807	0.0394	0.0090	0.0670	1.6124
25	Other chemicals & chemical products	0.0182	0.0024	1.4779	0.0506	0.0154	0.0588	1.6233
26	Plastics & plastic products	0.0167	0.0025	1.4804	0.0435	0.0117	0.0444	1.5992
27	Tires & rubber products	0.0199	0.0026	1.5535	0.0425	0.0097	0.0423	1.6706
28	Clay, ceramic & glass products	0.0191	0.0033	1.6625	0.0491	0.0099	0.0540	1.7978
29	Cement, stone & other nonmetallic products	0.0176	0.0052	1.6118	0.0456	0.0115	0.0548	1.7466
30	Iron, steel & nonferrous metals	0.0142	0.0032	1.5941	0.0544	0.0106	0.0503	1.7268
31	Metal products	0.0153	0.0030	1.5747	0.0489	0.0132	0.0468	1.7018
32	Farm, lawn & garden machinery	0.0174	0.0047	1.4793	0.0504	0.0141	0.0384	1.6042
33	Other nonelectrical machinery & equipment	0.0192	0.0037	1.5814	0.0556	0.0177	0.0520	1.7297
34	Computers & equipment	0.0123	0.0023	1.4382	0.0391	0.0080	0.0388	1.5387
35	Electrical machinery & equipment	0.0166	0.0026	1.5136	0.0417	0.0089	0.0401	1.6234
36	Appliances	0.0200	0.0037	1.5548	0.0587	0.0121	0.0512	1.7005
37	Electronic & controlling equipment	0.0150	0.0026	1.4852	0.0431	0.0098	0.0414	1.5972
38	Transportation equipment	0.0161	0.0032	1.4729	0.0468	0.0167	0.0438	1.5995
39	Furniture & fixtures	0.0163	0.0034	1.6860	0.0472	0.0099	0.0478	1.8107
40	Instruments & testing equipment	0.0178	0.0028	1.5668	0.0450	0.0096	0.0445	1.6865
41	Miscellaneous manufacturing	0.0184	0.0037	1.6371	0.0515	0.0140	0.0491	1.7738
42	Transportation	0.0170	0.0040	1.7609	0.0488	0.0098	0.0655	1.9061
43	Wholesale & retail trade	0.0137	0.0025	1.5865	0.0369	0.0057	0.0375	1.6828
44	Printing & publishing	0.0147	0.0029	1.6548	0.0447	0.0095	0.0542	1.7808
45	Software development & recording	0.0106	0.0031	1.6935	0.0485	0.0102	0.0500	1.8159
46	Radio, TV & motion picture recording	0.0067	0.0020	1.6140	0.0331	0.0054	0.0376	1.6987
47	Finance & insurance	0.0076	0.0021	1.7037	0.0370	0.0050	0.0322	1.7876
48	Real estate	0.0027	0.0010	1.2616	0.0212	0.0024	0.0125	1.3014
49	Rental services	0.0089	0.0029	1.6278	0.0384	0.0059	0.0452	1.7290
50	Accounting, design & legal services	0.0093	0.0031	1.7216	0.0384	0.0067	0.0469	1.8260
51	Admin, management & support services	0.0084	0.0029	1.7248	0.0436	0.0071	0.0445	1.8313
52	Research, technical & consulting services	0.0080	0.0026	1.6288	0.0344	0.0067	0.0424	1.7228
53	Other business support services	0.0154	0.0032	1.7461	0.0455	0.0078	0.0531	1.8710
54	Educational services	0.0095	0.0034	1.7874	0.0413	0.0075	0.0479	1.8971
55	Health care services	0.0120	0.0032	1.7429	0.0431	0.0081	0.0492	1.8585
56	Child care & social services	0.0142	0.0038	1.7393	0.0454	0.0095	0.0532	1.8654
57	Recreation & amusement services	0.0117	0.0037	1.7357	0.0430	0.0071	0.0464	1.8477
58	Hotels & accommodations	0.0076	0.0026	1.4676	0.0268	0.0046	0.0316	1.5409
59	Food & drinking places	0.0157	0.0080	1.7345	0.0504	0.0156	0.0543	1.8785
60	Equipment maintenance & repair services	0.0140	0.0034	1.6225	0.0470	0.0108	0.0463	1.7440
61	Personal services	0.0126	0.0034	1.7895	0.0465	0.0083	0.0492	1.9096
62	Civic orgranizations	0.0111	0.0038	1.8282	0.0498	0.0088	0.0542	1.9560
63	Other govt enterprises	0.0055	0.0021	1.4214	0.0233	0.0068	0.0311	1.4903

