Arkansas Water Resources Center

ANNUAL PROGRAM REPORT
for the Period
March 1, 1997 through February 28, 1998

Submitted to:
U.S. Department of Interior
U.S. Geological Survey
Reston, VA

By:
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GEOLOGICAL SURVEY

BY

ARKANSAS WATER RESOURCES CENTER
UNIVERSITY OF ARKANSAS
FAYETTEVILLE, ARKANSAS 72701

KENNETH F. STEELE, DIRECTOR

JUNE 30, 1998

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RESEARCH PROJECT SYNOPSES

SYNOPSIS

Project Number: B-01

Start: 3/1/97
End: 2/28/98

Title: Fiscal Year 1997 Arkansas State Water Resources Research Program

Investigators: Kenneth F. Steele, University of Arkansas, Fayetteville, Arkansas

Congressional District: AR 3

Focus Category: NPP, EDU

Descriptors: Ecosystems, Groundwater Quality, Streams, Water Quality, Water Quality Monitoring

Problem and Research Objectives:

The following water problems/issues are currently important in Arkansas:

1. non-point source contamination (nutrients and pesticides)
2. development of efficient septic systems
3. wetlands
4. zebra mussel infestation of Arkansas lakes and streams may be a serious problem in the near future
5. mercury content of fish flesh, especially in southeastern Arkansas, continues to be an important problem
6. Sources of bacteria in water and interpretation of the results

These six problems/issues were the focus of 34 Center projects this year and are briefly discussed below. The Center's training and information dissemination programs were also focused on these areas.

Non-point Source Contamination

Non-point source contamination by nutrients, bacteria, and pesticides, is an area of concern for the nation and Arkansas. This year one of the Center's projects, partially funded under section 104, was related to non-point source pollution by agricultural activities in the southern Mississippi River Delta. There were eighteen other projects involving non-point source pollution. In addition six GIS projects were also related to non-point source pollution. An Arkansas scientist collaborated with the North Carolina Water Resources Institute was on the use of water treatment sludge (alum) as a best management practice for phosphorus.

Efficient Septic Tank Design

One section 104 grant is assessing the impact of on-site wastewater systems on stream and ground water quality. In addition, work has continued on the development of efficient septic tank design for problem areas of Arkansas, e.g., those areas with shallow soils, or high ground water tables. The project is funded by the state through the University of Arkansas. The principal investigators work closely with the Arkansas Department of Health in development of projects and technical information transfer.

Wetlands

Wetlands are an important issue nationally and the Center has recognized the importance of these areas. The Center currently is involved in two constructed wetland studies. One project is administered by the Center and is investigating the remediation of wastewater at a swine rearing facility, and the other wetland project is using our Water Quality Laboratory for analyses of samples. Several other projects are producing GIS databases for the conservation of wetlands in the Mississippi Alluvial Valley.

Zebra Mussel Infestation

The northern areas of the United States have experienced problems with zebra mussels for several years. Zebra mussels have been present in Arkansas for several years, and it is important that baseline data be collected now concerning the possible infestation of these mussels in Lake Dardanelle. This project was supported in part with section 104 funds.

Mercury Content of Fish

The state recognized the mercury contamination of fish, especially in southeastern Arkansas several years ago. Two of the non-point source GIS projects are investigating factors related to mercury contamination of fish.

Bacteria Studies

The section 104 project assessing on-site wastewater impacts on stream and ground water includes bacteria as one of the parameters studied.

Methodology: AWRC has a Technical Advisory Committee composed of representatives of all of the state/federal water resources agencies, academia, industry and private groups that selects proposals for Regional Competition and that provides general advice for the Center's operation. The Center also assists agencies and other groups in forming research teams to address water resource issues. In addition, the Center helps academic researchers in presenting their ideas for research to the correct agency and agency representative. 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 (through the AWRC Water Quality Laboratory), are major areas of support offered to principal investigators.

The Center's training and information dissemination programs are intricately involved with the research projects. Many students are trained through participation in research projects and also at the Water Quality Laboratory. The information dissemination program consists of the publication of journal articles and other reports, presentation at professional meetings, and organization of conferences and short courses related to the research program.

