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Arkansas Water Resources Center
Annual Technical Report
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Introduction

Statewide Mission: The Arkansas Water Resources Center (AWRC) has a statewide mission to plan and conduct water resource research. AWRC cooperates closely with colleges, universities and other organizations in Arkansas to address the states water and land-related problems, promote the dissemination and application of research results, and provide for the training of scientists in water resources.

Support Provided: The Center acts as the liaison between funding groups and the scientists, and then coordinates and administers grants once they are funded. Accounting, reporting, and water analyses are major areas of support offered to principal investigators.

AWRC Water Quality Laboratory: The Center maintains a modern water quality laboratory that provides water analyses for researchers and for farmers and other who submit samples through the Cooperative Extension Service and the Department of Housing and Urban Development.

Geographical Information System (GIS) Support: The Center for Advanced Spatial Technology (CAST) and the GIS Laboratory in the Department of Crop, Soil, and Environmental Sciences provide support in developing GIS data for the management and protection of water.

Research Program

Occurrence of Animal Feed Additives in Northwest Arkansas Surface Water

Basic Information

Title:	Occurrence of Animal Feed Additives in Northwest Arkansas Surface Water
Project Number:	2001AR3621B
Start Date:	3/1/2001
End Date:	8/1/2002
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Non Point Pollution
Descriptors:	animal waste, feed additive, water quality, land application, non-point source pollution, occurrence, concentration
Principal Investigators:	Guangyao Sheng, John D Mattice

Publication

Problem and Research Objectives:

Land application of animal wastes is a common practice in Arkansas and surrounding states. Recycling of nutrients and organic matter is essential in reducing the need for fertilization and maintaining the soil quality with respect to organic matter content. Animal feeds are usually formulated with additives such as antibiotics and coccidiostats to promote growth and prevent intestinal diseases. These additives are largely excreted with the urine and feces by animals after intake (up to 90%). The levels of some antibiotics in dry poultry waste can be as high as 150 mg/kg. As a result of land application of animal wastes, additives are spread on agricultural soil, and in surface water following runoff. The consequences of the presence of additive residues in soils and water include: 1. impacting the soil fertility and agriculture productivity and therefore deteriorating the quality of the soil; 2. resulting in the emergence of antibiotic-resistant strains of bacteria and their subsequent release and spread in the environment. The danger to human and aquatic lives of transfer of the antibiotic-resistance to human pathogens may cause the serious health hazards. To date, our knowledge of occurrence and concentrations of animal feed additives in Northwest Arkansas surface water is little.

The objectives of this project are to develop an analytical protocol for selected antibiotics in water and to monitor their occurrence in surface water in Northwest Arkansas.