Table C-4. Interregional Column Multipliers for Rest of Missouri

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	0.0042	0.0057	0.0155	1.5103	0.0556	0.0207	1.6119
2	Other crop farming	0.0044	0.0062	0.0136	1.4087	0.0454	0.0178	1.4960
3	Cattle ranching & farming	0.0267	0.0200	0.0406	1.8298	0.1441	0.0444	2.1056
4	Poultry farming & egg production	0.0163	0.0402	0.0430	1.6987	0.0869	0.0235	1.9085
5	Hogs & other animal farming	0.0145	0.0322	0.0484	1.8273	0.0996	0.0311	2.0531
6	Logging & forest products	0.0131	0.0333	0.0775	1.8347	0.0651	0.0251	2.0488
7	Commercial fishing, hunting & trapping	0.0088	0.0095	0.0457	1.5810	0.1148	0.0406	1.8004
8	Agirculture & veterinary services	0.0117	0.0207	0.0143	2.0528	0.1162	0.0282	2.2438
9	Oil & gas extraction & support services	0.0067	0.0095	0.0122	1.5632	0.0936	0.1123	1.7975
10	Other mining	0.0080	0.0128	0.0116	1.6653	0.0703	0.0267	1.7947
11	Electrical power & utilities	0.0046	0.0066	0.0130	1.3696	0.0852	0.0778	1.5568
12	Construction	0.0120	0.0183	0.0210	1.9241	0.1133	0.0301	2.1188
13	Animal feed	0.0127	0.0153	0.0728	1.7097	0.0951	0.0262	1.9320
14	Flour & grain mlling	0.0086	0.0103	0.0506	1.7956	0.1160	0.0223	2.0033
15	Animal slaughtering, except poultry	0.0622	0.0242	0.0321	2.0048	0.2676	0.0658	2.4568
16	Meat processed from carcasses	0.0309	0.0197	0.0200	1.8152	0.1882	0.0417	2.1156
17	Rendering and meat byproduct processing	0.0118	0.0109	0.0601	1.5788	0.0825	0.0380	1.7821
18	Poultry processing	0.1198	0.0772	0.0884	1.8524	0.0790	0.0702	2.2870
19	Other food products	0.0171	0.0174	0.0184	1.7173	0.0987	0.0252	1.8940
20	Textiles, apparel & leather goods	0.0089	0.0112	0.0083	1.6457	0.0743	0.0175	1.7659
21	Sawmills & lumber products	0.0159	0.0378	0.0852	2.0365	0.0872	0.0263	2.2889
22	Pulp & paper products	0.0115	0.0120	0.0377	1.6716	0.0808	0.0265	1.8401
23	Petroleum refining & products	0.0115	0.0121	0.0237	1.7473	0.0919	0.0882	1.9748
24	Agricultural chemicals	0.0080	0.0098	0.0108	1.6133	0.0656	0.0197	1.7273
25	Other chemicals & chemical products	0.0105	0.0104	0.0158	1.7583	0.0833	0.0373	1.9157
26	Plastics & plastic products	0.0106	0.0109	0.0122	1.6385	0.0792	0.0235	1.7750
27	Tires & rubber products	0.0108	0.0116	0.0170	1.6698	0.0745	0.0213	1.8050
28	Clay, ceramic & glass products	0.0140	0.0154	0.0192	1.8331	0.0953	0.0275	2.0046
29	Cement, stone & other nonmetallic products	0.0132	0.0136	0.0188	1.8276	0.0909	0.0284	1.9923
30	Iron, steel & nonferrous metals	0.0096	0.0116	0.0183	1.6570	0.0805	0.0262	1.8032
31	Metal products	0.0095	0.0123	0.0204	1.6922	0.0855	0.0231	1.8429
32	Farm, lawn & garden machinery	0.0101	0.0157	0.0185	1.5890	0.0797	0.0194	1.7324
33	Other nonelectrical machinery & equipment	0.0107	0.0140	0.0190	1.7224	0.0901	0.0254	1.8817
34	Computers & equipment	0.0074	0.0103	0.0078	1.6355	0.0726	0.0162	1.7497
35	Electrical machinery & equipment	0.0094	0.0133	0.0103	1.7640	0.0845	0.0198	1.9014
36	Appliances	0.0098	0.0114	0.0164	1.6797	0.0791	0.0194	1.8157
37	Electronic & controlling equipment	0.0085	0.0116	0.0137	1.6371	0.0724	0.0180	1.7614
38	Transportation equipment	0.0093	0.0111	0.0127	1.5011	0.0632	0.0188	1.6162
39	Furniture & fixtures	0.0108	0.0155	0.0298	1.7786	0.0852	0.0226	1.9425
40	Instruments & testing equipment	0.0104	0.0130	0.0102	1.7253	0.0796	0.0194	1.8579
41	Miscellaneous manufacturing	0.0116	0.0148	0.0172	1.7820	0.0920	0.0232	1.9408
42	Transportation	0.0127	0.0183	0.0126	1.9022	0.1110	0.0338	2.0907
43	Wholesale & retail trade	0.0080	0.0120	0.0077	1.7317	0.0775	0.0177	1.8546
44	Printing & publishing	0.0093	0.0128	0.0187	1.7646	0.0974	0.0227	1.9255
45	Software development & recording	0.0090	0.0137	0.0106	1.8554	0.1133	0.0229	2.0248
46	Radio, TV & motion picture recording	0.0060	0.0085	0.0066	1.6992	0.1032	0.0206	1.8441
47	Finance & insurance	0.0073	0.0102	0.0097	1.9304	0.0986	0.0172	2.0733
48	Real estate	0.0026	0.0044	0.0036	1.3619	0.0405	0.0073	1.4204
49	Rental services	0.0074	0.0112	0.0083	1.8123	0.0887	0.0211	1.9491
50	Accounting, design & legal services	0.0088	0.0146	0.0090	1.8862	0.1060	0.0222	2.0468
51	Admin, management & support services	0.0076	0.0124	0.0088	1.8351	0.0946	0.0202	1.9787
52	Research, technical & consulting services	0.0080	0.0130	0.0088	1.7998	0.0953	0.0211	1.9461
53	Other business support services	0.0096	0.0142	0.0101	1.9084	0.1047	0.0252	2.0722
54	Educational services	0.0089	0.0150	0.0102	1.9712	0.1096	0.0228	2.1376
55	Health care services	0.0099	0.0145	0.0104	1.9302	0.1049	0.0241	2.0940
56	Child care & social services	0.0122	0.0155	0.0129	1.9276	0.1063	0.0268	2.1012
57	Recreation & amusement services	0.0087	0.0141	0.0097	1.8683	0.0932	0.0212	2.0152
58	Hotels & accommodations	0.0058	0.0095	0.0063	1.5625	0.0624	0.0147	1.6612
59	Food & drinking places	0.0226	0.0248	0.0174	1.8935	0.1063	0.0281	2.0927
60	Equipment maintenance & repair services	0.0101	0.0139	0.0116	1.7860	0.0939	0.0234	1.9390
61	Personal services	0.0096	0.0195	0.0116	1.9378	0.1030	0.0236	2.1051
62	Civic orgranizations	0.0098	0.0148	0.0111	2.0359	0.1180	0.0255	2.2152
63	Other govt enterprises	0.0056	0.0079	0.0084	1.4961	0.0587	0.0198	1.5965