Principle Findings and Significance:

Expansion of the Center's research support and capabilities continues to be one of the major goals of the Center. The Cooperative Extension Service, Department of Agronomy, and the Housing and Urban Development Agency cooperate with the Arkansas Water Resources Center Water Quality Laboratory in a water quality program for farmers and rural residents. The Laboratory is certified for drinking water by the Louisiana Health Department and for waste water by the Arkansas Department of Pollution Control and Ecology. This facility provides services to researchers and through its cooperators to citizens and state and federal agencies.

The Center's program includes significant effort in information dissemination. In addition to the publication of reports, journal articles, and books, the Center sponsors and co-sponsors conferences for dissemination of information. This past year the Center sponsored a conference on "Arkansas Diversity of Water Resources Research," a short course titled "Water Quality Monitoring Design and Statistical Analysis for Nonpoint Source Pollution Studies," Although the Center has a strong cooperative research programs with state and federal agencies, these can be expanded and strengthened. Cooperative efforts with environmental and industrial organizations can be strengthened.

The research priorities of the Center were reviewed and re-authorized at the February 24, 1998 Technical Advisory Committee meeting and are as follows:

Arkansas Water Research Priorities by Rank

1. Investigate the physical, chemical, and biological characteristics of streams, reservoirs, etc. (storm events, substrate/water interactions, identification of new resources, reference systems, etc.).

2. Quantify and qualify the trophic levels and associated parameters in lentil and lotic ecosystems (modeling, energy transfer, production, etc.).

3. Determine the impact of natural and synthetic chemicals on surface water quality (point and non-point sources, toxic material, pesticides, industrial and mining wastes, etc.).

4. Develop analytical techniques and protocols for assessing water quality (quality control, quality assurance, microbiological, indicator species, etc.).

5. Develop mechanisms for improving quality and quantity of water supplies for surface applications and the impact of the applications (water treatments, irrigation, return flow, leaching, etc.).

Regional Research Priorities:

In *addition to the state priorities the Southeastern and Islands Region of the National Institutes of Water Resources has the following priorities:*

Water Quality: Needs in the water quality area involve information, information management, and the protection of surface and ground water from degradation. It includes industrial and municipal wastewater treatment and municipal wastewater treatment and subsurface disposal of hazardous/toxic wastes. In addition, problems from non-point sources of both municipal and agricultural sources, including soil erosion, agricultural runoff, and pesticides, pertain to this area. The development and improvement of monitoring techniques and analysis are also important, as well as water quality problems associated with eutrophication and weed control.

Water Management: Research needs in the area of water management include legal, institutional, and financial arrangements. Specific items such as basin planning, water use control, transfers and/or diversions of water, flood control, and drought planning are all priority issues.

It also includes construction of facilities, financing and pricing, and water conservation and reuse. Management includes quality protection studies, upgrading of supplies, and state and/or federal and interstate interactions or compacts.

Water Quantity: Research needs in the water quantity area include studies of the basin water cycle for an understanding of prediction. It also includes items of surface water flow, basin planning, low flow predictions (7Q10), flood control, water use, and water allocation. Included also are studies of ground water availability and the locations, movement, and volume of ground water. Also of importance are use and user impacts and surface and ground water interaction.

Aquatic and Environmental Protection: Research needs in this area include studies of wetlands, swamps and marshes, fish and other biota, and the quality of life. It also includes studies of ecological balance, protection of endangered species, and studies of dredging and filling.

Emerging Problems: Studies not included in other priority areas, but which are dedicated to solving emerging water problems which are identified as critical issues by key state water management officials in the region, are included in this category.

During the next year, these research priorities will be reviewed with the Technical Advisory Committee. Although no major changes in the priorities are anticipated, more focus will probably be placed on current specific problems, e.g., non-point source contamination, wetlands, and ground water quantity. This focus should allow the Center and the state/federal agencies to continue to cooperate effectively in solving water resource problems in Arkansas.

The Arkansas Water Resources Center, in conjunction with state and federal agencies, is addressing many of the issues described under Water Problems and Issues of Arkansas.

SYNOPSIS

Project Number: C-01

Start: 9/1/96
End: 8/31/98

Title: Vulnerability and Use of Ground and Surface Waters in the Southern Mississippi Valley Region

Investigators: H. Don Scott, University of Arkansas, Fayetteville, Arkansas

Congressional District: AR 3

Focus Category: GW, WQ, MET

Descriptors: Ground Water Vulnerability, Pesticide Contamination, Models, GIS, Contaminant Transport

Problem and Research Objectives:

Knowledge of the vulnerability of ground water to pesticide contamination is required in order to assess pesticide pollution potential. The objectives of this work were (1) to examine the transport of contaminants to ground and surface waters, and (2) to evaluate the factors important in the quality and use of water in rice production.