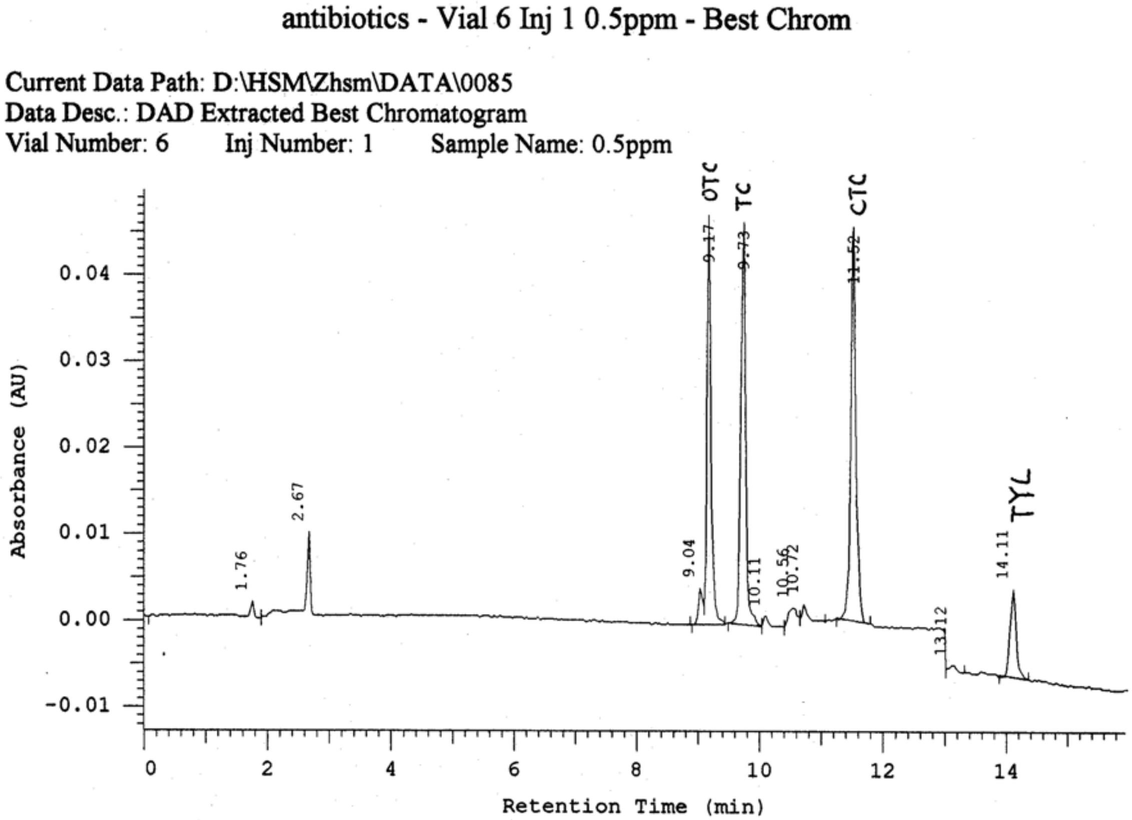
Methodology

Tetracycline (TC), oxytetracycline (OTC), chlorotetracycline (CTC), and tylosin (TYL), selected as model antibiotics, were purchased from ICN Biomedicals. A surface water was collected from a small pond in the Univeraity of Arkansas Animal Farm located in Savoy, AR. The water sample was stored in an ice-filled container, and immediately brought back to laboratory for analysis. Deionized water or surface water (100 ml each) was spiked with antibiotic standard solution (0.1 ml, ~2 mg/L each) and 0.55 g Na_2EDTA, adjusted with 0.1 mL 40% H_2SO_4 to a pH of 2.5-2.8, and rotated for 15 min to thoroughly mix samples. Spiked deionized water, surface water and spiked surface water were loaded onto and passed through HLB cartridges (Waters) that were pre-washed with 3 mL methanol, 3 mL 0.5 N HCl and 3 mL deionized water. The trapped antibiotics in the cartridge were then eluted with 10 mL methanol. Further elution did not find any antibiotics. The elutes were dried with a stream of N_2, and dissolved in 1 mL deionized water for analysis.

The concentrations of antibiotics in water were analyzed by direct injection of samples (400 μl), using a Hitachi reverse-phase HPLC fitted with UV-visible detection and a C-18 column. The mobile phase was a mixture of acetonitrile and water with a flow rate of 1.2 mL/min. The gradient system was: 0-1 min, 5 % acetonitrile; 1-15 min, 5% to 50% acetonitrile; 15-16 min, 50% acetonitrile; 16.1-20 min, 5 % acetonitrile. The wavelength was set as: 0-11.5 min, 360 nm; 11.5-13.5 min, 370 nm; 13.5-20 min, 295 nm. The concentrations of antibiotics were calculated from an external standard using peak heights.

Principal Findings and Significance

The chromatohram for the selected four antibiotics is shown below:



Clearly, with the setting we developed, these antibiotics are well separated. We calculated the recoveries tabulated in the following Tables. The recoveries are generally within the range of 50-120%. We also found that the water sample collected near the animal farm contains tetracycline and tylosin but not oxytetracycline and chlorotetracycline. These results will be highly useful in the further survey of antibiotics in Northwest Arkansas surface waters.

Table 1. Recoveries of TCs and TYL from spiked DI water.

Compound	Added/μg	Found/μg	Recovery/%	RSD/%
OTC	0.20080	0.19418	96.70	9.47
	0.02008	0.01088	54.15	9.46
TC	0.19840	0.17101	86.19	5.37
	0.01984	0.0093	46.79	0.39
CTC	0.43360	0.35961	82.70	12.27
	0.04336	0.01678	38.69	5.44
TYL	0.20600	0.17131	83.16	4.68
	0.02060	0.02019	98.04	6.35

Table 2. Recoveries of TCs and TYL from spiked fresh water and their residues in fresh water.

Compound	Added (µg)	Found (µg)	Found in blank (µg)	Residues In blank (µg/100 mL)	R (%)	Ravera ge (%)	RSD (%)
OTC	0.2008	0.2478	-	-	123.41	126.58	7.02
		0.2420	-		120.52		
		0.2462	-		122.61		
		0.2807	-		139.79		
TC	0.1984	0.2417	0.0474	0.05213 ± 0.0069 (13.23%)	97.93	103.25	8.58
		0.2440	0.05801		93.74		
		0.2608	0.04503		108.76		
		0.2814	0.05808		112.56		
CTC	0.4336	0.4088	-	-	94.28	104.26	9.70
		0.4222	-		97.37		
		0.4758	-		109.73		
		0.5015	-		115.66		
TYL	0.2060	0.3229	0.1931	0.2017 ± 0.0204 (10.12%)	63.01	63.39	10.59
		0.3044	0.1822		61.59		
		0.3063	0.2015		72.53		
		0.3115	0.2299		56.44		

Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds

Basic Information

Title:	Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds
Project Number:	2001AR3641B
Start Date:	3/1/2001
End Date:	11/5/2002
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Models
Descriptors:	Modeling, Nonpoint Source Pollution,Total Maximum Daily Loads
Principal Investigators:	Indrajeet Chaubey

Publication

1. Chaubey, I., A.S. Cotter, T.A. Costello, M.A. Nelson, and T.S. Soerens. 2002. Quantification of runoff and nutrient load prediction uncertainity due to GIS data resolution. Proceedings of the AWRC Annual Conference (In Press).
2. Cotter, A.S., I. Chaubey, T.A. Costello, M.A. Nelson, and T.S. Soerens. 2002. TMDL Data Requirements for Agricultural Watersheds. Proc. Total Maximum Daily Load (TMDL): Environmental Regulations Conference. ASAE, St. Joseph, Mo. Pg. 408-415.
3. A.S. Cotter, I. Chaubey, T.A. Costello, M.A. Nelson, and T.S. Soerens. 2001. Effect of DEM data resolution on SWAT output uncertainty. J. Hydrologic Processes. In Review.

