Western Kentucky University
Technical Assistance Center for Water Quality
Center for Water Resource Studies

"Supporting Small Water Systems in Meeting the Goal of Public Health Protection"

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Introduction

Western Kentucky University was awarded a grant by the Environmental Protection Agency (#X826659-01-0) to establish a Technical Assistance Center (the Center) for Water Quality for small public water systems. This program focuses resources and expertise toward assisting small water systems in achieving and maintaining capacity development, and meeting the primary goal of public health protection. The capacity development framework offers a forum within which this Center is working with other similar programs, federal and state regulatory agencies, and small drinking water systems. Development of this forum provides assistance to small systems for acquiring and maintaining technical, financial and managerial capacity. These capacities are needed to provide safe drinking water and achieve the public health protection goals of the EPA Safe Drinking Water Act. Likewise, the goal of public health protection is promoted through additional tasks of the Center that include a small systems circuit rider, the Utility Management Institute (UMI), Source Water Protection Program, and information technology.

Western Kentucky University has developed this Center with long-range goals, and a "regional" focus of projects that have a national perspective. The work plan for this Center is organized into tasks that have multi-year projects. These tasks are distinct in nature, but mutually supportive of small water systems and the provision of public health. **Task 1** addresses training in managerial and financial capacity development; **Task 2** provides for technical capacity development in a "circuit rider" approach; **Task 3** is a source water protection program consisting of field studies to assist and create source water protection models for small drinking water systems; **Task 4** is a database management system and development of information tools to receive, organize, integrate and distribute project information; **Task 5** establishes a forum to provide innovative technical assistance.

Executive Summary

Introduction. Western Kentucky University has established a Technical Assistance Center for Water Quality for small water systems. The underlying goal of the Center is to assist small water systems in a manner that promotes the protection of public health. Information presented in this report represents efforts during the first quarter of year four of this grant.

Synopsis. This second quarter, fourth contract year report depicts progress in each of the aforementioned tasks, with task activities that are focusing on the ultimate goal of improved public health. The Technical Assistance Center for Water Quality's efforts continue in developing and delivering management training courses for small systems; in working with Western Kentucky University to establish online courses in Water Utilities Management that can be completed as part of an Associates Degree; conducting on-site technical assistance for small system compliance; providing technical assistance to develop and promote source water protection, through sampling, analysis, methods assessment, and community relations; and developing and distributing information and information tools.

Administration. The primary focus of the Director in this second quarter of the fourth year has been to solidify the group of team members that make up the Center; to work with EPA Region 4 (Dale Froneberger, Region 4 Capacity Development Coordinator) to coordinate capacity development activities; to consolidate relationships with the Kentucky Division of Water and the Environmental Protection Agency; to work with the American Water Works Association (AWWA) as the Chairman of the Small Systems Committee for the Tennessee/Kentucky Section of AWWA; and to identify additional opportunities for productive work that fits within the mission of the Technical Assistance Center for Water Quality and the Center for Water Resource Studies at Western Kentucky University. In promoting the assistance provided by EPA and the goal of public health protection, during this quarter we have worked with Dale Froneberger of EPA Region 4 and Dave Riesen of EPA Region 6 to promote our capacity development training, the UMI, and future online courses. The director was invited to speak at the recent Region 4 and 6 capacity development workshop, Dallas, TX (April 2-4, 2002), and at the Region 4 state drinking water administrators conference in Atlanta, GA (April 22-24, 2002). Members of the UMI team (Andy Lange and Phillip East, with KRWA) and the Circuit Rider (Scott Wallace, with KRWA) assisted in presenting at these conferences. During the quarter the director and task manager of the Source Water Protection Program (Chris Groves), visited EPA headquarters to discuss source water protection initiatives of the Center and how the Center can best serve small drinking water systems in the region and nation. Members of the Center have served on committees with oversight of the Green and Tradewater Watersheds (a major portion of Western Kentucky), the Kentucky Pesticide Work Group that directs efforts to reduce pesticides in source water for public health protection, a water resources planning group with the Barren River Area Development District, and we have begun work with AWWA to promote capacity development of small systems.

The director and TACWQ staff are working with small systems in the task of source water protection and planning. We have begun a project working with McCreary County Water District. We will be conducting the susceptibility analysis of this system utilizing the Kentucky Division of Water methods and expand the work to include a watershed level analysis. This work will be beneficial on both a regional and national level, as it will be used to produce a source water protection how-to-guide in Year 5. Lastly, this work will help the Center develop a web toolbox for source water protection that can be accessed by water systems throughout the nation.

Task 1. During this quarter, the course titled "Utility Organization, Regulation & Law" was presented at the Holiday Inn – North in Lexington, Kentucky on March 27-28, 2002. There were fifteen (15) students participating in this course. Copies of the Course Assessments, filled out by the students, are included with this quarterly report.

Task 2. During the quarter, the Circuit Rider made 43 technical assistance visits to non-community and community water systems for a total of 616.5 program hours. A total of 106.5 hours were spent on-site with 33 different systems. On-site visits included Seventeen (17) for leak detection and ten (10) for assisting with Consumer Confidence Reports (CCRs). A total of ten (10) CCRs were completed during the quarter. The Circuit Rider attended the KRWA Legislative Breakfast in Frankfort, the KRWA Management Conference in Bowling Green, KY, and the Kentucky Water and Wastewater Operators Association Conference in Owensboro during the quarter.

<u>Task 3</u>. Work on the Source Water Protection Initiative's two major projects, the Demonstration Watershed Study and the Trihalomethane Study, each achieved scheduled progress. There was a delay in our quarterly sampling round, which was completed in early April. A significant accomplishment during the quarter was the completion of an initial Geographic Information Systems (GIS) and statistical evaluation of relationships between land use and source water quality over several years' data at our karst demonstration watersheds. We also continued special emphasis on the pesticide problems, particularly at Marion, Lewisburg, and Diamond Caverns Campground, which we have identified as our most serious source water concern for small suppliers. We also continued to work closely with the Kentucky Department of Agriculture, Division of Pesticides regarding this work, and traveled to Iowa to establish collaboration with the Upper Iowa River Watershed Alliance, where we plan to extend our work to study serious agricultural impairment of water quality in karst aquifers that supply water to a number or small rural communities. We have also met with Within the Trihalomethane Study work continued during the quarter on Manipulative Experiments, the Large River Survey, the Taylorsville Lake Study, and analysis of the Implications for THM Model Development and Water Management. We also made progress in dissemination of our results to the scientific community, including several presentations and editing of two manuscripts on the work to refereed scientific journals. Results of these projects are described in the body of this work.

<u>Task 4</u>. During this quarter, the Database Management and Information Tools group has improved our ArcExplorer Mapping tool CD set for water systems with the addition of new Geographic Information System data layers, including additional watershed boundaries at several scales, and a recently updated set of water system distribution lines, broken out by counties. A copy of this 2-CD set is included with this report. We have upgraded the installation program for our Water Loss Calculator so that it can be installed effortlessly under a broader range of operating systems; this improvement now renders the Water Loss Calculator distributable on a national scale. We undertook necessary additional testing of the internet interface we developed for querying our database, and have incorporated some new data sets. We have worked to analyze available data for patterns and trends, including geographic, water quality, and data from the EPA Safe Drinking Water Information System database. Some of these maps and analyses are presented in this report, including statistical trends describing relationships between source water bacteria and pesticides and distributions of land use type. We have also engaged in numerous education outreach and science advisory services for agencies, groups, and the public, also described in this report.

<u>Task 5.</u> Task 5 continues to expand into other area as projects are completed and other needs are developed.

1. Work on the Sanitary Survey Self-assessment continues to develop as information becomes available;
2. The paper, **The Wholesale Rate,** that was developed to be placed on the web along with a spread sheet that will allow someone to enter data and calculate a wholesale rate, is complete and on the web;
3. A reader friendly paper on The Membrane Technology continues to develop; and,
4. We have developed a project to assist West McCracken Water District with the collection of geographical data to build a Geographic Information System (GIS) of their infrastructure. We are working with Spatial Data Integrations (SDI), the developers of the Water Works FM

software, a low cost GIS management system for water utilities. SDI has committed to donating a copy of the software to the Center. In exchange, we will assist West McCracken Water District in collecting data using existing information and GPS technology in the field, developing the GIS system, training the District to use the GIS, and helping the District realize the management capabilities of the system. This project will serve as a demonstration as well as provide cost, effectiveness, and use information to other small systems considering using GIS as a management tool. The goals of the Center are to provide a guide to small systems considering this management option and assist these systems in increasing their technical and managerial capacities.

Administration

I. Work Status

Administrative activities included technical oversight for all tasks, management of personnel, planning, budgeting, grant cost accounting, and tracking of grant accounts. Administrative responsibilities further included meetings and interaction with officials in the U.S. EPA headquarters, Region 4, and Region 6, the Kentucky Division of Water, the Kentucky Rural Water Association, the Tennessee/Kentucky Section of the American Water Works Association, the Barren River Area Development District, the U.S. Department of Agriculture, and other Technical Assistance (TA) providers. Administrative activities assessed task efforts to insure accordance with the primary goal of protection of public health. The Director also met with and gave guidance to the Task Managers in order that activities were in accordance with the grant technical proposal and milestone schedules. Additionally, the Director reviewed the TACWQ activities with EPA, Source Water Protection, and continued to work with Dale Froneberger of EPA Region 4, Capacity Development Coordinator, to determine ways the Center may assist states and other TA providers.

A. Work Progress. McCreary County Source Water Protection Planning: We are working with KRWA and the Kentucky Division of Water to assess the states databases for identifying drinking water hazards in the source water protection zones. A major effort has been the development of spreadsheet tables for conducting the analysis, determining the sources of available data, and writing a plan of action for developing the Source Water Protection Plan for McCreary County Water District. During the next quarter we will utilize available databases to construct hazard maps for the source water protection zones. Throughout this process we will document our activities and be working to develop a source water protection how-to-guide. This will be a major focus of Year 5, the completion of the guide. Our work at McCreary County is focused to develop resources that can assist small water systems in developing technical capacity fro source water protection.

Online UMI Courses: Western Kentucky University (WKU) has approved all six UMI courses to be offered as part of an Associates Degree in Business Technology with a concentration in Water Utility Management. Bowling Green Community College will begin offering these courses, at the latest, in Spring 2003. We anticipate that the first course, however, will be offered in the Fall 2002. Currently, we have received a grant through WKU to develop the courses this summer. The program of study will allow TA providers, trainers, utility managers, office managers, operators and others to obtain a degree with a concentration in Water Utility Management from WKU. Our primary purpose for promoting this within the University was to establish a program that could increase the managerial capacity of small systems by allowing managers to complete a degree. We will continue to offer the free courses through the UMI. This will allow managers without available time resources to obtain a Utility Management Professional Designation from WKU and KRWA. In this manner, through the development and offering of managerial courses, the UMI will continue to provide for managerial capacity development of small systems.