Table C-5. Interregional Column Multipliers for State of Kansas

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	0.0021	0.0024	0.0071	0.0795	1.3266	0.0358	1.4534
2	Other crop farming	0.0021	0.0023	0.0054	0.0679	1.2811	0.0315	1.3904
3	Cattle ranching & farming	0.0049	0.0064	0.0099	0.1179	1.7088	0.0726	1.9205
4	Poultry farming & egg production	0.0074	0.0103	0.0125	0.1430	1.5888	0.0477	1.8096
5	Hogs & other animal farming	0.0063	0.0087	0.0115	0.1419	1.6367	0.0660	1.8711
6	Logging & forest products	0.0037	0.0142	0.0155	0.1411	1.4346	0.0813	1.6903
7	Commercial fishing, hunting & trapping	0.0038	0.0053	0.0189	0.0857	1.3547	0.0621	1.5305
8	Agirculture & veterinary services	0.0052	0.0075	0.0070	0.2001	1.8891	0.0648	2.1737
9	Oil & gas extraction & support services	0.0042	0.0034	0.0040	0.0974	1.4511	0.0563	1.6165
10	Other mining	0.0053	0.0049	0.0050	0.1277	1.5361	0.0503	1.7293
11	Electrical power & utilities	0.0025	0.0032	0.0041	0.0877	1.3323	0.0554	1.4851
12	Construction	0.0060	0.0105	0.0110	0.2093	1.7630	0.0655	2.0653
13	Animal feed	0.0083	0.0065	0.0109	0.1840	1.5321	0.0563	1.7982
14	Flour & grain mlling	0.0048	0.0041	0.0131	0.1585	1.6077	0.0488	1.8369
15	Animal slaughtering, except poultry	0.0096	0.0089	0.0145	0.1489	2.0017	0.1232	2.3069
16	Meat processed from carcasses	0.0143	0.0147	0.0127	0.1987	1.8585	0.0994	2.1982
17	Rendering and meat byproduct processing	0.0075	0.0075	0.0070	0.1254	1.4949	0.0579	1.7002
18	Poultry processing	0.0559	0.0734	0.0662	0.3194	1.4959	0.0918	2.1026
19	Other food products	0.0087	0.0080	0.0092	0.1692	1.5813	0.0491	1.8255
20	Textiles, apparel & leather goods	0.0053	0.0046	0.0044	0.1397	1.5042	0.0369	1.6951
21	Sawmills & lumber products	0.0062	0.0104	0.0279	0.1939	1.5720	0.0652	1.8757
22	Pulp & paper products	0.0075	0.0057	0.0273	0.1560	1.5272	0.0546	1.7782
23	Petroleum refining & products	0.0034	0.0024	0.0064	0.0716	1.3380	0.1135	1.5353
24	Agricultural chemicals	0.0054	0.0043	0.0081	0.1349	1.4882	0.0656	1.7066
25	Other chemicals & chemical products	0.0067	0.0045	0.0086	0.1514	1.4904	0.0585	1.7201
26	Plastics & plastic products	0.0072	0.0050	0.0086	0.1452	1.4908	0.0466	1.7034
27	Tires & rubber products	0.0118	0.0053	0.0183	0.1466	1.5028	0.0484	1.7331
28	Clay, ceramic & glass products	0.0075	0.0062	0.0074	0.1684	1.6138	0.0600	1.8632
29	Cement, stone & other nonmetallic products	0.0071	0.0062	0.0101	0.1751	1.5767	0.0610	1.8362
30	Iron, steel & nonferrous metals	0.0059	0.0061	0.0091	0.1557	1.5626	0.0582	1.7976
31	Metal products	0.0058	0.0056	0.0098	0.1539	1.5308	0.0518	1.7577
32	Farm, lawn & garden machinery	0.0066	0.0082	0.0081	0.1493	1.5027	0.0522	1.7272
33	Other nonelectrical machinery & equipment	0.0070	0.0072	0.0098	0.1647	1.5515	0.0520	1.7921
34	Computers & equipment	0.0043	0.0042	0.0040	0.1313	1.4973	0.0322	1.6732
35	Electrical machinery & equipment	0.0059	0.0053	0.0054	0.1417	1.5190	0.0344	1.7117
36	Appliances	0.0063	0.0057	0.0078	0.1591	1.5774	0.0415	1.7978
37	Electronic & controlling equipment	0.0058	0.0052	0.0060	0.1470	1.5256	0.0389	1.7286
38	Transportation equipment	0.0051	0.0050	0.0067	0.1301	1.4240	0.0381	1.6090
39	Furniture & fixtures	0.0064	0.0076	0.0174	0.1830	1.6055	0.0511	1.8710
40	Instruments & testing equipment	0.0076	0.0056	0.0058	0.1614	1.5568	0.0385	1.7758
41	Miscellaneous manufacturing	0.0073	0.0081	0.0102	0.1789	1.6297	0.0507	1.8849
42	Transportation	0.0066	0.0083	0.0068	0.2180	1.7510	0.0719	2.0625
43	Wholesale & retail trade	0.0051	0.0052	0.0041	0.1600	1.5992	0.0371	1.8108
44	Printing & publishing	0.0053	0.0056	0.0122	0.1688	1.6004	0.0451	1.8375
45	Software development & recording	0.0049	0.0066	0.0062	0.2016	1.7310	0.0506	2.0008
46	Radio, TV & motion picture recording	0.0028	0.0041	0.0035	0.1350	1.5877	0.0338	1.7670
47	Finance & insurance	0.0035	0.0047	0.0035	0.1771	1.7745	0.0359	1.9993
48	Real estate	0.0012	0.0019	0.0017	0.0598	1.3019	0.0156	1.3822
49	Rental services	0.0033	0.0044	0.0037	0.1293	1.6116	0.0452	1.7976
50	Accounting, design & legal services	0.0043	0.0066	0.0049	0.1861	1.7795	0.0480	2.0293
51	Admin, management & support services	0.0041	0.0059	0.0050	0.1850	1.7865	0.0558	2.0422
52	Research, technical & consulting services	0.0033	0.0050	0.0040	0.1438	1.6095	0.0421	1.8077
53	Other business support services	0.0054	0.0065	0.0053	0.1875	1.7736	0.0551	2.0333
54	Educational services	0.0042	0.0061	0.0052	0.1718	1.7957	0.0509	2.0339
55	Health care services	0.0051	0.0067	0.0057	0.1850	1.7799	0.0514	2.0339
56	Child care & social services	0.0066	0.0085	0.0073	0.1952	1.7879	0.0593	2.0646
57	Recreation & amusement services	0.0047	0.0061	0.0049	0.1788	1.7479	0.0474	1.9900
58	Hotels & accommodations	0.0032	0.0043	0.0033	0.1196	1.4850	0.0302	1.6456
59	Food & drinking places	0.0095	0.0182	0.0096	0.1940	1.7442	0.0571	2.0326
60	Equipment maintenance & repair services	0.0056	0.0072	0.0067	0.1674	1.6569	0.0513	1.8952
61	Personal services	0.0053	0.0143	0.0063	0.1894	1.8064	0.0547	2.0764
62	Civic orgranizations	0.0048	0.0068	0.0060	0.2064	1.8824	0.0614	2.1677
63	Other govt enterprises	0.0028	0.0039	0.0040	0.0919	1.4455	0.0356	1.5838