Problem and Research Objectives:

Nonpoint source transport of nutrients, sediment and pathogens from agriculturally dominated watersheds is a major concern in Arkansas. There is ample evidence to suggest that excess land application of animal manure and row crop agriculture have led to surface and ground water pollution. Runoff losses of nutrients and sediment have resulted in excess algal blooms, eutrophication and turbidity of lakes and streams. The 303(d) list of Arkansas identifies sedimentation, mercury and nutrients as top three pollutants of concern affecting more than 70% of total impaired water bodies in the state. Currently, a total of 39 water bodies representing more than 1300 miles of streams/rivers/shorelines and more than 7100 acres of lakes/estuaries are impaired with sediment, nutrients, and pathogens in Arkansas. The Clean Water Act of US EPA requires the states to establish Total Maximum Daily Load (TMDL) for the pollutants and watersheds of concern. The TMDL program is identified as the method to resolve continuing water quality problems, including polluted runoff from nonpoint sources.

Water quality models are frequently used to estimate NPS pollutant loads from watersheds and to predict stream response to various pollutant loading scenarios. Models are also used to estimate TMDLs from point and nonpoint sources that will result in desired optimum water quality improvement with minimum TMDL implementation cost. Because intensive monitoring of watersheds is very expensive, it is important that model estimates of effectiveness of various Best Management Practices (BMPs) are accurate so that costly mistakes of developing inaccurate, or sometimes, unattainable water quality goals can be avoided.

The Research Need:

A critical evaluation of currently available water quality models is needed before they can be used to develop TMDLs for agricultural watersheds in Arkansas. Currently, several NPS models are being used to develop TMDLs in other states. None of these models have been extensively validated/tested for watersheds in Arkansas. Because the accuracy of model prediction is directly dependent upon how well the model works in certain land use, soil, and hydrologic conditions, it is important to validate these models using the data obtained from watersheds in Arkansas. Accuracy of model prediction is also dependent upon accuracy of input data. A TMDL developed by a water quality model cannot be expected to be accurate if the model inputs were not accurate. It is imperative that spatial and temporal input data requirements of such models are evaluated so that effective watershed monitoring plans can be developed.

This project evaluates currently available water quality models for TMDL development in Arkansas and to determine the optimum-scale of temporal and spatial input data required to accurately develop TMDL for agricultural watersheds. No such comprehensive validation has been done in Arkansas. The models are evaluated using data obtained from Lincoln Lake watershed. This watershed has been extensively monitored for over a decade and very high quality data are available to critically evaluate

TMDL model needs. This project addresses a very critical need of the state agencies and will give valuable information to State and Federal agencies, and other groups involved with developing and implementing TMDL process decisions.

Methodology:

This study was carried out in two phases. First the SWAT model was calibrated for the Lincoln Lake watershed, located in western Washington County in Northwest Arkansas. The drainage area of the watershed is 3240 ha. Major land uses within the watershed are pasture (55%) and mixed forests (39%). Animal production is prevalent, in the form of numerous poultry and beef operations located in the watershed. Second, the output accuracy for each input GIS data resolution was evaluated. Acceptable resolution scales had greater than 90% accuracy in watershed response prediction.

Principal Findings and Significance:

Input DEM data resolution affected SWAT model predictions by affecting total area of the delineated watershed, predicted stream network, and sub-basin classification. Results of this study showed that input DEM resolution had the most significant impact on the SWAT model output. The optimum GIS data resolution to achieve 90% prediction accuracy depended upon the output of interest and ranged from 30m – 200 m. When modeling stream flow with the SWAT model, resolution of input DEM should be ≤ 200m. Land use and soil resolution had no impact on flow predictions. When modeling sediment, resolution of DEM and soil should be ≤ 30m, and ≤ 300 m, respectively. Land use resolution had no impact on sediment predictions. The minimum DEM, soil, and land use resolutions needed to reduce model uncertainty less than 10% are 30m, 150m, and 200m, respectively.

Economics of water management to sustain irrigated agriculture in eastern Arkansas watersheds

Basic Information

Title:	Economics of water management to sustain irrigated agriculture in eastern Arkansas watersheds
Project Number:	2001AR3661B
Start Date:	3/1/2001
End Date:	8/1/2002
Funding Source:	104B
Congressional District:	2,3,4
Research Category:	Not Applicable
Focus Category:	Surface Water, Economics, Models
Descriptors:	water quality and management, ground water,Surface water
Principal Investigators:	Eric J. Wailes

Publication

1. Wailes, E.J., K.B. Young, J. Smartt, P. Tacker, and J. Popp. 2001. Economics of on-farm reservoirs for Arkansas rice farms. In R.J. Norman and J.F. Meullenet (eds). B.R. Wells Rice Research Studies 2000. University of Arkansas Agricultural Experiment Station Research Series 485: 342-346.
2. Wailes, E.J., J. Popp, K.B. Young, and J. Smartt. 2002. Economics of on-farm reservoirs and other water conservation practices for Arkansas rice farms. In R.J. Norman (ed.). B.R. Wells Rice Research Studies 2001. University of Arkansas Agricultural Experiment Station Research Series (forthcoming): 313-319.
3. Wailes, E.J., K.B. Young, J. Smartt, and P. Tacker. 2002. Economic impacts on Arkansas rice from ground water depletion. In R.J. Norman (ed.). B.R. Wells Rice Research Studies 2001. University of Arkansas Agricultural Experiment Station Research Series (forthcoming): 348-379.

Problem and Research Objectives:

Four million of a total 7.7 million acres of Arkansas harvested cropland are irrigated. Rice, cotton, and soybeans are the dominant irrigated crops. The annual farm value of this irrigated output is nearly $1.5 billion with an additional $2.5 billion added in the region from further processing. Excessive ground water use to irrigate these crops is resulting in ground water depletion and water quality problems, including both salinity and alkalinity, for agriculture production in eastern Arkansas watersheds. When the salinity or alkalinity of irrigation water exceeds certain levels, their transport and accumulation into the soils builds over time and damage to crop plants occurs and yields are reduced. In addition, sediment runoff degrades the surface waters flowing out of this region. Current ground water use in the irrigated cropping systems of eastern Arkansas is not sustainable.