B. Difficulties Encountered. No unanticipated difficulties were encountered.

C. Preliminary Data Results. McCreary County Source Water Protection Planning: We have prepared maps of the source water protection zones, identified databases for the hazard identification, and completed the spreadsheet tables for performing the susceptibility analysis. According to reviewed data, McCreary County has an intake on a major recreational reservoir in Kentucky and may face threats from fecal contamination, pesticides, urban runoff, and abandoned mine discharges. However, the District has not had violations of drinking water regulations and wants to continue to produce high quality drinking water through the multiple barrier approach promoted by EPA. As such, we will be expanding the source water protection zone to a watershed-level in order to address interstate hazards to the water supply.

Online UMI Courses: We have obtained a grant through the University for the development of the online UMI courses. The Director has been working with a Business faculty member in the Community College, Dr. Dawn Bolton, to promote the program and prepare the courses online. We have already put the UMI 101 course into the CourseInfo system. The series of courses will be offered through the Kentucky Virtual University (http://www.kyvu.org/).

D. Anticipated Activities. Work will continue with Dale Froenberger to assist other states in Region 4 in developing training to increase managerial capacity. We will be speaking to state officials and technical assistance providers at the EPA Region 4 and 6 Capacity Development Workshop on April 2 – 4, 2002 and to Region 4 State Drinking Water Administrators the week of April 22. Likewise, the Director will continue all administrative duties and work to increase capacity development within the state of Kentucky and in the Region. To that end, we will be putting all of the UMI courses into an online format that will allow UMI courses to be taken remotely from throughout the United States. Finally, we will be working to become a leader in providing technical assistance for source water protection, including planning, assessment, and education.

II. Discussion of Expenditures

During the Second Quarter of Year 4, expenditures for the Administration Task were $23,154.66, with Year-to-Date expenditures of $39,007.53.

III. Changes in Key Personnel

There were no changes in key personnel for this period.

References

Hayes TB, A. Collins, M. Lee, M. Mendoza, N. Noriega, A.A. Stuart, and A. Vonk. 2002. Hermaphroditic, Demasculinized Frogs After Exposure to the Herbicide Atrazine at Low Ecologically Relevant Doses. Proceedings of the National Academy of Sciences of the United States of America 99(8):5476-5480.

Task 1: Utility Management Institute (UMI)

I. Work Status

The goal of the UMI is to develop and deliver a series of courses to be included in a "Utility Management Professional" certification program. This program is available to system managers, operators, and office managers of water systems serving rural areas and small municipalities with populations under 10,000.

A. Work Progress. The course titled "Utility Organization, Regulation & Law" was presented at the Holiday Inn – North in Lexington, Kentucky on March 27-28, 2002. There were fifteen (15) students participating in this course. Copies of the Course Assessments, filled out by the students, are included with this quarterly report.

B. Difficulties Encountered. No unanticipated difficulties were encountered.

C. Preliminary Data Results. The Utility Management Institute now claims a total of eighty-five (85) students. Seventy-five (75) water and wastewater managers have completed "Utility Management 101." Forty-three (43) of those managers have completed the "Utility Organization, Regulation & Law" course and twenty (20) have completed the course in "Utility Finance & Administration." Sixteen (16) of our students have now completed all three of the existing courses in the UMI Series.

D. Anticipated Activities. We will continue to work with the WKU Center for Math, Science, and Environmental Education to develop the course materials for future courses. During the third quarter, the UMI course on "Human Resource Management for Utilities" will be presented in Bowling Green, Kentucky on April 24-25, 2002 at the Carroll Knicely Center. In addition, the course "Modern Technology and Utility Management" will be conducted on June 5, 2002, in Morehead, Kentucky. Phillip East and Ritchie Taylor will make a presentation on the Center for Water Resource Studies and the Utility Management Institute at the Capacity Development Workshop hosted by the EPA Region 4 and Region 6 staff in Dallas, Texas on April 3, 2002.

II. Discussion of Expenditures

During the Second Quarter of Year 4, expenditures for Task 1 were $16,725.53, with Year-to-Date expenditures of $48,616.10.

III. Key Personnel Changes

There were no personnel changes during this quarter.

Task 2: Circuit Rider Program

I. Work Status

The "Circuit Rider" approach to providing a combination of on-site technical assistance and training is nationally recognized as the most effective method of assisting small public water systems to comply with state and federal environmental regulations. The Circuit Rider program works in partnership with Kentucky Division of Water (DOW) to target the public water systems serving populations under 3,300, with particular emphasis on systems serving less than 500 people. Our "Circuit Rider" approach works to target those small systems experiencing profound difficulties in complying with SDWA provisions in order to enhance protection of public health.

A. Work Progress. During the quarter, the Circuit Rider made 43 technical assistance visits to non-community and community water systems for a total of 616.5 program hours. A total of 106.5 hours was spent on-site with 33 different systems. Seventeen (17) of the on-site visits involved leak detection and ten (10) Consumer Confidence Reports (CCRs) were completed The Circuit Rider attended the KRWA Legislative Breakfast in Frankfort, the KRWA Management Conference in Bowling Green, and the Kentucky Water and Wastewater Operators Association Conference in Owensboro during the quarter.

Technical Assistance Report

As the following letter indicates, KRWA provided the City of Blackey many hours of on-site technical assistance during a flooding crisis in January 2002. The WKU program, through the Circuit Rider, provided <u>43.50 on-site hours</u> in a three-day period of time.

Letter submitted by the City of Blackey to a local newspaper

January 28, 2002

On Wednesday morning of last week, Letcher School closed and sent students home due to lack of water. Mayor Mark Stone was in Pikeville at a meeting. When he returned home at 6 p.m., he was updated on what was already a rough week for the Blackey Water System. On Monday morning of that week, the plant operator left and did not return. The City Council and Mayor were forced to find a replacement, pronto, and that was not an easy task. By Tuesday, just before the area flooding began, Barry Back from Kentucky Rural Water Association came and, along with Steve Taylor of U.S. Filter, worked until late in the night to re-fill the tanks which were very low, with help from both Mark and Peggy Bach, Bookkeeper at the water plant. The raging floodwaters, however, were making things difficult and progress was slow. Processing floodwater is generally too difficult for any water plant equipment to withstand and is usually not even attempted; standard procedure during a flood would be to use stored water previously treated, but since the tanks were too low to be able to keep up with demand, they had no other choice but to try. By 2 a.m., the water level was unchanged, it was just meeting the demand, but they were unable to do anything further. Wednesday morning is when the tank lost 2 feet of water rather quickly and kept losing until it was empty, and they knew that a break had occurred somewhere. Additional staff from Rural Water arrived, **Scott Wallace [the WKU Small Systems Circuit Rider]** and Jeff Lee. Tim Breeding of Isom helped Barry search for the leak. The floodwaters debris had clogged the intake screen and late that night, they had to find a way to bypass that. Hazard water system's Bobby Holland volunteered the necessary equipment and supplies. Charlie Caudill, who had worked at the Blackey plant in the past, came to help, too. It wasn't until 7 a.m. Thursday that they started working on it and it was 3:30 in the afternoon before the by-pass was complete and water was able to be processed.

But by 4:30, the auxiliary pump was clogged again. **Scott** and Jeff actually entered the floodwaters, waist-deep, gallantly risking their lives to move the pump to a better position to increase flow, and after 30 straight hours working for the people of Blackey, Dell Harris arrived to replace them. Friday afternoon, Larry Hall and Duke Mullins arrived from U.S. Filter to help with leak detection. It would have been possible to fill the tanks from an outside source, such as a truck bringing in clean water from elsewhere, and Mayor Stone was forced to contact Letcher County Judge Executive Carroll Smith for help at 11:30 p.m. on Friday. Paul Miles and Roy Benge of the Kentucky Division of Emergency Management, Heath Preston and Bob Mitchell from Hal Roger's office, Jeff Belcher, Tom Armstrong, and Jody Lassitor from the Governor's office, and Senator Ray Jones were all contacted. Mayor Stone was forced to declare a "state of emergency." On Saturday morning, Paul Miles and Roy Benge showed up to meet with all the parties involved. Later that day, Steve Capps of Kentucky Rural Water Association, also joined the team of workers. At that time, everyone knew that there was a leak or a break in the line somewhere, but with no water to pump through the lines, it was virtually impossible to find the leak. Water had to be made, but they were still working with floodwater only. It was decided that a tanker truck might be needed to bring in water to supplement water produced by the plant.

By Saturday, the community of Blackey and beyond had come to the rescue in full force. Phillip Hall of Maces Creek provided a new compressor. Vernon Hall of Mountain Outreach in Jenkins, the American Red Cross, Wal-Mart, and Carroll Forsythe of Culligan Water in Hazard all provided drinking water for Blackey residents. Breeding's Plumbing and Electric in Isom was available at all times. It would be hard to name all of the people who worked out in the mud, digging and straining their backs, providing assistance in the plant itself, donating tools and equipment, checking lines, bringing in water samples, and even meeting at midnight to check and re-check every single water line and valve until 6:30 in morning. It was a true rally and each and every person is to be commended. Mayor Stone had 7 total hours of sleep in a 4 day span, all in 1 to 4 hour increments, but he wasn't the only sleepless man in the Blackey area, there were ex-mayors Mike Dixon, Sam Oaks, and Jim Begley, council members Jim Flynn, Roger Hays, Joe Back, Janie Dixon, and community members Frank Campbell, Dave Duke, Greg Whitaker, Greg Pridemore, Merle Caudill, James Williams, Adrian Blair, Clarence Caudill, Robbie Williams, Keven Nichols, Loye Caudill, Mike Haynes (who missed the UK – Alabama ballgame during his shift), J.P. Campbell, Ray Arnold, and many, many others. The women of the Presbyterian Church, who were having a sale Saturday at the church, donated food. Other wives and women of the community helped out behind the scenes since the men felt obliged to deal with the harder physical work on their own. My most sincere apologies to anyone I failed to mention, but as those who were there can attest to, there was no time to take down names, there was work to be done and the people of the Blackey area proved that it could be done. By Sunday morning, the leak had been located above Burton Hill near the river. And that evening, the leak had been fixed by the team of Barry Back, Steve Capps, and community members with help and equipment from Cheddie Smith and John Adams from the Letcher County Road Department. All the lines were re-opened and the water began flowing.

During the entire five days that people were without water, of the some 250 meters serving a population of about 1000 individuals, only two complaints were made. That just proves that the people of Blackey truly do appreciate their water, and the community involvement showed that people do, in fact, feel an ownership of the water system itself. The camaraderie of the volunteer workers will not be soon forgotten by them or by all of the people who now have good, clean, healthy water flowing through the faucets of their homes again. We are all connected, not just by those blue water lines, but by the spirit of community that has helped the little town of Blackey to come back time and time again, from floods and fires, from loss of industry and commerce, from out-migrations and loss of schools. We are proud and we are resilient, and we have proved it once again.