Methodology:

Tests and evaluation of existing methods were conducted for assessing ground water vulnerability to pesticides. In this study we examined the usefulness of the incorporation of fuzzy logic techniques into a modified DRASTIC model to facilitate ground water sampling decisions in Woodruff County, Arkansas. The DRASTIC model has been used with varying success to serve as a predictive model to select monitoring locations. Four fuzzy logic-based models were developed to provide predictions of ground water vulnerability from alternative approaches to the modified DRASTIC model by using the same factors as in the DRASTIC model. Comparisons were made between the results based on the fuzzy logic models and the modified DRASTIC model along with experimental data obtained from the analysis of pesticide concentrations in wells.

Principle Findings and Significance:

The results showed that the areal extent and spatial distributions of the various fuzzy categories varied among the four models. No relation was found between any of the fuzzy categories and pesticide contamination of wells. Contaminated wells were present in all except the low vulnerability fuzzy category; whereas, in the modified DRASTIC model, contaminated wells were present in the low vulnerability category but not in the high vulnerability category. In general, the fuzzy logic models tended to reflect a higher vulnerability of the ground water at the contaminated wells than the modified DRASTIC model.

The number of rules in the output within a fuzzy category varied by rulebase. These rulebases were independent of each other with the majority of the rules written in the moderate and moderately high fuzzy categories. For Rulebase I, 50% of the total number of rules were in the fuzzy category moderate and 34.4% in the moderately high vulnerability category. For Rulebase II, 32.1 and 44.4% of the total number of rules were in fuzzy categories moderate and moderately high, respectively, whereas for Rulebase III, 29.1 and 34.5% and for Rulebase IV 36.2 and 40.3% were in these same two categories, respectively.

Areal distribution for each fuzzy category varied by model and rulebase. For the 5-class modified DRASTIC, the highest percentage of land area was in the low fuzzy category (almost 39%) and the percentage decreased as the vulnerability category increased. For the 4-class modified DRASTIC model the moderate category contained slightly over 50% of the land area. For both models only about 2.2% of the area was in the high fuzzy category. The area in the high vulnerability category to pesticides tended to occur between the Cache and White Rivers.

For Rulebase II with five fuzzy sets about 43% of the land area in Woodruff County was in the moderately high fuzzy set. As compared to Rulebase I, a greater proportion of the land area was in the low category and a lower proportion was in the moderate and high fuzzy categories. Rulebase II also showed greater areal coverage than the 5-class modified DRASTIC for the high category, which was attributed to the defensive nature of fuzzy logic. In comparison with the 5-class modified DRASTIC model, a lower proportion of the land area was placed in the lower vulnerability classes with this rulebase. The lower potential vulnerability areas were mainly found in the eastern part of the county while higher potential areas were found mainly in the north central part of the county.

For Rulebase III with five fuzzy sets about 28% of the land area in Woodruff County was in the moderately high fuzzy set. As compared to Rulebase I and II, a lower proportion of the land area was in the low category and a lower proportion was in the moderately high and high fuzzy categories. For the fuzzy category moderate, rulebase III showed greater areal coverage than Rulebase II and IV, but lower than Rulebase I. Rulebase III also showed greater areal coverage than the five class modified DRASTIC for the high category, which was attributed to the defensive nature of fuzzy logic. In comparison with the 5-class modified DRASTIC model, a lower proportion of the land area was placed in the lower vulnerability classes with this rulebase. The lower potential vulnerability areas were mainly found in the eastern part of the county while higher potential areas were found mainly in the central part of the county.

For Rulebase IV, the highest proportion of land area Woodruff County was in the moderately high fuzzy category. The land area in the low and high fuzzy categories was about 13%. In comparison with the 5-class modified DRASTIC model, this rulebase had a higher proportion of the land area in the higher vulnerability classes. Lower potential vulnerability areas were found in eastern part of the county while moderately high and high areas were found in the central part of the county.