On-farm reservoirs, tail-water recovery systems and access to surface waters have been identified as needed components to address these problems. However, producers and policy-makers need decision tools to help them investigate and understand the potential benefits and costs of investment and water management using on-farm reservoirs and other water conservation practices. Farmers in eastern Arkansas have developed a strong interest in alternatives to pumping ground water for irrigation, not only because of ground water depletion but also due to much higher energy prices. Without assistance in changing their irrigation systems, the common property ground water resource will be depleted, soil and water quality will deteriorate, and high-valued irrigated agriculture will decline.

The project investigated the economics of farm-level irrigation systems. It evaluated optimal investment in on-farm reservoirs, tail-water recovery systems and access to surface water. Best irrigation management practices in eastern Arkansas watersheds to conserve groundwater and sustain irrigated crop production were identified. Specific research objectives of this project included:

1) Evaluate the costs and benefits of on-farm reservoirs to achieve sustainable water and soil quality for irrigated agriculture in eastern Arkansas.

2) Evaluate water conservation practices to protect the depleting ground water supply. The research will assess the benefits and costs of new technologies including: 1) alternative irrigation delivery systems, 2) alternative irrigation water sources, and 3) alternative cultural practices, including shorter season crop varieties and earlier termination of irrigation application.

3) Develop a user-friendly decision tool for use by extension agents to assist farmers in evaluating the investment in on-farm reservoirs and irrigation management strategies.

Methodology:

The research methods of this proposal included a literature review, case studies of representative farms located in eastern Arkansas watersheds, and computer modeling and simulation to add water and soil quality attributes to the analysis. The MARORA (Modified Arkansas Off-stream Reservoir Analysis) model is a farm level irrigation management and investment simulation framework that evaluates the economics of multiple source (ground water and surface) water supplies for Arkansas rice and soybean farms under various farm resource conditions. The investment analysis determines the optimal size and use of the on-farm reservoir needed to maximize a 30-year time-stream of net returns to the farming operation. Current attempts to assess the impacts of water quality on the incentives to invest in on-farm reservoirs have been based on static assumptions about the yield impacts from using irrigated water with different salinity characteristics. The model was modified to incorporate water quality dimensions.

Two major enhancements have been made to the MARORA model to assess the water quality problem. The first allows the model to keep track of the soil contained in runoff water. The amount of soil lost and the amount of soil recovered in a tail-water recovery system (if a tail-water recovery system was specified), are recorded. The second enhancement allows the model to keep track of soil salt balances for six salts most commonly found in poor quality well water. Yearly deposits in kilograms per hectare are recorded for calcium, magnesium, sodium, potassium, sulfate, and chloride. The equations for determining silt loss and yearly salt balances were taken from "A Salt and Water Balance Model for a Silt Loam Soil Cropped to Rice and Soybean" J.T. Gilmour, J.A. Ferguson, B. R. Wells, Arkansas Water Resources Research Center, publication no. 82, 1981.

Soil loss in runoff

Soil loss in rice and soybean fields depend on the time of the year and more specifically the state of the field. When fields are fallow, but spring field operations are likely (week 14 to week 22), the concentration of soil in the runoff water is 1660 ppm (milligrams per liter). At all other times during the fallow season, concentration is set at 1050 ppm.. During soybean season soil concentration in runoff is set to 1860 ppm. For rice, soil loss is set to zero when fields are flooded. Thus the accounting for soil loss consists of keeping track of the runoff amounts and the seasonal soil loss concentrations for each crop.

Soil loss (in milligrams/liter) = seasonal soil loss concentration x runoff volume (in liters)

Soil salt balance

Keeping track of soil salt balances is more complex. The user interface is modified to allow the user to input well and surface water salt concentrations for calcium, magnesium, sodium, potassium, sulfate, and chloride. These salts are added to the soil via infiltration of irrigation water. Removal is facilitated in various ways. During runoff events, salts are removed based on the concentration of salts in the runoff water. Additional salts are lost via erosion. When infiltration proceeds beyond the soil profile, salts are again lost. And finally, salts are removed via crop uptake. The methodology for tracking salt additions and removals is outlined in the following paragraphs taken from the Gilmour, Ferguson, and Wells publication referenced above.

Runoff water salt concentrations

When cumulative runoff following removal of rice floodwater is less than or equal to 10 cm, the following equation is used.

RWAT = WAT x EXP(D x CUMROFF + E)

Where,
RWAT is runoff water concentration (meq/l),
WAT is irrigation water concentration (meq/l),
CUMROFF is cumulative runoff (cm), and
D and E are constants.

The values for D for Ca, Mg, Na, K, SO4, and Cl are -0.28, -0.27,-0.23, -0.12, -0.44, and -0.35 (cm/l), respectively. The values for E for Ca, Mg, Na, and K are -1.00, -0.45, 0.20, 0.80, respectively. The E values for SO4 and Cl are related to irrigation water concentration (WAT) and are computed using the equation below.

E = F x WAT + G

Where:
F and G are constants equal to –2.43 and 3.44 respectively.

When cumulative runoff following rice floodwater removal is greater than 10 cm, runoff water concentrations are assigned constant values using the equations above where,

CUMROFF = 10 cm.