By Nikki Stone

B. Difficulties Encountered. No unanticipated difficulties were encountered.

C. Preliminary Data Results. See Work Progress above.

D. Anticipated Activities. During the next quarter, the WKU Small System Circuit Rider will continue to assist systems with operational and management problems. An increasing amount of the Circuit Rider's time is expected to be spent with systems that have made specific requests for assistance through the KRWA office. Many of these requests have resulted from on-site visits. The Circuit Rider will also continue to identify systems that have technological needs. The Circuit Rider will continue to create educational opportunities for the communities we serve. Educational activities will focus on elementary, middle, and high school children and will emphasize the role small utilities play and the importance of good source water quality. This work will be coordinated with efforts within the WKU Center for Water Resource Studies. The Circuit Rider will be working with other staff members to complete the GIS project with West McCracken Water District.

II. Discussion of Expenditures

During the Second Quarter of Year 4, expenditures for Task 2 were $25,527.54, with Year-to-Date expenditures of $35,617.60.

III. Changes in Key Personnel

There were no changes in key personnel for Task 2.

Task 3: Source Water Protection Initiative

I. Work Status

A. Work Progress

Work on the Source Water Protection Initiative's two major projects, the Demonstration Watershed Study and the Trihalomethane Study, each achieved scheduled progress.

a. Demonstration Watershed Study

The Demonstration Watershed Study uses three interrelated programs to characterize each study site's source-water catchments: 1) water sampling and water analysis, 2) Geographic Information System (GIS) land use analysis, and 3) the examination of macroinvertebrates indicative of water quality. We made significant progress in programs 1) and 2), results are outlined below.

Work has continued on our quarterly sampling program at the Demonstration Watersheds (Auburn, Cadiz, Diamond Caverns, Guthrie, Logsdon River, and Marion), in order to characterize and monitor the sites' source water issues. We continue to focus on the most significant source water problems that we have identified: pesticides and bacteria. Work on pesticide contamination at Lewisburg (Spa Lake) has been led by graduate student Katie Seadler. Sampling for her graduate research at Lewisburg is completed and a finished Master's thesis is expected December 2002. During the 3rd Quarter, Ms. Seadler will be familiarizing Task 3 field technicians with sampling locations and techniques. During Ms. Seadler's fieldwork at the site that was thought to have been non-karst, a large karst spring was discovered. Task 3 groundwater dye traces are now nearing completion in the watershed. These traces are being conducted to delineate the extent of the spring's watershed. Task 3 plans to continue its work at Spa Lake to verify findings from her portion of the research project. Work at both Spa Lake and Marion is ongoing with cooperation of the Kentucky Pesticide Work Group (consisting of Western Kentucky University, Ky Division of Pesticides, Ky Division of Water, Ky Department of Conservation, Ky Corn Growers Association, Ky Rural Water Association, the U.S. Geological Survey, U.S. Natural Resources Conservation Service, and the Syngenta Corporation).

Work at the Logsdon and Diamond Caverns sites has continued with emphasis on the role of sediment in the transport of pesticides through the sites' shared karst aquifer. Graduate student Mike Anderson has been conducting research on Logsdon River pesticide transport as his Master's thesis. All sampling has been completed for his research project. A draft manuscript has been completed and his final thesis is expected August 2002. Task 3 plans to continue quarterly sampling at the Logsdon and Diamond Wells with cooperation of the National Park Service in order to continue developing source-water protection techniques and monitor effects of the newly implemented Conservation Reserve Enhancement Program (CREP).

Water Sampling

Quarterly Sampling at the Demonstration Watersheds

The quarterly sampling took place for the regular list of parameters (Appendix 3-1). For the last several months, the wells at Logsdon River and Diamond Caverns (Hawkins River) were not operating properly due to a broken well-pump. The wells are now in full operation.

Geographic Information Systems Analysis

Geographic Information Systems Analysis of Land Use and Karst Drinking Water Resources in Kentucky

In many regions, the quality of both surface and drinking water sources is closely related to land use practices in the areas draining to the source. This is especially true in karst aquifer/landscape systems, where rapid recharge and groundwater flow rates allow contaminants to travel long distances with little of the amelioration of water quality common to some non-karst settings. Karst terrains are estimated to provide drinking water to some 25 percent of the world's population, including significant numbers in the United States. Within Kentucky, karst landforms and aquifers developed on soluble rocks occupy 55 percent of the state.

The Western Kentucky University Technical Assistance Center for Water Quality Source Water Protection Program, along with scientists from Mammoth Cave National Park (Olson, 2001), is working to use Geographic Information Systems (GIS) as a tool to understand threats to water quality within Kentucky's karst areas. The goal has been to understand relationships between land use and source water quality, and to investigate methods whereby the quality of source waters can be improved with the premise that the better the quality of source waters reaching a water treatment facility, the easier and cheaper the and water will be to treat. The project uses several strategies to characterize each watershed, including water and Geographic Information System (GIS) analyses of land use. In this quarter we have made significant progress in the develop of methodology to quantitatively related the land use from the GIS segment of the project to measured water quality. This work shows by example how GIS can serve as a tool for the investigation of source water quality, and is described more fully in the data section, below.

Continuing Geographic Information Systems (GIS) Development and Land Use Analysis

The GIS layer of USGS Anderson Level III land use parcels has been completed for the Spa Lake watershed (pending results of the dye traces). The results, however, have not been field checked for accuracy. The land use parcels and USGS codes were created by interpreting aerial infrared photographs of the Spa Lake watershed. During this quarter, these remotely sensed data will be compared to 1999-2001 crop coverage maps created by the Natural Resources Conservation Service. These data will enable us to determine the number of acres and locations of corn and other residue row crops (and therefore, the lands on which Atrazine was applied) over the past three years. The initial, remotely sensed Anderson Level I land use data is presented in Table 3-1

The status of Task 3 GIS is that we have created GIS land use coverages, completed quality control measures, and written metadata for seven sites; the remaining tasks at Spa Lake will be completed during the upcoming quarter.

Table 3-1. Anderson Level I Initial Land Use within the Spa Lake Watershed

Anderson Level I Land Use Type	**Area (in km^2)**	**Number of polygons**
Urban and Built Up	1.78	67
Agricultural	33.81	231
Forestland	14.50	66
Water	1.08	20
Total	51.17	384

b. Trihalomethane Project (Dr. Jeffrey Jack, University of Louisville)

Work continued during the quarter on Manipulative Experiments, the Large River Survey, the Taylorsville Lake Study, and THM Model Development. Results are discussed in the data section, below.

c. Dissemination of Results

During the 2nd Quarter, Task 3 disseminated results through several posters and presentations at scientific meetings.

Manuscript to a peer-reviewed journal:

Glennon, J. and C. Groves, 2002, "An Examination of Perennial Drainage Density within the Mammoth Cave Watershed" was submitted, reviewed, and accepted for publication in the April 2002, *Journal of Cave and Karst Studies*. The article deals with the organization of the karst drainage networks, which underlie between 40-50% of Kentucky. The study (not directly funded by TACWQ) used data and GIS developed by Task 3.

Presentations and posters at scientific conferences:

Seadler, K., Groves, G., and R. Taylor, 2002, *"Pesticides in Kentucky Karst Aquifer Drinking Water Sources"*. Presentation at the 2002 Western Kentucky University Sigma Xi Student Research Conference.

Pfaff, R. and W. Hawkins, 2002, *Geographic Information Systems Analysis of Kentucky Water Quality*, poster presented at the January 10, 2002, "Posters at the Capitol", a poster session at the Kentucky State Capitol for state legislators to highlight undergraduate research in Kentucky Universities. The EPA grant was acknowledged for contributions to this goal in the process of working on this grant.

Pfaff, R. and W. Hawkins, 2002, *"Geographic Information Systems for the Study of Kentucky Water Quality"*. Poster presented at the spring 2002 Southeastern and North-Central Sections Joint Meeting of the Geological Society of America.

We have submitted a manuscript to Canadian Journal of Fisheries and Aquatic Sciences entitled *"Algal production and trihalomethane (THM) formation potential: An experimental assessment and inter-river comparison."* We submitted a revised manuscript back to the CJFAS and we are waiting for the editor's decision.

Other Progress

During the quarter we continued to meet with the Kentucky Department of Agriculture, Division of Pesticides, to discuss 1) our pesticide data from the Marion watershed and to coordinate our sampling of this problem site with the data being collected by the state and Syngenta Corporation, the manufacturers of Atrazine, 2) our 16 month long pesticide focus on the watershed, 3) cooperation between Task 3 and the Department on other serious atrazine problems at Spa Lake at Lewisburg, Kentucky, and 4) planning for land use education workshops for our demonstration watersheds. In January we gave a report to NRCS officials and landowners in the Lewisburg (Spa Lake) watershed on the results of our program and to make plans for continued voluntary Land use practices designed to lower atrazine concentrations in source water through the 2002 growing season. The farmers were helpful and cooperative and agreed to continue.

During quarter we started work associated with expansion of our programs to a new, significantly impaired site in the Coldwater Groundwater Basin, near Decorah, Iowa. The Coldwater basin site has been significantly impacted by agricultural activities, resulting in contamination of the karst aquifer there by pesticides, bacteria, and nitrates. Because of our experience in karst aquifer water quality and relationships to agricultural land use, we have developed partnerships to study this impacted basin at the request of the Upper Iowa River Watershed Alliance in conjunction with the Iowa Geological Survey, the University of Iowa, and the Illinois Geological Survey. We traveled to Iowa to meet with these groups and describe our programs in February. This project not provides an opportunity to use our experience to provide service to groundwater quality agencies in that region, but represents the first expansion of our programs beyond Kentucky, and both an excellent opportunity to leverage funding between our programs and these agencies and to expand the exposure to our programs to a national level. Other than being significantly impacted, this aquifer serves as a model for a number of small water supplies in rural northeast farming communities, including the town of Decorah (population 8,500). Because the larger karst aquifer extends northward from the Coldwater Basin into southern Minnesota, we have also met for planning with Minnesota Department of Natural Resources to share methodologies and data. The work will be conducted as a closely supervised Master's of Science thesis research project for Ms. Patricia Kambesis, and a detailed proposal is given in Appendix One.

We have also begun discussions with the Department of Geology at the University of Florida and the US Geological Survey there to plan investigations on karst drinking water sources in the Floridian Aquifer, have identified problems and methods of investigation, and will be continuing discussions over the upcoming year. If we are successful in developing a productive work plan, we don't anticipate actual work on the ground to commence until the year beginning 10/1/04..

B. Difficulties encountered

A scheduling problem caused us to take redundant quarterly water samples in both March and early April. Since much of Task 3 work focuses on pesticides, we resampled the source water demonstration sites. The bottles holding the water for pesticide analysis were not delivered to the analytical lab in time to conform to our quality control protocol. As a result, we are reporting only the April results. Also the well-pump at Logsdon and Diamond Caverns failed during the 2nd quarter. The wells have now been fixed, we will be completely replacing the well pumping system for the sites to avoid such problems in the future.

No other difficulties were encountered.

C. Data Results

Source Water Demonstration Watershed Study

Geographic Information Systems Analysis of Land Use and Karst Drinking Water Resources in Kentucky

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Introduction

In many regions, the quality of both surface and drinking water sources is closely related to land use practices in the areas draining to the source. This is especially true in karst aquifer/landscape systems, where rapid recharge and groundwater flow rates allow contaminants to travel long distances with little of the amelioration of water quality common to some non-karst settings (Quinlan and Rowe, 1978; Ford and Williams, 1989; Field, 1993; Veni *et al.*, 2000). Karst terrains provide drinking water to some 25 percent of the world's population, including 40 percent of those in the United States (Ford and Williams, 1989; Karst Waters Institute, 2001). Within Kentucky, landforms and aquifers developed on soluble rocks occupy 55 percent of the state (Cobb and Currens, 2001).