Comparisons were made of the vulnerability predictions and well contamination. The highest number of contaminated wells were found in the moderately high category of Rulebase III. The modified DRASTIC model showed the highest number of wells for

moderate category and Rulebase IV showed maximum number of wells in the high category. Rulebase I showed maximum wells in moderate category and almost equal in high category. The Rulebase II showed more wells in moderately high and high categories. The results show that for these wells there was no relation between fuzzy categories and pesticide contamination of wells. For the four rulebases all of the contaminated wells were found in other fuzzy categories except the low while for the modified DRASTIC contaminated wells were found in low vulnerability area and not in high vulnerability areas. In general, the categories of the fuzzy logic models tended toward the higher vulnerability categories.

SYNOPSIS

<u>Project Number</u>: C-02

Start: 9/1/97
End: 8/31/98

<u>Title</u>: Investigation of Optimum Sample Number and Timing for Determining Pollution Loads

<u>Investigators</u>: Marc A. Nelson, Thomas S. Soerens, David G. Parker, University of Arkansas, Fayetteville, Arkansas, and Jean Spooner, North Carolina State University, Raleigh, North Carolina

<u>Congressional District</u>: AR 3

<u>Focus Category</u>: HYDROL, NPP, NU, SW, WQL

<u>Descriptors</u>: Streams, Suspended Sediments, Nutrient Transport, Water Quality Monitoring

<u>Problem and Research Objectives</u>: Accurate measurements of pollution loads in streams are critical for determining the impacts of non point source (NPS) pollution. Although researchers are attempting to determine these impacts, there are no consistent rules or guidelines for determining the best sampling technique to be used. The ideal technique is to continuously measure stream flow and the concentration of the pollutants of interest. Pollutant loads may then be calculated with a high degree of precision and accuracy; however, this technique is not realistic due to economic and/or technical restraints.

A solution to water sampling for determining pollution loads is frequently to continuously monitor flow and intermittently collect water samples. Pollutant loads are then calculated by assuming a uniform pollutant concentration between samples. This technique can lead to errors, particularly during storm runoff events when the concentrations may change rapidly between samples. These errors may occur because the samples were not collected close enough together to detect fluctuations in the concentrations or because the samples were not taken during the critical portion of a hydrograph. Research has shown that different pollutants reach their peaks at different times during a storm and they may or may not be directly related to the flow. Inadequate sampling times can cause load calculations to over or under estimate the actual value. Any errors in measuring pollution loads makes determining trends in water quality very difficult and therefore impacts the effectiveness of any TMDL determinations.

The objective of this research is to determine the optimum number and timing of storm and baseflow water quality sampling to determine pollutant loads in streams with high precision and accuracy.

<u>Methodology</u>: Two stream sites in the Illinois River basin were sampled: 1) the Arkansas Highway 59 bridge over the Illinois River (3rd order morphology) south of Siloam Springs, Arkansas; and 2) Moores Creek, a 1st order stream, located in the headwaters of the Illinois River near Lincoln, Arkansas. The water quality constituents measured were total phosphorus, ortho-phosphorus, total suspended solids, nitrate, ammonia, and total Kjeldahl nitrogen.

The study was designed to sample two storms at the Moores Creek site and eight storms at the Highway 59 site with 3 baseflow samples between storms. The storm sampling included sampling every 30 minutes on the rising portion of the hydrograph and every hour on the falling portion. All sample analysis were performed at the Arkansas Water Quality Lab. Storm loads were calculated with all the data and with subsets of the data. Correlations between the constituent concentrations and discharge were calculated. Various statistical analyses are being employed to interpret the data.

Principle Findings and Significance: Sampling was begun on November 1, 1997. A total of 364 samples were taken as of 2/28/98. These samples, and those samples taken during the remainder of the project, represent a large and valuable database on nutrient concentrations during storms. Preliminary data analyses showed results consistent with those expected - a large percentage of the total nutrient load in a stream is transported during storms and a major portion of the storm load occurs during the rising portion of the hydrograph. Load calculation accuracy is very sensitive to storm sampling frequency and initial sample timing. When a subset of the data, representing a wider sampling interval, was used to calculate a load, a concentration spike or outlier had a larger influence on the calculated load. The concentrations of several constituents were correlated to flow, total suspended solids, and other constituents.