Runoff water salt concentration during runoff from soybean irrigation is assumed to be equal to the irrigation water quality.

Losses from erosion

Erosion losses are tied to the soil loss concentration values described in the paragraph above describing soil loss as demonstrated in the following equation.

SEROS = SOIL x DROFF x PPM x 10 to the minus 7

Where,
SEROS is erosion salt loss in kg/ha,
SOIL is the soil salt concentration constants for Ca, Mg, Na, K, SO4, and Cl which are 1280, 160, 100, 70, 55, and 0, respectively
DROFF is runoff depth in cm and PPM was runoff soil concentration as described in the soil loss paragraph above.

Salt additions and removals in water

When salt is added to the soil via infiltration of irrigation water or removed from the soil during runoff, the following equation was used to compute salt added or removed.

$$SALT = K1 \times DEPTH \times CONC$$

Where,
SALT is the amount of salt in kg/ha,
DEPTH is the depth of water in cm,
CONC is the concentration in the water in meq/l, and
K1 is a conversion factor of 2.0, 1.2, 2.3, 3.9, 4.8, and 3.5 for Ca, Mg, Na, K, SO4, and Cl, respectively.

Concentration was calculated as follows:

$$C2 = (C1 \times D1 + WAT \times DIRR) / (D1 + DRAIN + DIRR - DE)$$

Where,
C2 is the new concentration,
C1 is the old concentration,
WAT is the irrigation water concentration,
D1 is the original water depth,
DIRR is the depth of irrigation water,
DRAIN is the depth of rainfall, and
DE is the depth of water lost to evapotranspiration.

Crop Uptake

Crop uptake of salts is described by the following equation:

$$RCROP = YIELD \times SEED/100$$

Where,
RCROP is crop uptake in kg/ha,
YIELD is grain yield in kg/ha, and
SEED is percent of salt in the grain.

The values for percent salt in the grains for rice are 0.017, 0.122, 0.129, 0.351, 0.346, 0.257 for Ca, Mg, Na, K, SO4, and Cl, respectively. The values for percent of salt in the beans for soybean are 0.142, 0.216, 0.548, 1.648, 0.535, 0.126 for Ca, Mg, Na, K, SO4, and Cl, respectively.

Water Quality Effects on Rice Yield

The original MARORA model was programmed to use reservoir water first for irrigation – using well water only if the reservoir water was insufficient or if the reservoir water was totally depleted. This version of the model uses well and reservoir water in a ratio that minimizes the effects of salts found in either the well or reservoir water. The EC level of the water is monitored for the first 40 days after rice emergence and yield reductions are assessed as follows: if the average EC value during this time is above 1200 micro mhos then the yield is reduced 20%. Yield reductions of 30% and 45% are assessed for EC values over 2000 and 3000 respectively. Running the model in non-optimization mode provides information on the predicted effects of a given combination of well and/or reservoir water on the rice yield. Running the model in optimization mode predicts an optimal size reservoir that will maximize profits by minimizing the yield loss associated with poor quality irrigation water. (EC values for both well and reservoir water can be input directly as one of the input parameters or can be calculated from the salt values for Ca, Mg, Na, K, SO4 and CL for both well and reservoir waters entered in meq/l). Yield reductions are based on research by J.T. Gilmour, "Water Quality in Rice Production", Rice Research Studies 2000, Research series 485, Arkansas Agricultural Experiment Station, August 2000, pp.171-177.

Principal Findings and Significance:

An on-farm reservoir is estimated to be not profitable in the good ground water situation as a water conservation practice because of the relatively low pumping cost for ground water and loss of valuable cropland for reservoir construction. The NPV per acre on the 320-acre tract is $2,145 with the baseline irrigation efficiency, $2,157 with underground pipe, and $2,639 to $2,696 with both underground pipe and land leveling in the good ground water situation. Sedimentation reductions do not pose a sufficient benefit to support construction of a reservoir.

NPV per acre is $1,456 in the poor ground water situation with no government cost share for an on-farm reservoir of 640 acre feet capacity covering 70 cropland acres with the low 45 percent soybeans/50 percent for rice baseline irrigation efficiency. This NPV is 68 percent of the NPV in the good ground water situation. NPV per acre increases to $1,598 with underground pipe, and to a level of $2,099 to $2,170 when both underground pipe and land leveling are combined with a reservoir. The required optimal reservoir size declines from 640 acre-feet at the baseline efficiency level to as low as 480 acre-feet as irrigation efficiency is increased. The underground pipe and field leveling improvements save up to 16 acres of valuable cropland.

A benefit-cost analysis of these three conservation practices shows that all are profitable at full cost without the cost share by the government except for on-farm reservoirs in the good ground water situation. NPV per acre without a reservoir at the baseline efficiency level is only $629 in the poor ground water situation and is increased by $1,269 per acre with a reservoir. The return on the reservoir investment with poor ground water is high. The rate of return is 187 percent based on a per acre $1,269 return and a per acre reservoir cost of $442 with no government cost share. With a 65 percent government cost share, the rate of return is 719 percent.

Water Quality

Water with an EC level over 1200 micro mhos is known to damage rice seedlings and reduce yields. In addition to model assumptions discussed above, results were based on the assumption that the well water was plentiful but of poor quality (50 feet saturated depth of water table with 0.5 foot decline per year; well water EC of 1800 micro mhos and reservoir water EC of 500 micro mhos). Simulations were run to show the effects on average yearly income assuming; crop yield reductions of 10, 15, 20, 25, and 30 percent without a reservoir; and with a reservoir of 200 acre-feet providing sufficient water to mix with the well water in a 1 to 1 ratio to bring the EC level down below 1200. A base simulation assuming plentiful high quality well water was also included as a benchmark.