The Western Kentucky University Technical Assistance Center for Water Quality Source Water Protection Program, along with scientists from Mammoth Cave National Park (Olson, 2001), is working to use Geographic Information Systems (GIS) as a tool to understand threats to water quality within Kentucky's karst areas (Ek *et* al., 2000; Pfaff *et* al., 2000), including a major effort to improve drinking water quality by assisting small (fewer than 10,000 customers) water systems in meeting the requirements and goals of the Safe Drinking Water Act. Beginning in 1999, eight Kentucky drinking water source areas, including six with Mississippian-aged karst hydrogeology, were selected as demonstration study sites as part of an Environmental Protection Agency funded Source Water Protection Initiative (SWPI) (Groves *et al.*, 2000, 2001). The goal has been to understand relationships between land use and source water quality, and to investigate methods whereby the quality of source waters can be improved with the premise that the better the quality of source waters reaching a water treatment facility, the easier and cheaper the and water will be to treat. This can be done both with the development of Best Management Practices (BMPs), as well as the identification of treatment strategies that take into consideration natural temporal variations in source-water quality. The BMPs are land use practices that strive to balance minimization of the impacts to drinking water quality with the economic and cultural needs of those who live on the landscape. The SWPI project uses several strategies to characterize each watershed, including water and Geographic Information System (GIS) analyses of land use. The purpose of this paper is to describe the GIS segment of the project and how the GIS serves as a tool for the investigation of source water quality in Kentucky karst aquifers.

Potential water contamination threats may come from a variety of land use practices (Crawford *et* al., 1987; Ford and Williams, 1989; Crawford and Groves, 1995; Byl *et al.*, 2001; Wolfe and Haugh, 2001). With groundwater flow in karst areas often being rapid, unfiltered, and turbulent, groundwater quality problems are compounded in karst environments and such systems are extremely vulnerable to contamination. Karst waters can move several kilometers per day, which can allow contaminants to travel into and through an aquifer in a short time. Additionally, the turbulent flow present in karst aquifers can rapidly carry contaminants that are attached to soil particles. In fact, dye tracing has shown that septic tank effluent can percolate through the thin soils commonly found in karst areas and reach a spring within a few hours (Crawford, 1979).

Background Land Use - Water Quality Relationships

Agricultural practices are the surface land uses that are the most common sources of potential groundwater contamination within the SWPI sites (Groves *et al.*, 2000, 2001). A watershed with extensive coverage of row crops, for example, is likely to have pesticides present in the recharge area's surface and groundwater. Agricultural lands are also prone to soil erosion (Marsh, 1998); as soil particles are transported, pesticides that are adsorbed on soil particles can also be washed away. When fields are tilled, the topsoil is exposed and the particles can become more mobile. Moreover, many fields are also left barren during the winter months, with no vegetation cover to decrease erosional forces. Through time, crops may require more chemicals and fertilizers to sustain outputs as weeds and pests become resistant to pesticides. Fertilizers are primarily composed of nitrogen and phosphorus, which can also cause eutrophication of water bodies (Marsh, 1998). Eutrophication, an increase in the growth of algae and bacteria, degrades water quality for both humans and animals. Pesticides, which are composed primarily of synthetic compounds, can cause health problems, including skin irritations, intestinal disorders, neural disorders, and cancer, depending on the chemical and the length of exposure (Environmental Protection Agency, 1999b). Other agricultural sources of contamination may be from confined feeding operations and heavily overgrazed pasture. These land uses are sources of nitrates, phosphates, and fecal coliform, which are indicators for the presence of other harmful, disease-causing pathogens (Environmental Protection Agency, 1999c).

Urban land use practices are also potential contaminant threats to karst aquifers (Crawford, 1984; 1987; Crawford and Whallon, 1985; Wolfe, *et al.*, 1997), potentially including contamination from automobiles, industrial plants, landfills, and gas stations. There also may be urban water quality hazards just below the surface, including underground storage tank leakage and sewer or septic tank runoff (Crawford, 1979). As the recharge area is covered with increasing amounts of impervious surfaces, sinkhole flooding becomes a major problem in karst regions. Paved surfaces, such as parking lots and roads, do not allow rainwater to percolate into the soil, and therefore, can contribute to increased runoff rates. During heavy rainstorms, "ponding" often occurs in sinkholes, since there is more water on the surface trying to sink underground than the sinkhole can drain (Crawford, 1989). When wells are drilled to allow the sinkholes to drain, the contaminants that have been washed from the streets and parking lots can flow directly into the aquifer below with little or no attenuation (Crawford and Groves, 1985).

Serious threats are also posed by transportation of hazardous substances across karst areas (O'Connor and Brazos, 1991; Crawford and Ulmer, 1994). A toxic spill along an interstate or rail line located in the recharge area, for example, could potentially have rapid and devastating impacts on the aquifer's water quality. Spills are even more problematic in karst areas, since it is difficult or impossible to remediate contamination that quickly sinks into the subsurface. A 15,000 liter highway diesel spill in the south-central Kentucky karst in August 2001, for example, demonstrated the need for protection of karst aquifers and the difficulty of cleaning up spills in karst areas (Minor, 2001). Previous dye tracing showed that the fuel moved toward the Mill Hole River, one of the major underground rivers of Turnhole Spring Basin and Mammoth Cave area (Ray and Currens, 1998a, 1998b). Unfortunately, due to the presence of sumps (locations where the cave ceiling drops lower than the river's surface) along the conduit, the floating diesel will likely be trapped within the aquifer, perhaps for many years. Both the fuel entrained by the flow that leaks out in small amounts, as well as the soluble components such as naphthalene, would flow toward Mammoth Cave National Park. Eventually, these contaminants may reach the Green River and the water intake for the town of Brownsville.

Karst Watershed Demonstration Study Sites

There are six karst demonstration watersheds in the SWPI program:

(1) *Auburn* is located in the Pennyroyal Sinkhole Plain in Logan County, in south central Kentucky. The water supply for Auburn is a large spring called Auburn Spring, which serves about 2,000 people.

(2) *Diamond Caverns* is a private campground located north-northwest of Park City, Kentucky. The water supply consists of two wells that intersect Hawkins River, a major underground river that forms part of the Mammoth Cave System (Ray and Currens, 1998). The site is located at the boundary of the Pennyroyal Plateau and the Mammoth Cave Plateau, marked by the Dripping Springs Escarpment (Meiman and Groves, 2001)

The portion of the Pennyroyal adjacent to the Mammoth Cave Plateau is a well-developed sinkhole plain on Mississippian St. Louis, and Ste. Genevieve limestones (Palmer, 1981). Surface drainage is practically nonexistent on the sinkhole plain.

(3) The *Logsdon River* is intersected by two 145 m deep wells in a hydrogeologic setting similar to the Diamond Caverns site. Logsdon River at that point drains an area of about 25 km^2 and represents a well-instrumented research site not currently used as a water supply.

(4) *Guthrie*, which serves about 2,700 people, is located in the southern portion of the Mississippian Plateau of the Pennyroyal Region in Todd County. Moderate relief and karst landscape development characterize the region. The Guthrie area contains primarily agribusiness, but industrial activity is also present in the community. Guthrie's water supply comes from Meriwether Spring, which is located approximately two miles west of the town.

(5) *Cadiz* is located in the southern portion of the Mississippian Plateau of the Pennyroyal Region, characterized by moderate relief and karst landscape development. Cadiz City Spring, which supplies approximately 4,900 people, is located approximately nine kilometers east of Lake Barkley.

(6) *Spa Lake*, located southeast of Lewisburg in south central Kentucky, is a one km^2 dammed stream valley that now serves as the source water supply for northern Logan and Todd counties. The watershed drains about 43 km^2 of various pastures, crops, and rural communities. Although clastic rocks underlie the main part of the topographic watershed for the lake, the lower elevations cut down into limestone, and a large karst spring draining into the creek upstream from the lake was identified in 2001. A dye-tracing program to delineate the additional watershed area contributing to the lake has been initiated. Spa Lake has had serious problems with the pesticide, atrazine, and levels have exceeded EPA Maximum Contaminant Levels (MCLs) in the treated drinking water.

Water Quality Data Collection

Water quality data collection from the watersheds' raw water intakes began in 1999. Baseline samples that were analyzed for the complete suite of primary (including bacteria, fifty-seven pesticides, solvents and other organic chemicals, sixteen metals and other inorganic compounds) and secondary (fifteen less harmful parameters) drinking water standards, were collected at each site under very dry conditions after a prolonged drought in late 1999 and under wet conditions in January 2001. Monthly and quarterly sampling for a smaller set of parameters has continued, along with event-based monitoring at selected sites and times. These include a series of major cations, anions, bacteria, and organic pesticides (Table One). These analyses have identified contaminants of special concern and have provided a general range of potential concentrations to be expected under different seasonal and antecedent moisture conditions.

GIS Development/Land Use Classification

The land use classification method employed at the study basins was the United States Geological Survey (USGS) Anderson Level III system (Anderson *et al*., 1976), in which higher levels indicate increasing specificity. Although automated remote sensing-land use functions are commonly used in GIS, land use classifications were completed manually for this study. In general, although methods are significantly more labor intensive than automated procedures, our group relies heavily on manual land use classification for several reasons, primarily that it gives a higher level of accuracy, for there are visual clues that a trained analyst can pick up about some features that might confuse automated analysis software. This is especially important in the context of the current study, as concentrated discreet sources of contamination, such as animal feedlots, can have an impact of water quality degradation far out of proportion to the percentage of land area that they occupy within a watershed. Our laboratory is also very active in training of students in hydrogeological methods associated with GIS and find that such analyses provide excellent training opportunities for carefully supervised students. All analyses described in this report exceeded the 85% agreement level between land use classification from images and checking in the field (Anderson, 1976).

Remote sensing interpretation techniques (Lillesand and Kiefer, 1994; Star *et al*., 1997) were used to classify Anderson Level III land use practices from color infrared images obtained from the USGS's National Aerial Photography Program (USGS, 2002). Aerial photographs were examined under a magnifying loupe for specific land use activities through both observation of physical features (roads, houses, and vegetation cover, for example) and color patterns in each watershed. In infrared photography analysis, for example, reds and greens are various types of vegetation and farmland; purple trees are pines or evergreens; and reddish brown trees are cedars (USGS, 2000). Reds often indicate dense, vigorous growth, while lighter reds, pinks, and even greens indicate less intensely growing, or even dying, plants and bare soils (USGS, 2000). Water bodies, such as farm ponds, lakes, streams, and reservoirs, were found commonly within the study basins. Pristine waters are indicated by a dark, at times black appearance, while lighter, whiter bodies indicate accumulations of sand and sediment within the bed. Human-created features, such as concrete, asphalt, and roofs, often give off colors similar to their normal appearance or colors that are related to the materials from which they were made (USGS, 2000).