Table C-6. Interregional Column Multipliers for State of Oklahoma

	Industry	WR-AR	WR-MO	RofAR	RofMO	KS	OK	Total
1	Oilseed & grain farming	0.0103	0.0053	0.0288	0.0372	0.0383	1.7341	1.8540
2	Other crop farming	0.0101	0.0051	0.0259	0.0327	0.0321	1.6650	1.7708
3	Cattle ranching & farming	0.0138	0.0116	0.0617	0.0503	0.0828	1.7369	1.9571
4	Poultry farming & egg production	0.0318	0.0342	0.0740	0.1068	0.0983	1.8148	2.1598
5	Hogs & other animal farming	0.0211	0.0225	0.0685	0.0779	0.0853	1.6826	1.9580
6	Logging & forest products	0.0095	0.0068	0.0655	0.0304	0.0360	1.6710	1.8192
7	Commercial fishing, hunting & trapping	0.0066	0.0044	0.0375	0.0328	0.0474	1.3987	1.5273
8	Agiculture & veterinary services	0.0139	0.0078	0.0245	0.0435	0.0383	2.0146	2.1425
9	Oil & gas extraction & support services	0.0174	0.0037	0.0198	0.0248	0.0240	1.6216	1.7112
10	Other mining	0.0250	0.0055	0.0290	0.0416	0.0317	1.6917	1.8245
11	Electrical power & utilities	0.0070	0.0034	0.0275	0.0160	0.0194	1.5591	1.6325
12	Construction	0.0162	0.0100	0.0440	0.0427	0.0420	1.9181	2.0729
13	Animal feed	0.0276	0.0133	0.0551	0.0760	0.0846	1.6177	1.8743
14	Flour & grain mlling	0.0159	0.0040	0.0437	0.0683	0.0695	1.6329	1.8344
15	Animal slaughtering, except poultry	0.0209	0.0113	0.0429	0.0549	0.1235	1.9980	2.2516
16	Meat processed from carcasses	0.0396	0.0102	0.0442	0.0663	0.2245	1.7712	2.1562
17	Rendering and meat byproduct processing	0.0274	0.0076	0.0325	0.0358	0.0653	1.6416	1.8102
18	Poultry processing	0.1283	0.0424	0.2066	0.1106	0.0339	1.7302	2.2519
19	Other food products	0.0344	0.0074	0.0338	0.0523	0.0593	1.7210	1.9082
20	Textiles, apparel & leather goods	0.0209	0.0044	0.0146	0.0272	0.0213	1.5983	1.6867
21	Sawmills & lumber products	0.0156	0.0093	0.1477	0.0330	0.0302	1.8605	2.0963
22	Pulp & paper products	0.0278	0.0058	0.0661	0.0374	0.0285	1.7151	1.8806
23	Petroleum refining & products	0.0116	0.0035	0.0354	0.0194	0.0246	1.6864	1.7810
24	Agricultural chemicals	0.0154	0.0040	0.0232	0.0220	0.0206	1.6272	1.7124
25	Other chemicals & chemical products	0.0208	0.0045	0.0209	0.0319	0.0245	1.5907	1.6933
26	Plastics & plastic products	0.0234	0.0047	0.0257	0.0389	0.0304	1.5879	1.7111
27	Tires & rubber products	0.0299	0.0052	0.0383	0.0353	0.0256	1.6592	1.7935
28	Clay, ceramic & glass products	0.0260	0.0066	0.0476	0.0400	0.0324	1.7556	1.9082
29	Cement, stone & other nonmetallic products	0.0267	0.0068	0.0586	0.0843	0.0456	1.7250	1.9470
30	Iron, steel & nonferrous metals	0.0198	0.0058	0.0325	0.0401	0.0358	1.7584	1.8924
31	Metal products	0.0214	0.0056	0.0309	0.0409	0.0363	1.6992	1.8344