Maturity Date

An additional analysis was conducted to measure the irrigation conservation benefits of earlier maturing rice varieties. The shorter the maturation process the less irrigation water needed. Shorter season rice varieties can provide conservation benefits in terms of requiring a smaller size reservoir to meet optimal investment and less water for irrigation use over the growing season. The optimal reservoir size can be reduced by 50 acre-feet capacity (5 surface acres) as maturity date is reduced by 25 days. Annual income for the 320 acres is estimated to increase on average by $170 per day reduction in maturity date of rice and soybeans.

Significance of findings

The results of this study show a high economic return from on-farm reservoirs when ground water is limited and also high returns to other water conservation practices under alternative ground water supply conditions. On-farm reservoirs are estimated to be highly profitable when ground water is depleted and are essential to maintain irrigation unless other surface water access is available. Underground pipe and land leveling are profitable for both good and poor ground water supply conditions as long as irrigation is sustainable. On-farm reservoirs can be economic in good ground water situations if ground water quality is a problem. The significant ground water depletion problem that is occurring in rice production areas of Arkansas can be addressed through the use of the MARORA models by assisting producers to make sound financial investments to improve water conservation and sustain rice production. The MARORA model has been enhanced to account for sedimentation loss and salt accumulation and damage. The model demonstrates that on-farm reservoirs can be a valuable investment to address water quality issues.

Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)

Basic Information

Title:	Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)
Project Number:	2001AR15B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	First
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrogeochemistry, Hydrology, Water Quantity
Descriptors:	Ecohydrology, essential habitat, chemical hydrology
Principal Investigators:	Robyn E Hannigan

Publication

1. Bogdevich, Oleg and Hannigan, Robyn. 2002. Environmental Risk Assessment of Toxic Element Pollution in Agricultural Regions of Moldova and Arkansas. Advances and Prospects of Ecological Chemistry., Proceedings of the Second International Conference on Ecological Chemistry. Chisinau Moldova. 128-134.
2. Wine, M.S. and S.C. Blumenshine. Endemic darter population distributions in spatially and temporally dynamic habitats: Consequences for listing status. In review for Proceedings of the Southeastern Asociation of Fish and Wildlife Agencies.

Problem:

Streamflow, which is strongly correlated with many critical physiochemical characteristics of lotic systems, such as water temperature, channel morphology, and habitat diversity, can be considered a “master variable”. Surface flow sets a template for finer scale properties operating on scales of stream reaches or reach units such as riffles. Suspected reduction in base flow for tributaries of the Little Red River (LRRH) above Greers Ferry Lake has been linked to reduction in the range and abundance of the Yellowcheek darter (*Etheostoma moorei),* a species endemic to these tributaries. U.S. Fish and Wildlife Service (USFSW) has stated that conservation of newly established 'species of concern' such as Yellowcheek darter places a regional priority on identification of critical habitat, habitat conservation methods and prevention of further habitat degradation. Land use activities such as clear-cutting, pastureland and poultry farming have impacted the region. These activities combined with natural hydrologic conditions may severely restrict or impair endemic species habitat. The proposed study will address these issues and serve to answer critical questions concerning the impact of changes in basin hydrology on habitat contraction.

Research Objectives:

There is clear evidence for a decline in Yellowcheek Darter abundance and range since the last status survey 20 years ago. This range contraction as discussed above appears to be related to the hydrology of the LRRH headwaters. This project assessed the relationship between habitat contraction and hydrology and investigated processes operating at finer scales such as changes in riffle size due to changes in bank storage and the impact of geochemical variations such as bioavailablitlty of essential nutrients throughout space and time.

The results of this study were integrated into results from on-going Yellowcheek darter research, and allowed for the development of management strategies which encompass hydrologic variables as well as biological factors. An initial goal was to address a the questions of resistance and resilience of Yellowcheek to drought, and more generally the potential effectiveness of conservation measures against a template of climactic variability. Bases on the results of this study we were unable to draw direct connections between the population of Yellowcheek Darter and drought resistance however we were able to establish the broad linkages between hydrology and habitat contraction and in so doing discovered unique chemical fingerprints indicative of decreases in water quality regardless of quantity. These issues of water quality could not be correlated to human activities and so the PI has received funding from the National Science Foundation to further investigate the chemistry of tributaries within the LRRH which drain metal rich bedrock. The impact of this chemical weathering on habitat quality will be investigated further by support from the NSF.

Methodology:

We chose sites along the four main tributaries in the LRRH headwaters in order to test the relationship between habitat contraction and basin hydrology. Critical components of the flow regime were measured. These included measurements of flow and channel cross-sectional area in order to estimate discharge at least once a month over the study period. Data from the three stations per tributary were compared with historical data. Peak flow at each site was also be measured after precipitation events. Staff gauges were installed at each site in July 2001. At least once a month during the study period, gauge height was measured from these locations. Each gauge site was 8-12 meters above locations where discharge was measured, and compared against USGS gauging station data. Stage height and discharge data combined with precipitation data provided a predictability measure for future studies. All of this data describes the nature of flow within the region and was examined in the context of habitat contraction. We also measured channel width and embeddedness to further explore the effect of flashiness on tributary shape and habitat contraction.