The patterns and parcels observed under magnification on the paper photographs were matched to the same parcels on black-and-white digital orthophoto quarter quadrangles (DOQQs) used as base maps in ArcView. A land use polygon layer was created by "tracing" around the feature on the DOQQ. Using the hard-copy photograph, infrared color interpretation of polygon under study was used to assign an Anderson level III code to the feature. The land use code was then entered into the attribute table. Since precise karst groundwater basin boundaries are subject to revision as additional dye tracing takes place, and can change under different flow conditions, an additional 300 meter wide buffer outside the groundwater basin was included in the land use database.

At each of the study watersheds, ten percent of the polygons in each watershed were field checked for QA/QC measures. Classifications using these manual methods were above the 85 percent accuracy standard established by Anderson (1976). In order to create data useable by other scientists and state agencies, FGDC-STD-001-1998 metadata were written for each data layer (Federal Geographic Data Committee, 1998).

To begin the development of quantitative relationships between water quality impairments revealed in the sampling program, the land use attributes were queried. GIS queries provide summations, including areas and percentages of the broad land use types and statistics involving specific land use activities.

Statistical Analyses of Land Use – Water Quality Relationships

A goal of this project is to establish quantitative relationships between source water quality and land use practices within the demonstration watersheds. Statistical methods were employed in the development of a multivariate regression model to understand better the quantitative relationship between agricultural practices and contaminants and to predict contaminant levels based on inputs of several independent variables. A goal of this statistical research was the development of a predictive regression model with only random errors remaining. Regression analysis was used to hypothesize and test the functional and causal relationships between a dependent variable and a set of independent, explanatory independent variables (Rogerson, 2001).

For a statistical study, the testable null hypothesis was that there was a statistically random relationship between surface agricultural land uses and groundwater contamination. The groundwater parameters that were studied in particular were phosphorus, nitrate, and fecal coliform, since they were likely related to agriculture. For the null hypothesis to be not rejected, r^2 values should be less than 0.5, many unexplained residual errors should be present, and the model should be reflective of only a random relationship between the independent and the variance of dependent variables (Rogerson, 2001). Additionally, *p*-values should not be significant at the $\alpha = 0.05$ level. The alternate hypothesis, which this research proposed represented the true relationship between the variables, projected a higher r^2, smaller residual errors, and significant *p*-values.

To develop a multiple regression model involving land use and water quality, the land use database was aggregated based on several attributes and placed as independent variables in SPSS. Using the query function of ArcView, data were generated to serve as independent variables of the statistical model. The variables developed from the land use data included the percentage of the total watershed that was used for any form of agricultural activity obtained by summing the area column in the attribute table and dividing the figure by the size of the respective basin (PERTOTAG), the total number of feedlots per watershed obtained by querying the GIS database for feedlots and totaling the features selected (TOTFEED), and an index of the feedlot potential (POTFEED). The feedlot potential was determined by dividing the area of each feedlot by the square of the distance from the center of a feedlot to the sampling location. A query for feedlots was completed in ArcView; from the feedlot location, the distances were measured in a direct line to the sampling point. The general equation for the feedlot potential was

$$x_{potfeed} = \sum_{1}^{m} \frac{\text{area of feedlot}}{\text{distance to sampling point}^2}$$

where *m* was the total number of feedlots in the drainage basin. As the distance increased in the denominator, the index value decreased, since a larger number was dividing the numerator. This formula provided more weight to feedlots that were larger and were closer to the sampling location. The feedlot potentials were summed for each drainage basin and added to SPSS. The feedlot potential, however, may not necessarily hold true in karst basins due to the nature of rapid and unfiltered recharge.

Other proposed independent variables that may affect water quality were related to the geologic and hydrologic setting of the region. Because digital geology layers are not yet available, other means were sought in quantifying a geology and surface flow variable. Using a Digital Elevation Model (DEM), the change in surface slope (ELCHANGE) was determined using Spatial Analyst for ArcView. The minimum elevation value was subtracted from the maximum elevation value found in the DEMs of each basin. (Surface drainage density values and discharge data were also considered as variables and should be included in future analyses.) Several “dummy” variables were also added in SPSS as independent variables. For the variable, karst (KARST), a one was added to designate that a site was karst, while a zero represented non-karst observations. When the observation was zero, it had no effect on the model. Other dummy variables were included to represent the potential seasonal variation in the data. Three separate seasonal variables, SPRING, SUMMER, and FALL, were created, with a 1to indicate that the observation occurred in that particular season, and a 0 to indicate that the observation was not in that season. Precipitation (PRECIP) data were also aggregated into a variable to represent the rainfall total for the three days before the water-sampling event. The points at which precipitation data were collected were not necessarily the points at which water samples were collected, which may have introduced systematic errors into the model.

The dependent variables in this model included various water quality parameters that have been collected monthly and quarterly in the years 2000 and 2001. Fecal coliform, nitrate, and phosphorus were the dependent water quality parameters selected for this study. Phosphorus and nitrate are likely related to all types of agricultural activities, including feedlots and row crops, while fecal coliform is linked mainly to feedlots. The fecal coliform results were not discriminated into human versus agricultural wastes. For this model, the number of observations, *n*, equaled seven basins x ten repetitions, for 70 total observations. While this number of independent variables may be great for 70 observations, such a comprehensive study sought to quantify the numerous and complicated relations that likely exist between land use and water quality.

A logarithmic transformation was performed on each of the observations for the dependent variables, since the frequencies of the fecal coliform, nitrate, and phosphorus data were not normally distributed and had a wide range of values. The logarithm of each observation allowed very small values and very large values to be “standardized” to a smaller range with more of a normal distribution. These variables were labeled LOGFEC, LOGNIT, and LOGPHOS and added to SPSS.

Regression Results and Discussion

When the independent variables were included in a regression model, the resulting r^2 values were less than hypothesized. A regression using the independent variables was run on LOGFEC, LOGNIT, and LOGPHOS. The resulting r^2 values left much variation in the dependent variables unexplained. The r^2 values for LOGFEC were slightly higher than regression analyses performed on untransformed data, with the model explaining 25.5% of the LOGFEC variation. The histogram of residuals for the entire model appeared to be more normally distributed, and fell within a smaller range of standard deviations. A scatter of the residuals and predicted values also appeared to be more random, although there was still a downward slope of points. The regression model for LOGNIT resulted in an r^2 of 0.403. The transformation on the nitrate values enabled big increases in the r^2 and significances of the stepwise model. The residuals histogram and scatterplots indicated that the assumptions underlying the regression model may be satisfied, since the residuals were fairly normally distributed and the predicted/residuals scatter was somewhat random. The phosphorus regression model also experienced an increase in r^2 values when a log transformation was applied to the observations. The r coefficient was 0.703, indicating a strong positive correlation, while r^2 value was 0.494, meaning that almost half of the variation in the phosphorus observations was explained by the independent variables. The residual histogram was more normally distributed and within two standard deviations. The predicted vs. residual scatterplot was also more "scattered," although there were some groupings between 0 and 1, and a few points in a downward trend. The log function appeared to have an impact on the model by increasing the regression coefficients and R-squares, decreasing the residual values, and decreasing the likelihood that the assumptions of regression analysis have been violated.

Summary of Regression Analyses and Directions

Using this model, in which $y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, \varepsilon)$, the null hypothesis failed to be rejected because all of the r^2 values the model produced were less than 0.5 and none of the *p*-values was significant at the $p = 0.05$ level. The low r^2 values that resulted from the models indicated that the relationship between land use and the water quality parameters might not be as direct, simple, or linear as originally hypothesized. Groupings of outliers that were still present after the transformation might have distorted the best-fit regression line and increased the residual error terms. Some of the scatterplots and histograms produced of the residual terms indicated that the assumptions of regression analysis may have been violated, although the residuals of the transformed data were more evenly distributed and scattered. There may also be concerns with spatial dependence at the adjacent karst Hawkins and Logsdon River basins. While this represents a first attempt at a developing a methodology to quantitatively evaluate relationships between specific land use practice and source water quality, the magnitude of the residual errors indicate that the model will require additional development, possibly to complete other data transformations, examine other types of best-fit lines, or include other variables as data becomes available. Further model development continues.

References

Anderson, J. R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*. U.S. Geological Survey Professional Paper 964.

Cobb, J. and J. Currens. 2001. *Karst: The Stealthy Hazard*. Internet. Available at http://www.geotimes.org/may01/feature2.html; accessed 1 Dec 2001.

Crawford, N.C. 1998. *Introduction to Karst Environmental Problems: Groundwater Contamination*. Internet. Available at http://www.dyetracing.com/karst/ka01013.html; accessed 1 Dec 2001.

Crawford, N.C. 1993. Karst Hydrologic Problems. In *Karst Hydrology Workshop Manual*, lecture 6. Bowling Green, KY: Western Kentucky University.

Crawford, N.C. 1979. Grider Pond-Cave Mill Road Interceptor Project Phase II: Dye Tracing of Septic Tanks Believed to be Contributing to the Impairment on Water Quality of the Lost River in Bowling Green, KY. Report to G. Reynolds Watkins Consulting Engineers.

Environmental Protection Agency. 1999a. Understanding the Safe Drinking Water Act, EPA Publication 810-F-99-008. Environmental Protection Agency. Washington, DC

Environmental Protection Agency. 1999b. *Drinking Water Contaminants*. Internet. Available at http://www.epa.gov/OGWDW/hfacts.html; accessed 1 Dec 2001.

Environmental Protection Agency. 1999c. *Drinking Water Pathogens and Their Indicators: A Reference Resource*. Internet. Available at http://www.epa.gov/enviro/html/icr/gloss_path.html; accessed 1 Dec 2001.

Farm Service Agency. 2001. *Conservation Reserve Program/Kentucky Enhancement Program Fact Sheet*. Internet. Available at http://www.fsa.usda.gov/pas/publications/facts/html/crepky01.htm: accessed 1 Dec 2001.

Federal Geographic Data Committee. 1998. FGDC-STD-001-1998 Content standard for digital geospatial metadata (revised June 1998). Federal Geographic Data Committee. Washington, D.C.

Ford, D.C. and P.W. Williams. 1989. *Karst Geomorphology and Hydrology*. London, UK: Unwin Hyman.

Karst Waters Institute. 2001. *What Is Karst (and Why Is It Important)?* Internet. Available at http://www.karstwaters.org/kwitour/whatiskarst.htm; accessed 1 Dec 2001.

Lillesand, T.M., and R.W. Kiefer. 1994. *Remote Sensing and Image Interpretation*. New York: Wiley & Sons.

Marsh, W.M. 1998. *Landscape Planning: Environmental Applications*. Third ed. New York: Wiley & Sons.

Minor, R.L. 2001. Karst hurdle in spill on I-65. *Bowling Green Daily News*. Internet. Available at http://www.bgdailynews.com/cgibin/view.cgi?200108/31+karst20010831_news.html +20010831; accessed 12 November 2001.

Palmer, A.N. 1981. *A Geological Guide to Mammoth Cave National Park.* Teaneck, NJ: Zephyrus Press.