32	Farm, lawn & garden machinery	0.0286	0.0088	0.0288	0.0527	0.0378	1.6766	1.8333
33	Other nonelectrical machinery & equipment	0.0261	0.0074	0.0307	0.0496	0.0399	1.7225	1.8762
34	Computers & equipment	0.0169	0.0045	0.0145	0.0297	0.0218	1.6175	1.7050
35	Electrical machinery & equipment	0.0249	0.0055	0.0191	0.0334	0.0252	1.6724	1.7805
36	Appliances	0.0270	0.0056	0.0316	0.0485	0.0346	1.6171	1.7645
37	Electronic & controlling equipment	0.0253	0.0061	0.0254	0.0421	0.0271	1.6353	1.7614
38	Transportation equipment	0.0214	0.0066	0.0260	0.0429	0.0340	1.5181	1.6491
39	Furniture & fixtures	0.0229	0.0068	0.0657	0.0413	0.0355	1.7407	1.9128
40	Instruments & testing equipment	0.0274	0.0056	0.0205	0.0363	0.0281	1.6944	1.8123
41	Miscellaneous manufacturing	0.0222	0.0070	0.0340	0.0426	0.0354	1.7484	1.8896
42	Transportation	0.0188	0.0103	0.0259	0.0363	0.0407	1.9637	2.0958
43	Wholesale & retail trade	0.0216	0.0052	0.0163	0.0288	0.0207	1.7270	1.8196
44	Printing & publishing	0.0206	0.0056	0.0353	0.0370	0.0293	1.7772	1.9051
45	Software development & recording	0.0144	0.0067	0.0207	0.0330	0.0285	1.9876	2.0908
46	Radio, TV & motion picture recording	0.0074	0.0033	0.0114	0.0183	0.0158	1.7303	1.7866
47	Finance & insurance	0.0122	0.0042	0.0179	0.0214	0.0207	1.8817	1.9581
48	Real estate	0.0038	0.0017	0.0068	0.0087	0.0097	1.3382	1.3689
49	Rental services	0.0099	0.0046	0.0111	0.0186	0.0171	1.5829	1.6441
50	Accounting, design & legal services	0.0122	0.0062	0.0185	0.0275	0.0244	1.9160	2.0048
51	Admin, management & support services	0.0127	0.0055	0.0188	0.0283	0.0260	1.9550	2.0463
52	Research, technical & consulting services	0.0109	0.0055	0.0175	0.0259	0.0237	1.8301	1.9137
53	Other business support services	0.0236	0.0065	0.0208	0.0348	0.0274	1.9550	2.0682
54	Educational services	0.0128	0.0061	0.0192	0.0284	0.0260	1.9605	2.0530
55	Health care services	0.0167	0.0064	0.0209	0.0326	0.0275	1.9445	2.0486
56	Child care & social services	0.0210	0.0075	0.0262	0.0374	0.0313	1.9270	2.0505
57	Recreation & amusement services	0.0171	0.0066	0.0191	0.0314	0.0250	1.8877	1.9868
58	Hotels & accommodations	0.0110	0.0052	0.0131	0.0205	0.0176	1.5852	1.6524
59	Food & drinking places	0.0226	0.0149	0.0400	0.0468	0.0446	1.8754	2.0443
60	Equipment maintenance & repair services	0.0191	0.0070	0.0221	0.0382	0.0315	1.7899	1.9079
61	Personal services	0.0179	0.0196	0.0229	0.0404	0.0307	1.9624	2.0940
62	Civic orgranizations	0.0152	0.0064	0.0207	0.0343	0.0296	2.0742	2.1805
63	Other govt enterprises	0.0066	0.0036	0.0151	0.0192	0.0197	1.5304	1.5945