At each site we measured the following chemical variables: conductivity, pH, temperature, total solids (dissolved and suspended) and hardness in the field. We collected filtered water samples for analysis of dissolved and particulate (organic/inorganic) phosphate and nitrate, chloride, sulfate, dissolved oxygen, organic carbon and trace metals (V, Cr, Cu, and As) for measurement in the laboratory. Major cation and anion concentrations were measured by ion chromatography (Dionex 120), phosphate species were measured by UV-visible spectrophotometry. Dissolved organic carbon was measured by a combustion carbon analyzer (Dohrmann 80). All metals were measured by Inductively Coupled Plasma Mass Spectrometry (Elan 9000).

Yellowcheek darter presence/absence was assessed through a kick seine method. Field collections were conducted each month until each site has been sampled (see Table 1 below). Riffle areas within 0.8 km (one-half mile) reaches at each survey site were measured and sampled. We conducted random spot-checks of pools via backpack electrofishing during extreme low-water conditions in order to further address the possibility that Yellowcheek are refuging in pools.

Fine-scale variation in Yellowcheek darter presence/absence across headwater reaches and riffles was examined through a multivariate statistical technique, canonical correspondence analysis (CCA). The primary function of this approach in this context is to reveal how environmental gradients are related to factors pertinent to conservation of Yellowcheek darter.

Principal Findings and Significance:

The presence/absence surveys showed that, in stark contrast to earlier studies, Yellowcheek catch-per-unit-effort (CPUE) is extremely low. Where Yellowcheek have been captured, they are now a distant fourth in abundance compared to other riffle fishes, suggesting that declines are more likely a species rather than community phenomena. The hydrology of the basin as defined by changes in run-off, bank storage, precipitation and groundwater discharge was assessed. Based on the data collected there was no identifiable link between the hydrology of the river and the distribution of Yellowcheek darter. In other words there appeared to be no preferential habitat use defined by regions of small or shallow riffles. Again the low CPUE of the Yellowcheek is indicative of a species specific phenomenon and not own impacting all darter and therefore water quantity does not seem to be the culprit in the decline in abundance of these organisms in the LRRH.

We further investigated the issues of water quality by collecting water in regions where Yellowcheek darter are abundant and comparing the chemistry to regions identical in physical hydrology but containing no Yellowcheek darter. Based on this investigation we discovered a compelling water quality problem. The regions in the northern-most portion of the study area just south of the confluence of the Little Red River and Trace and Cover creeks showed high abundances in essential and toxic metal species. Chemical speciation modeling using equilibrium thermodynamic models such as PHREEQC indicated that these regions contained a higher overall abundance in toxic metal species regardless of the abundance of total metal. For example in the case of Copper the overall copper concentration throughout the LRRH was, on average, 1-3 ppm. However when the speciation of Cu is calculated the dominant copper species in the northern protion of the study area is Cu^{2+} which is both bioavailable and toxic whereas the dominant species to the south where Yellowcheek are more abundant is $Cu(OH)^{+}$ which is bioavailable but not toxic. Based on this preliminary data the PI submitted a proposal to the National Science Foundation – Hydrologic Science program and was recently granted funding to investigate the causes and impact of this metal contamination in the northern Little Red River watershed where metal-rich black shales dominate the landscape and human perturbation is minimal.

Information Transfer Program

Development of GIS Data Sets for Water Quality and Source Water Protection

Basic Information

Title:	Development of GIS Data Sets for Water Quality and Source Water Protection
Project Number:	
Start Date:	1/1/2001
End Date:	7/31/2002
Funding Source:	Supplemental
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Management and Planning, Water Use, None
Descriptors:	
Principal Investigators:	Ralph K Davis

Publication

1. Davis, R.K. and C.D. Cooper, 2002, Conceptual Model Development Beaver Lake Watershed, Northwest Arkansas. CD-ROM containing maps, and vector and raster GIS data layers for the Beaver Lake Watershed. Arkansas Water Resources Center.
2. Davis, R.K. and C.D. Cooper, 2002, GIS Dataset for Illinois River Watershed, Northwest Arkansas. CD-Rom containing maps, and vector and raster GIS data layers for the Beaver Lake Watershed. Arkansas Water Resources Center.

We have just completed a project that compiled available digital data sets, identified location and type of other data sets, and identified data gaps for the Beaver Lake Watershed, Northwest Arkansas. These data are available on a CD-ROM that includes a combination of output formats that most users can access. Compilation of these data sets is the first step that each of the local Watershed Advisory Groups will need if they are to be effective groups. Providing this information in a ready to use format is essential for future planning within our watersheds.

Arkansas Water Resources Center Annual Conference

Basic Information

Title:	Arkansas Water Resources Center Annual Conference
Project Number:	
Start Date:	3/3/2001
End Date:	3/4/2001
Funding Source:	104B
Congressional District:	3
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Quantity, Hydrology
Descriptors:	
Principal Investigators:	Kenneth F. Steele

Publication

1. Proceedings of the Arkansas Water Resources Center Annual Conference: TMDLs and Related Water Quality Issues. Arkansas Water Resources Center Pulbication No. MSC -284.2001. 92p.

Annual conference of the Arkansas Water Resources Center held each spring in Fayetteville, Arkansas at the Continuing Education Facility, University of Arkansas. This conference generally draws between 100 and 125 participants from across the state and region including representatives from federal, state and local agencies, universities and colleges throughout the state, and a few from the general popolution.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	13	16
Masters	3	0	0	18	21
Ph.D.	1	0	0	9	10
Post-Doc.	0	0	0	0	0
Total	7	0	0	40	47

Notable Awards and Achievements

Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds - Amy Cotter presented the research findings in a student competition at the annual conference of the AWW&WF and won first prize.