The results of this research will be useful in all parts of the country for optimizing sampling strategies used in the determination of TMDLs. The observed patterns and correlations can be used to more accurately estimate loads based upon limited data and to choose when to sample. The information gained will allow water quality investigators to design sampling schemes for their particular sites and conditions that use only enough samples to adequately characterize pollutant loads and concentrations, saving time and money. It will also increase the precision and accuracy of the load calculations, making assessments of improvements from Best Management Practices more reliable and assisting in setting more accurate TMDL limits. The project will continue until 8/31/98. An extension to the project has been proposed.

SYNOPSIS

Project Number: C-03

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Start: 9/1/96
End: 8/31/97

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Title: Assessing the Effects of a Small Community Using Onsite Waste Water Treatment Systems on Ground and Surface Water Quality

Investigators: Terry Nichols, Marc Nelson, Ralph Davis, and Paul Vendrell, University of Arkansas, Fayetteville, Arkansas

Congressional District: AR 3

Focus Category: GW, HYDROL, NPP, SW, WW, WQL

Descriptors: Bacteria, Groundwater Hydrology, Groundwater Quality, Groundwater Movement, Hydrogeology, Rivers, Septic Tanks, Surface Groundwater Relationships, Wastewater, Water Quality

Problem and Research Objectives: Nonpoint source contamination of the upper White River is having a serious impact on Beaver Lake, a major drinking water supply for Northwest Arkansas. Both human and animal waste contribute pollution to the river. This study of the town of St. Paul is an effort to determine the extent to which domestic on-site wastewater systems in alluvium contribute to the pollution load on streams, the upper White River as an example.

Methodology: Long-term monitoring of surface and shallow ground water at St. Paul, Arkansas was used to determine ambient quality and the impact of local septic systems in alluvium.

Principle Findings and Significance: The town of St. Paul is situated on shallow alluvial deposits, which slope to the White River channel bottom, adjacent to town. Water samples from eight hand-dug wells in town indicate that all the shallow ground water is contaminated with effluent from individual septic systems in the town. Total coliform counts up to 165,000 MPN/100 mL and _Escherichia. coli_ as high as 3,000 MPN/100 mL were obtained from these wells. Chloride and sulfate levels both reached 17 mg/L and nitrate levels reached 5.6 mg/L in the shallow wells. Analysis of samples from the White River revealed no impact from the town on the river. The maximum total coliform count in the river was 14000 MPN/100 mL and the maximum _E. coli_ count was 300 MPN/100 mL. The highest chloride reading in the river was 6 mg/L. Sulfate and nitrate maximum observations were 5.1 and 0.5 mg/L, respectively. For all the analytes mentioned here, river samples taken above, adjacent to and below St. Paul revealed no significant differences and no discernible trends. Even with a regional school of 350 students, this town of approximately 175 residents is not markedly impacting the water quality of the White River. The results from this study apply to septic systems in allivual deposits adjacent to streams nationwide.

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PUBLICATIONS
RESULTING FROM USGS FUNDED PROJECTS

1. Articles in Refereed Scientific Journals

Citation	Supporting Project No.
Steele, K.F., W.C. Stimmel, and Warren Viessman, 1997, AWRC Education at the Grass Roots Level: Sections and Chapters *in* Water Resources Education, Training, and Practice: Opportunities for the Next Century, John J. Warwick, ed., American Water Resources Association, Herdon, Virginia, p. 875-879.	B-01

2. Book Chapter

Citation	Supporting Project No.
None.	

3. Dissertations

Citation	Supporting Project No.
None.	

4. Water Resources Research Institute Reports

Citation	Supporting Project No.
Nichols, Terry, Marc Nelson, Ralph Davis, and Paul Vendrell, 1997, Assessing the Effects of a Small Community Using On-Site Waste Water Treatment Systems on Ground and Surface Water, Arkansas Water Resources Center Technical Completion Report.	C-03
Scott, H.D., T. Lavy, E. Wailes, K. Young, A. Johnson, D.R. Shaw, S.W. Manley, and F.M. Kaminiski, 1997, Vulnerability and Use of Ground and Surface Waters in the Southern Mississippi River Valley, Arkansas Water Resources Center Technical Completion Report.	C-01

5. Conference Proceedings

Citation	Supporting Project No.
Steele, K.F., Proceedings of the Arkansas Water Resources Center Annual Research Conference, March 24 and 25, 1997, Fayetteville, Arkansas.	B-01

Steele, K.F., W.C. Stimmet, and Warren Viessman,   B-01
1997, AWRA Education at the Grass Roots Level:
Sections and Chapters, American Water Resources
Association and University Council on Water Resources
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6.   Other Publications

Citation

None.