Table C-7. Industrial Impacts Occurring in the White River Basin in Arkansas by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$1.3	0	-$0.1	-$0.1	-$0.5	$0.0
Cattle ranching & farming	-$10.4	0	-$0.4	$0.0	-$0.3	-$0.3
Poultry & eggs	-$9,830.6	-34	-$713.3	-$573.5	-$2,051.3	-$50.2
Hogs & other animals	-$0.9	0	$0.0	$0.0	-$0.1	$0.0
Other agriculture	-$150.7	-3	-$50.6	-$19.0	-$0.1	-$3.6
Mining	-$0.1	0	$0.0	$0.0	$0.0	$0.0
Utilities	-$145.7	0	-$23.0	-$1.5	-$46.9	-$12.2
Construction	-$89.4	-1	-$23.8	-$6.6	-$2.4	-$0.4
Animal feed	-$1,826.0	-3	-$147.5	-$0.7	-$52.6	-$13.3
Meat processing	-$0.4	0	$0.0	$0.0	$0.0	$0.0
Poultry processing	-$1,689.6	-10	-$313.5	-$3.4	-$0.5	-$14.4
Other Manufacturing	-$0.8	0	$0.0	$0.0	$0.0	$0.0
Transportation	-$975.7	-8	-$302.2	-$13.4	-$102.4	-$12.9
Wholesale & retail trade	-$1,580.2	-22	-$609.9	-$55.6	-$253.0	-$253.4
Communications	-$78.4	0	-$17.2	-$5.2	-$16.3	-$4.5
Finance, Insurance & Real Estate	-$967.2	-5	-$128.9	-$27.3	-$427.6	-$71.3
Business services	-$948.6	-8	-$436.1	-$19.5	-$182.0	-$11.4
Personal & other services	-$1,033.6	-16	-$406.0	-$49.4	-$97.9	-$11.7
Total	-$19,329.7	-111	-$3,172.7	-$775.2	-$3,234.0	-$459.7