Quinlan, J.F., & R. Rowe, 1978, Hydrology and water quality in the central Kentucky karst, *Water Resources Institute,* University of Kentucky, Research Report 109, 42p.

Ray, J.A. and J.C. Currens, 1998a, *Mapped Karst Ground-Water Basins in the Beaver Dam 30 x 60 Minute Quadrangle*, Kentucky Geological Survey.

Ray, J.A., and J.C. Currens, 1998b, *Mapped Karst Ground-Water Basins in the Campbellsville 30 x 60 Minute Quadrangle,* Kentucky Geological Survey.

Rogerson, P.A. 2001. *Statistical Methods for Geography*. London: Sage Publications.

Star, J.L., J.E. Estes, and K.C. McGwire. 1997. *Integration of Geographic Information Systems and Remote Sensing*. New York: Cambridge University Press.

Taylor, R., O. Meier, C. Groves, S. Johnson, J. Lyon, A. Glennon, K. Seadler, A. Lange, S. Wallace, and J. Jack. *Western Kentucky University Technical Assistance Center for Water Quality and Center for Water Resource Studies Third year, Third Quarter Report, 1 April – 30 June 2001, US EPA Grant X826659-01-0*. Progress report submitted to US EPA Office of Water.

USGS. 2002. *National Mapping Information*. Internet. Available at http://mapping.usgs.gov; accessed 17 January 2002

USGS. 2000. *What do the different colors in a CIR photograph represent?* Internet. Available at http://edcwww.cr.usgs.gov/glis/hyper/news/aerialfaq.html; accessed 30 October 2000.

Trihalomethane (THM) Project, Dr. Jeff Jack, University of Louisville

The work performed during this period included the following items.

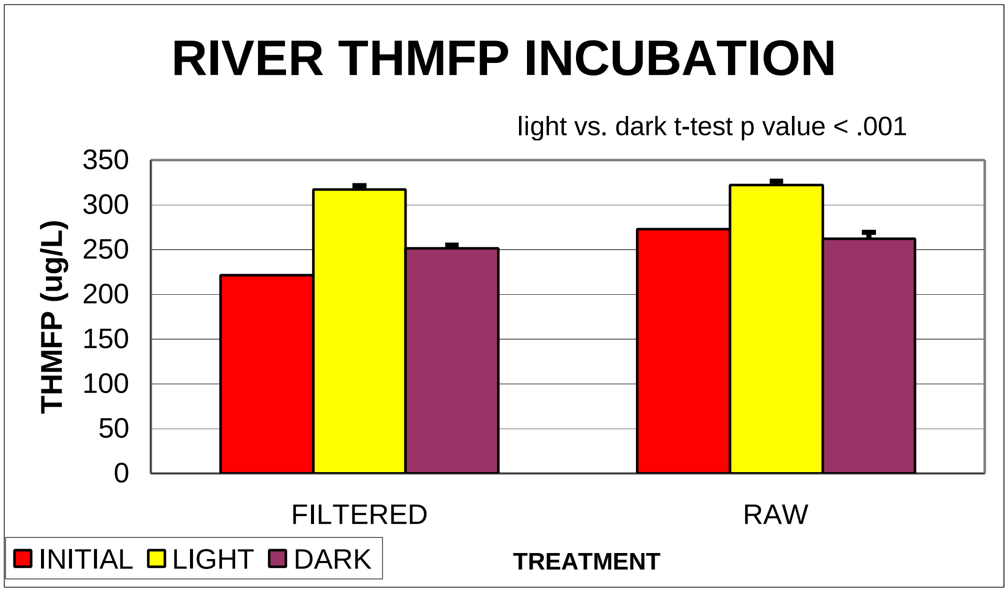
Manipulative Experiments

The analysis of the mesocosm experiment on the Ohio River was completed. Because of the rainfall patterns this summer, we did not get a period of extended low flow in the Ohio Which we needed to fully bracket discharge levels commonly experienced in the river. The longest transit time we got was 14 days. We say strong association so if SUVA and the production of THMs, and weaker associations for TOC as reported in the last quarterly report.

We also completed an experimental study of Taylorsville Lake source and basin water. THMFP from filtered and unfiltered water was incubated under constant light and temperature conditions that were similar to those experienced in Taylorsville Lake during the summer. In summary, we found that either TOC or chla may be good predictors of THMFP, depending on the source of the water. The filtration of the water did not have a strong effect on the yield of THMFP (see below).

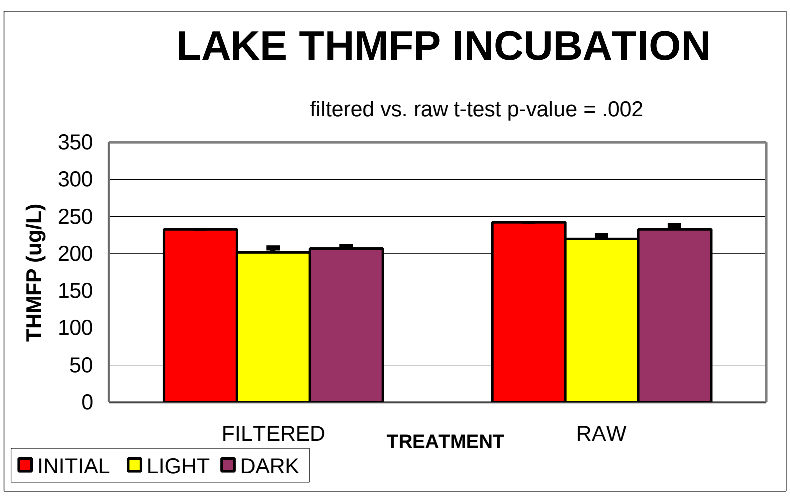
Large River Survey

We have completed an intensive survey of the McAlpine Pool of the Ohio River. We are using the data collected to develop a more extensive survey for the summer of 2002.



Taylorsville Lake Study

We have obtained the first full year of useable THM data from Taylorsville Lake (USGS Water Year 2001, Oct-Oct). We are now focusing our reservoir efforts on the production of the lake budget and THMFP model.



Implications for THM Model Development and Water Management

We have begun the evaluation of potential surrogate parameters for the prediction of THMFP in Kentucky waters. DOC (dissolved organic carbon) does not seem to be as useful a predictor of THMFP as suggested by work in other systems, but there does seem to be a relationship between TOC and THMFP. Other parameters such as UV (SUVA) absorption have been tested and show a strong correlation ($r2>0.80$). SUVA may prove to be the most powerful predictor of THMFP in both the Ohio River study and the Taylorsville Lake study.

Dissemination of Results

We have continued to present preliminary findings from the first half of this project to professional and scientific groups. We presented one the Kentucky Water Resources Conference (February 2002) and we plan to submit two papers at the American Society of Limnology and Oceanography (June 2002).

II. Discussion of Expenditures

During the Second Quarter of Year 4, expenditures for Task 3 were $22,012.59, with Year-to-Date expenditures of $52,082.91.

We are approximately on schedule within the Demonstration Watershed Study. Compared to our milestones we are on target for the river survey and ahead of schedule for the THM manipulative experiments. We are three months behind on the Taylorsville Lake project because of the data analysis problems we encountered last Spring. We do not anticipate this being a problem for model development. No discrepancies to report.

III. Changes in Key Personnel

There were no changes in key personnel during the quarter.

Task 4: Database Management and Information Tools

I. Work Status

It is the responsibility of the Database Management component of this Task to provide appropriate methods and structures for reporting data and metadata to facilitate: reporting of information by other Tasks, appropriate capture and storage of data and metadata, and access to information and materials by end users. The Information Tools function of our Task works to put technology, information, and the tools to create information capacity and capability directly into the hands of water providers, and to make that technology and information as accessible as possible in order to promote the protection of public health.

A. Work progress.
Efforts by Task 4 this quarter were focused in several areas:
(1) Improvement of our ArcExplorer mapping tool CD for water systems with the addition of new GIS layers: watershed boundaries at several scales, and a recently updated set of water system distribution lines, broken out by counties;
(2) Upgrading the installation program for our Water Loss Calculator so that it can be installed effortlessly under a broader range of operating systems;
(3) Additional testing of an internet interface for querying our database;
(4) Analysis of data for publication, including geographic, water quality, and data from the EPA Safe Drinking Water Information System database; and
(5) Education outreach and science advisory services for agencies, groups, and the public.

(1) Mapping Tools for Water Systems. Subsequent to duplication and initial distribution of more than 100 copies of our 2-CD set, "ArcExplorer Watershed Mapping for Drinking Water Systems - Kentucky edition" directly to water system managers and support organizations, we have identified and obtained additional data layers that would be helpful to water systems to include in this mapping tool. We have incorporated those additional data layers, including USGS surface watershed boundaries at several scales as 6-, 8-, 11-, and 14-digit Hydrologic Unit Codes (HUC) polygons. We have also included recently available updated layers showing water distribution lines. As before, we have taken this very large statewide layer and broken it out into counties, so that water systems with limited computer power will be able to call up just the coverage they need more efficiently. We will distribute the revised mapping tool to water systems in the coming quarter. We will also make relevant subsets of that information available to local governments, citizen groups, and agencies needing information that will help protect source water of small systems on a local basis throughout the Commonwealth.

(2) Software and Information Tools for Water Providers. In previous quarters we beta-tested the stand-alone version of our Water Loss Calculator, fixed some minor bugs discovered during the process, and improved its graphing capabilities. The program is able to calculate dollar losses due to undetected leaks, and can chart production, distribution, water loss, and dollar loss values per month for multiple selected months so the user can easily examine trends over time. This quarter we completed final modifications to the Water Loss Calculator's installation program so that it installs correctly and easily to a broader range of operating systems that drinking water providers may have. A copy of the final version of this program can be downloaded from our website, http://water.wku.edu . Now the tool can be appropriately used by water systems anywhere in the country, and in the coming quarter we will distribute it directly to other Technical Assistance Centers and to the National Drinking Water Clearinghouse for further distribution.

(3) Internet-Accessible Data Upload and Query Capability. One of the primary missions of Task 4 is to facilitate information retrieval of a voluminous amount of water quality data. We receive data from other tasks as well as researchers working outside of Western Kentucky University. We wanted to make it easier for researchers to access their own data for query and analysis. During this quarter, we performed some additional necessary testing of this program. We are still presently using and testing this system only within the Western Kentucky University network due to current firewall constraints. At the end of this quarter we received water quality data from Task 3 for the years 2000 and 2001, so during the next quarter we expect to incorporate this data into our database and make it accessible to Task 3 personnel for querying.

(4) Analysis and Synthesis of Data for Publication. New data is now available from the EPA Safe Drinking Water Information System (SDWIS) site describing patterns of drinking water Maximum Contaminant Level (MCL) violations in the southeastern U.S. (EPA Region 4 and adjoining states). We will complete the download of this information and updates to our SQLServer database, and can then begin mapping the new data for this area. Task 4 has also been working to map and analyze in more detail the spatial distribution of potential impact sources and recently available water quality data at monitoring sites in the Green River / Tradewater Basin of Kentucky; this analysis will be presented at a joint Kentucky Biodiversity / Mammoth Cave research conference in April. Some of the maps resulting from preliminary analysis are included in this report. We will include copies of manuscripts with the Task 4 report as they are ready for submission to peer-reviewed journals.