Aboubakar Sako was awarded an NSF award to participate in the Nyanza Project in Tanzania in the summer of 2002. Aboubakar Sako was awarded second place in the student presentation competition at the Fall meeting of the American Geophysical Union in December 2002.

Marc Nelson, Kati White and Thomas Soerens recently compiled a phosphorus mass balance for the Illinois River system in northwest Arkansas. These data are critical input to a Decision Support System being developed for watersheds in northwest Arkansas that have been impacted by point and nonpoint source contaminants. Contaminant load to the Illinois River was estimated to be 43 percent from point sources (municipal effluent) and 57% from nonpoint sources (animal manures, poultry litter, commercial fertilizer, and natural sources) within the watershed. These data are important because excessive phosphorus has resulted in eutrophic conditions in impoundments on the Illinois and other rivers in region. The Illinois flows west into Oklahoma where a new phosphorus standard of 0.37 mg/L has been proposed. Based on the mass balance estimations prepared by Nelson and others it is clear that this limit is being exceeded during base flow conditions due in large part to the point sources within the watershed, and during storm pulses due primarily to the nonpoint source contribution. Basing planning and management decisions on quality data is the key to successfully reducing impacts of eutrophication in this and other watersheds throughout the Ozarks.

Publications from Prior Projects

1. Wailes, E.J., G.L. Cramer, K.B. Young, J. Smartt, and P. Tacker. 1999. Economic impacts on Arkansas rice from ground water depletion. In: R.J. Norman and T.H. Johnston (eds). B.R. Wells Rice Research Studies 1998. Arkansas Agricultural Experiment Station Research Series 468: 423-426.
2. Wailes, E.J., K.B. Young, and J. Smartt. 200. "Economic Analysis of On-farm Reservoirs to Sustain

Irrigated Agriculture in Eastern Arkansas." Proceedings, Arkansas Water Resources Center Conference, University of Arkansas, Arkansas Water Resources Center Pub. No. MSC 0: 65-72.

3. Wailes, E.J., G.L. Cramer, K.B. Young, J. Smartt, and P. Tacker. 2000. Economic impacts on Arkansas rice from groundwater depletion. In R.J. Norman and C.A. Beyrouty (eds). B.R. Wells Rice Research Studies 1999, Arkansas Agricultural Experiment Station Research Series 476.
4. Wailes, E.J., K.B. Young, J. Smartt, J. Popp, and G. Cramer. 2000. Economics of on-farm reservoirs to distribute diverted surface water to depleted ground water areas for the southern Mississippi Valley region. Final Report, U.S. Geological Survey. Staff Paper 182000, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville.
5. Dixon, B., T.H. Udouj, H.D. Scott, R.L. Johnston, J.M. McKimmey. 2001. Soils of Randolph County, Arkansas. Arkansas Agricultural Experiment Station. Special Report 199.
6. Scott, H,D., D.M. Miller and F.G. Renaud. 2001. Rice soils: physical and chemical properties. In (C.W. Smith, and R.H. Dilday, eds.): Rice: Origin, history, technology and production. Chapter 3.3 John Wiley and Sons, Inc. New York. pp. 297-329.
7. Dixon, B. T.H. Udouj, H.D. Scott, and J.M. McKimmey. 2001. Soils of Clay County, Arkansas. Arkansas Agricultural Experiment Station. Special Report 202.
8. Renaud, F.G., H.D. Scott, and D.W. Brewer. 2001. Soil temperature dynamics and heat transfer in a soil cropped to rice. Soil Sci.
9. Sojka, R.E., and H.D. Scott, 2002. Measuring Soil Aeration. In (L. Lal ed.) Encyclopedia of Soil Science.
10. Soerens, Thomas, and M. Nelson, "Designing Stream Sampling Networks for Load Determination", in Warwick, John J. (Editor) 2001, AWRA Annual Spring Specialty Conference Proceedings. Water Quality Monitoring and Modeling. American Water Resources Association, Middleburg, Virginia, TPS-01-1, pp. 71-76.
11. Soerens, Thomas, and M. Nelson, Evaluation of Sampling Strategies On Load Estimation for Illinois River at Highway 59 (Part II), Proceedings of Arkansas Water Resources Center Annual Research Conference, April 2001.
12. Culpepper, Brian, "Geospatial Methodologies for Source Water Assessments", National Consortium for GeoSpatial Innovations in America (RGIS) Bulletin 2001 (4 pages)
13. Cooper, C.D., 2002, Spatial Characterization of Hydrochemistry for the Alluvial and Sparta Aquifers of the Grand Prairie Region, Eastern Arknasas. Unpublished Masters Thesis. Department of Geosciences, University of Arkansas. 165p.
14. Wilson, A.D., Hydrochemical Characterization for the Sparta Aquifer in South-Central Arkansas. Unpublished Honors Thesis. Department of Geosciences, University of Arkansas. 54p.
15. Hamilton, S., 1999, Survival Study of Escherichia Coli in Sediment in a Spring and Stream in the Mantled Karst of Northwest Arkansas, Savoy Experimental Watershed. Unpublished Masters Thesis, Department of Geosciences, University of Arkansas. 48p.
16. Davis, R.K. and P.E. Anderson, 2000, Arkansas' Source Water Assessment Program Delineations for Groundwater and Implications in Mantled Karst Aquifers. Geological Society of America Abstracts with Programs, v. 32, n.3, p. A7.