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs

Table C-8. Industrial Impacts Occurring in the White River Basin in Missouri by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$1.1	0	-$0.1	$0.0	-$0.6	$0.0
Cattle ranching & farming	-$9.7	0	-$0.3	-$0.7	-$0.5	-$0.3
Poultry & eggs	-$3,114.1	-15	-$135.9	$0.0	-$1,090.7	-$15.9
Hogs & other animals	-$0.9	0	$0.0	$0.0	-$0.1	$0.0
Other agriculture	-$50.6	-1	-$16.3	-$8.3	-$0.2	-$1.2
Mining	-$0.1	0	$0.0	$0.0	$0.0	$0.0
Utilities	-$160.6	0	-$18.5	-$3.0	-$92.5	-$7.1
Construction	-$108.0	-1	-$28.3	-$11.2	-$3.6	-$0.5
Animal feed	-$873.4	-1	-$73.0	-$2.4	-$29.0	-$6.7
Meat processing	-$3.2	0	-$0.6	$0.0	-$0.4	$0.0
Poultry processing	-$5,409.4	-33	-$984.6	-$49.7	-$1.5	-$46.7
Other Manufacturing	-$1.0	0	-$0.1	$0.0	$0.0	$0.0
Transportation	-$654.8	-6	-$199.5	-$41.0	-$54.3	-$9.6
Wholesale & retail trade	-$1,372.8	-19	-$505.5	-$86.1	-$208.9	-$212.0
Communications	-$230.5	-2	-$57.5	-$14.1	-$40.0	-$10.1
Finance, Insurance & Real Estate	-$1,042.8	-6	-$159.9	-$23.4	-$418.5	-$75.8
Business services	-$601.2	-7	-$241.1	-$44.1	-$99.3	-$8.4
Personal & other services	-$1,139.2	-17	-$461.5	-$39.5	-$69.7	-$15.3
Total	-$14,773.6	-108	-$2,882.7	-$323.5	-$2,109.9	-$409.6

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs

Table C-9. Industrial Impacts Occurring in Rest of Arkansas by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$55.9	-1	-$1.6	-$9.6	-$13.5	-$1.6
Cattle ranching & farming	-$3.4	0	-$0.2	$0.0	$0.0	-$0.1
Poultry & eggs	$40.1	0	$2.9	$2.3	$8.4	$0.2
Hogs & other animals	-$0.7	0	-$0.1	$0.0	$0.0	$0.0
Other agriculture	-$32.5	0	-$1.5	-$2.2	-$5.5	-$0.5
Mining	-$4.8	0	-$0.7	-$0.7	-$1.1	-$0.3
Utilities	-$147.5	0	-$25.9	-$1.4	-$59.9	-$13.7
Construction	-$94.4	-1	-$25.6	-$6.2	-$2.5	-$0.4
Animal feed	-$143.7	0	-$12.8	-$0.1	-$4.7	-$1.2
Meat processing	-$21.7	0	-$3.4	$0.0	-$2.3	-$0.2
Poultry processing	-$742.2	-5	-$132.9	-$1.7	-$0.2	-$6.1
Other Manufacturing	-$132.1	0	-$9.4	-$0.1	-$4.9	-$1.0
Transportation	-$1,378.1	-9	-$403.9	-$37.9	-$130.0	-$26.1
Wholesale & retail trade	-$1,018.1	-15	-$398.5	-$45.0	-$154.9	-$156.0
Communications	-$175.5	-1	-$39.1	-$22.8	-$34.7	-$9.0
Finance, Insurance & Real Estate	-$850.9	-5	-$158.8	-$22.3	-$300.7	-$45.2
Business services	-$118.7	-3	-$44.9	-$12.5	-$12.3	-$2.3
Personal & other services	-$923.7	-13	-$384.6	-$43.2	-$71.7	-$9.0
Total	-$5,803.9	-54	-$1,641.0	-$203.3	-$790.5	-$272.5

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs

Table C-10. Industrial Impacts Occurring in Rest of Missouri by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$129.7	-4	-$2.9	$0.0	-$49.6	-$3.9
Cattle ranching & farming	-$19.1	0	-$1.1	-$1.5	-$0.6	-$0.6
Poultry & eggs	-$309.2	-2	-$25.5	$0.0	-$96.3	-$1.6
Hogs & other animals	-$4.8	0	-$0.6	$0.0	-$0.2	-$0.1
Other agriculture	-$73.1	-2	-$28.5	-$14.7	-$0.9	-$1.5
Mining	-$9.3	0	-$1.5	-$0.5	-$1.4	-$0.3
Utilities	-$590.6	-1	-$105.1	-$10.6	-$189.3	-$58.4
Construction	-$338.7	-3	-$112.5	-$23.1	-$12.0	-$1.7
Animal feed	-$1,208.3	-2	-$141.6	-$5.9	-$112.6	-$13.0
Meat processing	-$38.3	0	-$5.4	-$0.2	-$1.0	-$0.3
Poultry processing	-$385.5	-2	-$73.0	-$4.2	-$0.1	-$3.5
Other Manufacturing	-$116.0	0	-$8.2	-$0.4	-$4.4	-$1.0
Transportation	-$4,641.6	-28	-$1,403.9	-$109.9	-$477.1	-$140.0
Wholesale & retail trade	-$6,658.7	-82	-$2,624.5	-$226.8	-$1,028.5	-$1,037.8
Communications	-$2,005.1	-10	-$617.4	-$151.9	-$349.9	-$80.8
Finance, Insurance & Real Estate	-$6,312.9	-32	-$1,252.8	-$195.1	-$2,112.1	-$362.1
Business services	-$5,040.1	-43	-$2,350.0	-$185.5	-$856.5	-$64.2
Personal & other services	-$3,562.4	-52	-$1,513.2	-$140.6	-$217.4	-$57.9
Total	-$31,443.5	-263	-$10,267.7	-$1,070.9	-$5,509.9	-$1,828.5