(5) Education Outreach and Science Advisory Duties.
Public health and small rural water systems benefit from the presence of an informed public, skilled citizens' groups who care about source water protection, and sympathetic and knowledgeable state and regional agencies. When feasible, we take advantage of opportunities to participate in educational programs, outreach events, and science advisory service to agencies and groups entrusted with protecting the streams and rivers that serve as the source water for small water systems. In the past quarter, Dr. Meier has continued to work with Green River Basin Management Team (formed by the Kentucky Division of Water), to serve as basin delegate to the Kentucky Waterways Alliance, and to work to create an Upper Green River Biological Preserve along both banks of the Green River in Hart County upstream from Mammoth Cave National Park (we have now received our final total of over $1,000,000 toward land purchase and management from the Kentucky Heritage Land Conservation Fund Board).

Public education and advocacy for safe drinking water and source water protection have been important components of efforts with a broader impact as well. Within a local public school, Dr. Meier and others in the Biology Dept. at WKU are near completion of the first year of development of a hands-on science curriculum that has been implemented through weekly science labs that 350 elementary school children attend with their teachers. Many of the labs developed feature the properties of water, human treatment and use of water, public health, the ecology of aquatic systems, and the importance of informed stewardship in protecting our essential water resources. The particular vulnerabilities of aquatic systems located in karst hydrogeologic environments have been highlighted. Based on teacher feedback, we plan to refine and publish the curriculum as a model that can be adopted and adapted by other schools. In recognition of her work in drinking water protection, research, and public education, this past quarter Dr. Meier received the Women of Achievement Award in Science and Health from the Bowling Green Human Rights Commission.

B. Difficulties encountered. No insurmountable difficulties have been encountered.

C. Preliminary data results. We have mapped data from the Watershed Watch program as part of a preliminary analysis of the relationships between source water and drinking water in the Upper Green River basin of Kentucky. This information will be presented at the Annual Kentucky Biodiversity Conference, which be held jointly with Mammoth Cave National Park's Research Conference on April 18-19, 2002 (next quarter). These maps, along with ancillary information for presentation, are provided immediately following the Task 4 section of this report (53 figures on 9 pages). Results of linear regressions of selected water quality parameters against arcsin-transformed percentages of aggregated land use types in the HUC 14 watershed immediately surrounding each sampling site are shown in Table 4-1.

Table 4-1. Relationships Between Water Quality Parameters and Land Use Types, Upper Green River Watershed Watch Data 2001. Meier, Meier, and Johnson.

Water Quality Parameter	**Percent of Land Use Type in Immediate Watershed**		
	Urban	**Agricultural**	**Forested**
Fecal coliform (n=49)	**$p = 0.0004$** **$r^2 = 0.24$ (slope positive)**	**$p = 0.046$** **$r^2 = 0.08$ (slope positive)**	**$p = 0.0002$** **$r^2 = 0.26$ (slope negative)**
E. coli (n=49)	**$p = 0.003$** **$r^2 = 0.18$ (slope positive)**	$p = 0.08$ $r^2 = 0.06$	**$p = 0.0002$** **$r^2 = 0.26$ (slope negative)**
Triazines (n=46)	$p = 0.62$ $r^2 = 0.01$	$p = 0.28$ $r^2 = 0.03$	$p = 0.15$ $r^2 = 0.05$
Metolachlor (n=46)	$p = 0.93$ $r^2 = 0.0002$	$p = 0.49$ $r^2 = 0.01$	$p = 0.71$ $r^2 = 0.003$

For fecal coliform bacteria, there was a positive relationship with percent of land in urban and agricultural use, but a negative relationship with percent of land in forest. The same pattern holds for *E.coli* bacteria, but interestingly, the relationship between agricultural land use and *E. coli* is no longer statistically significant. This is worth noting because the Kentucky Division of Water is considering substituting *E. coli* for the currently-required fecal coliform analysis in its source water assessments. It is also very interesting that there are no significant relationships of any kind between two common herbicides, triazines and metolachlor, and land use type. We are evaluating several potential conditions that might explain this lack of correspondence.

Additional data reported previously describing patterns of drinking water Maximum Contaminant Level (MCL) violations using EPA Safe Drinking Water Information System

(SDWIS) data for the southeastern U.S. and adjoining states is currently being analyzed and prepared for publication. Task 4 has also been working to analyze in more detail the spatial distribution of potential impacts to water quality in the Green River / Tradewater Basin of Kentucky in conjunction with currently available water quality data; this analysis will also be the subject of a publication. We will include copies of these manuscripts with the Task 4 report as they are ready for submission to peer-reviewed journals.

D. Anticipated activities. Anticipated activities for next quarter include a focus on distribution of the final version of the Water Loss Calculator, especially beyond Kentucky, and the ArcExplorer Watershed Mapping Tool for Drinking Water Systems we have developed. As described earlier, we will also proceed with analysis, synthesis, and publication of spatially distributed information and water quality data sets; continued development and maintenance of the project database as data is released by other tasks; and further use of our internet query interface with the databases. We also anticipate initiating efforts toward providing an online mapping tool for the use of water systems. In the next quarter we are planning to help host a joint Kentucky Biodiversity / Mammoth Cave National Park research conference, design and conduct a Kentucky Science Olympiad statewide competition event in Water Quality, and host and coordinate Watershed Watch citizens' water quality monitoring training sessions, including a special session for employees of the Barren River District Health Department. We will also have to spend some time, effort, and funds in much-needed computer upgrades in the coming quarter.

II. Discussion of Expenditures

During the Second Quarter of Year 4, expenditures for Task 4 were $15,752.90, with Year-to-Date expenditures of $32,168.43.

III. Key Personnel Changes

There have been no changes in key personnel within Task 4 during this quarter. Dr. Ouida Meier, who directs the efforts of Task 4, is working on Technical Assistance Center for Water Quality business half-time rather than full-time during Year 4. The remainder of her efforts (and compensation) will be invested in work on behalf of the Kentucky Center for Wastewater Research.

As always, we are grateful to our team of bright, talented undergraduate students who assist with the work in Task 4. Mr. Seth M. Johnson continues to develop the online interface with our SQL database and harvests data from the EPA SDWIS database. Mr. Jake Lyon has conducted the renovations in our website, developed the online and stand-alone versions of the Water Loss Calculator, and helped author and revise our ArcExplorer Watershed Mapping Tool for Drinking Water Providers. Mr. Rupesh Mamidi assists ably with our GIS efforts. The Center is very grateful for the dedicated and skillful efforts of each of these individuals. It is a goal of the Center to help educate students through applied research and to help "grow" scientists and technicians that are aware of the issues facing drinking water systems and public health protection.

Task 5: Innovative Technical Assistance

I. Work Status: Within Task 5 we have worked to create articles, and tools used in wholesale ratemaking. As they are completed, they will be placed on the TACWQ web site. The following are deliverables that will be provided.

1. A rate manual is being prepared to assist small system managers to understand their rate structure, learn to maintain records needed for a rate study, and how to conduct one as needed. (WORD)
2. A CD and disk is being prepared that explains the data needed to conduct a wholesale rate study and a formula that calculates the wholesale rate when data is entered into the tables provided. (EXCEL)
3. A pocket manual is being prepared on Membrane Filtration.
4. Other pocket manuals are planned as time permits that deal with technical, managerial, and financial capacity.

We are working within this task to assist the West McCracken Water District with the development of a GIS system for management of their system. The work will be initiated next quarter. This quarter we developed an abbreviated work plan and an outline of activities. This project will serve other systems by showing a cost, technology, and effort evaluation for using GIS as a tool to increase managerial capacity.

A. Work Progress:
The rate manual is approximately 60% complete.
The wholesale rate formula is complete.
The pocket manual on Membrane Filtration is approximately 90% complete.
The other pocket manuals are in the planning stage.
The work plan for the West McCracken GIS project is presented below.

GIS Development for West McCracken Water District: Cost, Effort, and Technology Analysis for the Implementation of Water Works FM

Introduction

West McCracken Water District (the District) is located in rural McCracken County and serves a population of approximately 4300. The District serves both industrial and residential customers, through its 1230 connections and 60 miles of drinking water lines. Service from the District was started in 1968 with about 350 customers. Source water for the District is purchased from the City of Paducah.

West McCracken Water District is a progressive system with a strong customer base and excellent management. In an effort to better utilize current resources, the District is evaluating new and existing technologies to reduce long-term costs and more efficiently manage their system. Due to their track record and exemplary compliance history, the Center for Water

Resource Studies at Western Kentucky University, in conjunction with Kentucky Rural Water Association, has approached the District about conducting a technology analysis of Spatial Data Integrations (SDI) Water Works FM software. Water Works FM is a Geographic Information System (GIS) software package designed specifically for applications to water systems. The designed application of Water Works FM is to allow water systems to digitally map infrastructure resources, streamline water system management, and track system assets. Additionally, Water Works FM can allow a system to map their own system resources in-house, eliminating the costs of out-sourcing mapping efforts.

Work Plan

The Center for Water Resource Studies, partnering with SDI for software support, will work with West McCracken Water District to develop a GIS of their water system. Beginning in June of 2002 the Center will acquire existing data from the District and begin to develop a baseline GIS with the SDI Water Works FM software. Following baseline development, CWRS will work with the District to collect on-site water system data including, meter, hydrant, and valve locations. To provide a comprehensive GIS, infrastructure information will be included in the database, such as pipe size and material, meter type, date of equipment installation, and other ancillary data. Data collection will be completed by August of 2002.

By collecting as-built drawings and system information, an initial GIS will be developed. The Center will supply manpower in the data collection phase to go on-site with District personnel. While the District is conducting meter readings during the months of June and July, CWRS will use Geographical Positioning System (GPS) technology to collect point data for meters, hydrants, and valves. Trimble GPS equipment will allow instantaneous collection of on-site data that can be input into the baseline Water Works FM database. Also, data collected in the field will provide a verification of the existing data the District possesses.

Upon returning to the WKU GIS laboratory final updates and verification to the data will be completed by CWRS personnel. We will screen the data for accuracy by comparing it to previous data, by doing on-site verifications, and by evaluating the database against other data layers, such as Digital Ortho-quads (DOQQs). All data layers will be checked by at least two members of the project team and District staff will conduct final approval. All revisions will be discussed with the District.

During the process of GIS development SDI will be consulted as to the use of their software. Prior to initiation of the project SDI will provide a Water Works FM training session for CWRS personnel. This will allow Center personnel to develop capabilities to manage a Water Works FM GIS. To assist the District in Water Works FM use, CWRS will provide the initial training upon delivery of the database to the District. While SDI will provide software to CWRS, it will be the responsibility of the District to purchase a software license from SDI and provide computer hardware for on-site GIS management. Specific technical support will need to be directed to SDI while database management and updates can be provided by CWRS, at the request of the District.