PUBLICATIONS
RESULTING FROM NON-USGS FUNDED PROJECTS

1. Dissertations

   Citation

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   Lin, H.S., H.D. Scott, and K.F. Steele, 1996, Development of a Ground Water Vulnerability Map for Pesticide Contamination for the Arkansas Delta Using GIS: American Water Resources Association Annual Symposium on "GIS and Water Resources," Fort Lauderdale, Florida, September 22-26, 1996.

   Lin, H.S., H.D. Scott, and K.F. Steele, 1996, Use of GIS to Identify Optimal Locations for Sampling Ground Water for Pesticides in the Arkansas Delta: Lower Mississippi Delta Conference, Memphis, Tennessee, August 14, 1996.

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4.   Other Publications

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Sager, C.L., Final Report: Inventory and Mapping of the Riparian Zone (Wetlands) at Buffalo National River, a Final Report to the U.S. Forest Service, Buffalo National River.

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INFORMATION TRANSFER PROGRAM

The professional presentations and publications by the principal investigators of Section 104 grants are listed in the Publications section on page 11 of this report. The Center sponsored a conference attended by over 100 persons titled "Water Quality of Surface and Ground Water and Best Management Practices," along with a short course titled "Watershed Management - Modeling and GIS Aspects," by Kent Thornton of FTN Associates, Little Rock, and Fred Limp of the Center for Advanced Spatial Technologies, University of Arkansas, Fayetteville. The Director organized a session for the Northwest Arkansas Wastewater and Water Technicians Association on "Nutrient Transport"," held December 1997. In addition to these efforts, the Director and many of the investigators have communicated information to various groups and individuals in less formal discussions. These activities include discussions of research topics with state and federal agencies and private groups, and interviews with media reporters, including appearances on television news and information programs. Most of these activities have served the dual purpose of informing professional groups and the public of:

1) water resources problems and solutions, and;
2) the Center's activities in water resources.

During the grant period, the principal investigators and Director produced the following:

From USGS funded projects:
1) Presentations: 5
2) Professional Publications: 1

From Non-USGS funded projects:
1) Presentations: 50
2) Professional Publications: 39

In addition, the Center staff publishes the Arkansas Water Resources Center Newsletter bi-annually.

Several technology transfers were conducted during the last year involving 104 funded projects as shown below:

Project B-01 - Kenneth F. Steele, Director, Arkansas, Water Resources Center, conducted the "Arkansas Water Resources Center Annual Research Conference," March 24 and 25, 1997, Fayetteville, Arkansas.

Project C-02 - T.S. Soerens, M.A. Nelson, and D.G. Parker presented "Optimal Sampling for Determining Pollution Loads," at the 1997 District meeting of the Northwest Arkansas Wastewater and Water Association, December 10, 1997.

STUDENT SUPPORT
USGS Funded Projects

| | SECTION 104 AWARDS | | NIWR-USGS | SUPPLEMENTAL | |
	BASE GRANT	RCGP AWARDS	INTERNSHIP	AWARDS	TOTAL
UNDERGRAD.	1	2			3
MASTERS		1			1
PH.D.					
POST-DOC.					
TOTAL	1	3			4

STUDENT SUPPORT
Non-USGS Funded Projects

UNDERGRAD.	25
MASTERS	37
PH.D.	0
POST-DOC.	1
TOTAL	63

NIWR-USGS STUDENT INTERNSHIP PROGRAM

None.

Achievement/Award	Supporting Project No.
This project integrated faculty and students representing six research teams from three universities in the work on the Delta on BMP's for agriculture, GIS investigation of environmental factors affecting agricultural chemicals, and economic aspects of the region.	C-01
The results of this research will be useful in all parts of the country for optimizing sampling strategies used in the determination of TMDLs. The observed patterns and correlations can be used to more accurately estimate loads based upon limited data and to choose when to sample. The information gained will allow water quality investigators to design sampling schemes for their particular sites and conditions that use only enough samples to adequately characterize pollutant loads and concentrations, saving time and money.	C-02
Information has been provided to the residents and officials of St. Paul, Arkansas, regarding the quality of ground water of the area which has peaked interest in this resource and will benefit the community in decision making.	C-03