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs

Table C-11. Industrial Impacts Occurring in Kansas by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$115.5	-2	-$2.5	$0.0	-$43.1	-$3.2
Cattle ranching & farming	-$53.5	0	-$2.6	-$4.6	-$2.0	-$1.7
Poultry & eggs	-$9.9	0	-$0.6	$0.0	-$3.3	-$0.1
Hogs & other animals	$0.4	0	$0.0	$0.0	$0.0	$0.0
Other agriculture	-$14.2	0	-$4.4	-$3.5	-$0.4	-$0.4
Mining	-$7.9	0	-$1.0	-$1.3	-$1.8	-$0.6
Utilities	-$162.7	0	-$24.6	-$4.2	-$58.1	-$15.0
Construction	-$78.1	-1	-$23.2	-$5.4	-$2.8	-$0.4
Animal feed	-$252.1	0	-$26.6	-$0.2	-$20.4	-$2.4
Meat processing	-$166.3	0	-$20.0	-$0.1	-$2.8	-$1.5
Poultry processing	-$4.7	0	-$1.1	$0.0	$0.0	-$0.1
Other Manufacturing	-$117.8	0	-$9.1	-$0.1	-$6.4	-$0.9
Transportation	-$1,032.7	-6	-$300.4	-$41.5	-$106.8	-$16.0
Wholesale & retail trade	-$1,546.1	-20	-$602.1	-$64.3	-$238.5	-$239.8
Communications	-$454.9	-2	-$124.1	-$23.6	-$100.5	-$27.0
Finance, Insurance & Real Estate	-$1,385.1	-7	-$261.6	-$45.5	-$461.1	-$75.5
Business services	-$504.1	-6	-$203.9	-$31.7	-$70.2	-$6.9
Personal & other services	-$994.4	-15	-$395.3	-$46.0	-$67.7	-$12.5
Total	-$6,899.7	-62	-$2,003.2	-$272.1	-$1,186.1	-$403.7

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs

Table C-12. Industrial Impacts Occurring in Oklahoma by Type

Sector	Output	Employ-ment	Employee Compensation	Proprietors' Income	Other Property-Type Income	Indirect Business Taxes
Crop farming	-$26.9	-1	-$1.2	-$10.4	-$1.7	-$0.7
Cattle ranching & farming	-$44.3	-1	-$1.8	$0.0	-$1.0	-$1.4
Poultry & eggs	-$160.7	-1	-$8.7	-$25.0	-$11.6	-$0.8
Hogs & other animals	-$3.1	0	-$0.3	$0.0	-$0.2	-$0.1
Other agriculture	-$24.1	-1	-$6.7	-$3.8	-$1.2	-$0.6
Mining	-$111.4	0	-$17.8	-$13.6	-$26.9	-$8.6
Utilities	-$322.3	-1	-$44.5	-$16.5	-$88.0	-$32.6
Construction	-$151.0	-2	-$38.3	-$13.2	-$4.3	-$0.7
Animal feed	-$148.0	0	-$12.1	-$0.9	-$7.6	-$1.2
Meat processing	-$61.7	0	-$8.1	-$0.5	-$1.6	-$0.5
Poultry processing	-$598.4	-4	-$103.5	-$9.5	-$0.2	-$5.1
Other Manufacturing	-$46.9	0	-$3.3	-$0.3	-$1.5	-$0.4
Transportation	-$1,873.1	-12	-$525.7	-$113.0	-$134.2	-$50.9
Wholesale & retail trade	-$2,256.7	-32	-$856.3	-$124.5	-$345.5	-$346.6
Communications	-$655.2	-3	-$120.1	-$33.1	-$171.9	-$32.9
Finance, Insurance & Real Estate	-$2,101.3	-13	-$376.0	-$69.9	-$693.2	-$106.0
Business services	-$1,455.8	-18	-$514.5	-$91.8	-$303.2	-$24.2
Personal & other services	-$1,514.2	-24	-$573.7	-$73.1	-$111.6	-$18.9
Total	-$11,555.0	-110	-$3,212.7	-$599.0	-$1,905.4	-$632.1

Note: All monetary values are in thousands of 2007 dollars and employment is in full and part-time jobs.

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