This project will provide a case analysis of the SDI Water Works FM software and its use as a tool for water system management. Detailed information pertaining to project costs, man-hours, water system requirements, and logistics in transferring current system data and maps into a GIS management tool will be documented. Documented information will be used to write technical reports and articles that may appear in trade journals and magazines. However, specific West McCracken system information will not be shared, distributed, or utilized outside of the context of preparing the GIS for the District.

At the conclusion of this project an evaluation will be prepared by the Center to include the comments and suggestions of the District. This information will be distributed to SDI for future consideration in software development. In this manner, the District will receive a GIS of their system and SDI will get the invaluable review of their software by a water system.

Timeline and Deliverables

Adjustments to the timeline will not be made without the prior approval of the District and SDI. All deliverables will be completed by May 1, 2003, based on a project initiation date of June 1, 2002. The deliverables are outlined below.

Deliverables for West McCracken GIS Project (Start June 2002 – Complete May 2003)

1. Collect Existing Data
2. Develop Baseline GIS
3. Data Acquisition
    a. Approach
    b. Collection
    c. Assessment
    d. Management
4. Technology Transfer
    a. System Setup
    b. Training
    c. Management Assistance
5. GIS Development and Software Evaluation
    a. Cost Analysis
    b. Effort Analysis
    c. Technology Assessment
6. Project Assessment
    a. West McCracken Assessment
    b. CWRS/KRWA Assessment
    c. SDI Assessment
    d. Technical Paper

B. Difficulties Encountered:

No difficulties were encountered.

C. Preliminary Data Results:

The Wholesale Rate Formula is complete and will be available soon.

D. Anticipated Activities:

Will continue to work on **The Rate Manual.** Completion is expected by the end of this year. Will continue to work on the **Membrane Technology** and **other pocket manuals** as time permits.

The West McCracken project will be initiated according to the work plan in June of 2002.

II. Discussion of Expenditures

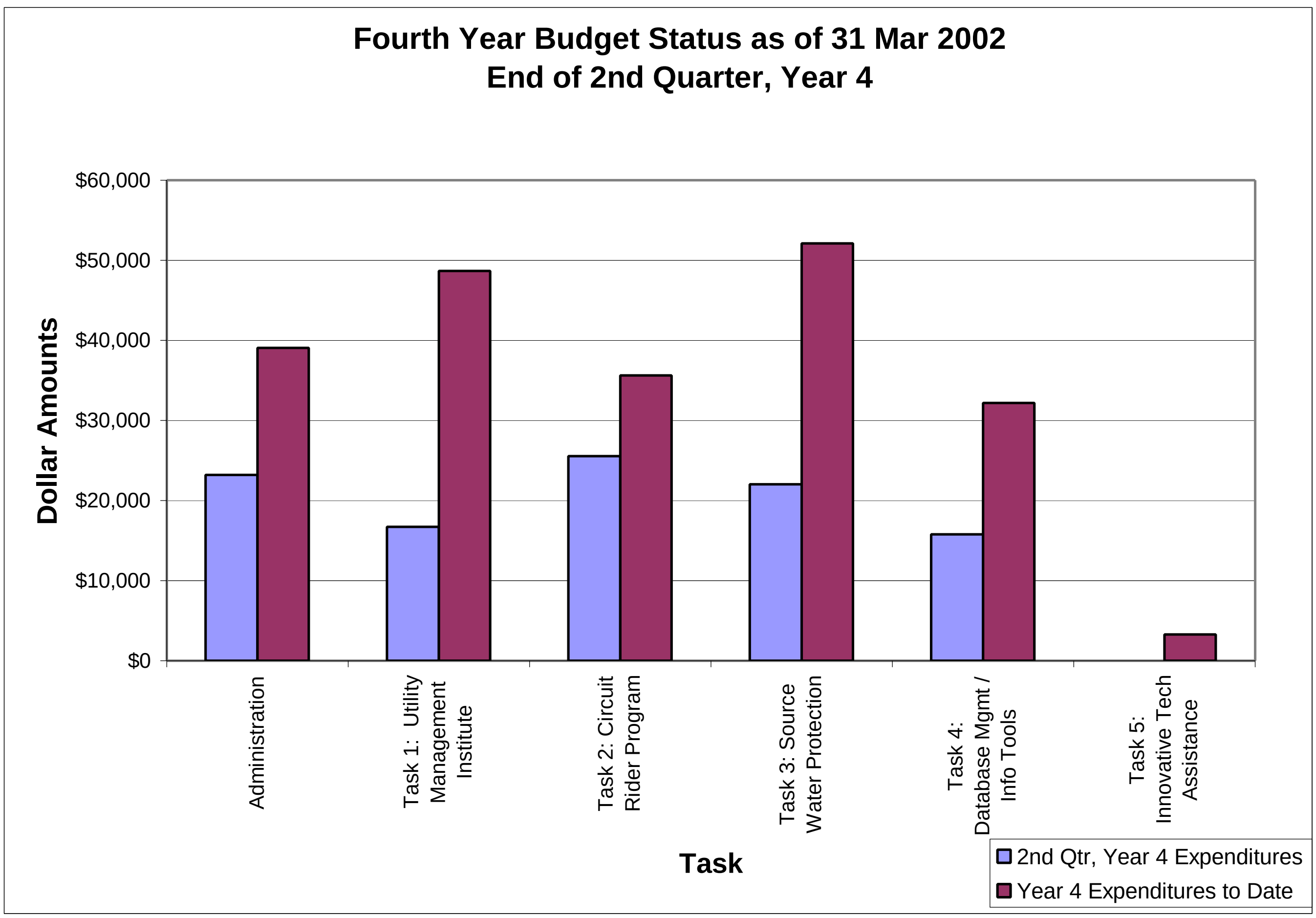
During the Second Quarter of Year 4, expenditures for Task 5 were $0.00, with Year-to-Date expenditures of $3,260.25.

III. Key Personnel Changes

There have been no changes in key personnel with Task 5.

APPENDIX A

TACWQ Expenditures for Year 4, Quarter 2 and Year-to-Date



APPENDIX 1-1

Utility Management Institute

"Utility Organization, Regulation & Law"
presented at the Holiday Inn–North in Lexington, Kentucky
March 27-28, 2002

Course Evaluations by Participants

APPENDIX 3-1

Source Water Protection Initiative

Demonstration Sites:

Quarterly Water Sampling Results, April 2002

Auburn Demonstration Site, April 16, 2002

Analyte	Results	Units	Lab Name	Analytical Method
Conductivity	498	microSiemens	field	meter
pH	6.58	pH_units	field	meter
Temperature	16.1	degC	field	meter
Aluminum	<0.000785	mg/L	WKU MCC	ICP-TOFMS
Antimony	<0.000184	mg/L	WKU MCC	ICP-TOFMS
Arsenic	<0.00731	mg/L	WKU MCC	ICP-TOFMS
Barium	0.0320518000	mg/L	WKU MCC	ICP-TOFMS
Beryllium	<0.00121	mg/L	WKU MCC	ICP-TOFMS
Boron	<0.011	mg/L	WKU MCC	ICP-TOFMS
Cadmium	0.0008380140	mg/L	WKU MCC	ICP-TOFMS
Calcium	86.2277500000	mg/L	WKU MCC	AA-3100
Chromium	0.0129348000	mg/L	WKU MCC	ICP-TOFMS
Cobalt	0.0844427000	mg/L	WKU MCC	ICP-TOFMS
Copper	0.0010731800	mg/L	WKU MCC	ICP-TOFMS
Iron	0.1543340000	mg/L	WKU MCC	ICP-TOFMS
Lead	<.0000554	mg/L	WKU MCC	ICP-TOFMS
Lithium	0.0012868250	mg/L	WKU MCC	ICP-TOFMS
Magnesium	3.6323100000	mg/L	WKU MCC	ICP-TOFMS
Manganese	<0.000340	mg/L	WKU MCC	ICP-TOFMS
Nickel	0.0004375330	mg/L	WKU MCC	ICP-TOFMS
Phosphorus	0.0648930000	mg/L	WKU MCC	ICP-TOFMS
Potassium	0.6567340000	mg/L	WKU MCC	ICP-TOFMS
Selenium	0.0029481200	mg/L	WKU MCC	ICP-TOFMS
Silicon	1.1541560000	mg/L	WKU MCC	ICP-TOFMS
Silver	0.0022129100	mg/L	WKU MCC	ICP-TOFMS
Sodium	1.4213060000	mg/L	WKU MCC	ICP-TOFMS
Strontium	0.1627480000	mg/L	WKU MCC	ICP-TOFMS
Sulfur	<10	mg/L	WKU MCC	SC-432
Thallium	<0.0000388	mg/L	WKU MCC	ICP-TOFMS
Tin	<0.00113	mg/L	WKU MCC	ICP-TOFMS
Vanadium	0.0003194430	mg/L	WKU MCC	ICP-TOFMS
Zinc	0.0014992370	mg/L	WKU MCC	ICP-TOFMS
Acetochlor	<0.00021	mg/L	WKU TraceOrg	GC-MS
Alachlor	<0.00009	mg/L	WKU TraceOrg	GC-MS
Atrazine	<0.00004	mg/L	WKU TraceOrg	GC-MS
Chloroneb	<0.00014	mg/L	WKU TraceOrg	GC-MS
Linuron	<0.0001	mg/L	WKU TraceOrg	GC-MS
Metolachlor	<0.00004	mg/L	WKU TraceOrg	GC-MS
Metribuzin	0.00343	mg/L	WKU TraceOrg	GC-MS
Pendimethalin	<0.0001	mg/L	WKU TraceOrg	GC-MS
Propachlor	<0.00014	mg/L	WKU TraceOrg	GC-MS
Propazine	<0.0002	mg/L	WKU TraceOrg	GC-MS
Simazine	<0.00011	mg/L	WKU TraceOrg	GC-MS
Trifluralin	<.00071	mg/L	WKU TraceOrg	GC-MS

Cadiz Demonstration Site, April 15, 2002

Analyte	Results	Units	Lab Name	Analytical Method
Conductivity	289	microSiemens	field	meter
pH	6.24	pH_units	field	meter
Temperature	23.5	degC	field	meter
Aluminum	0.0962528000	mg/L	WKU MCC	ICP-TOFMS
Antimony	<0.000184	mg/L	WKU MCC	ICP-TOFMS
Arsenic	<0.00731	mg/L	WKU MCC	ICP-TOFMS
Barium	0.0423343000	mg/L	WKU MCC	ICP-TOFMS
Beryllium	<0.001208658	mg/L	WKU MCC	ICP-TOFMS
Boron	<0.011	mg/L	WKU MCC	ICP-TOFMS
Cadmium	<0.0000452802	mg/L	WKU MCC	ICP-TOFMS
Calcium	55.6825500000	mg/L	WKU MCC	AA-3100
Chromium	0.0075694600	mg/L	WKU MCC	ICP-TOFMS
Cobalt	0.0561588000	mg/L	WKU MCC	ICP-TOFMS
Copper	0.0051321700	mg/L	WKU MCC	ICP-TOFMS
Iron	0.1199100000	mg/L	WKU MCC	ICP-TOFMS
Lead	0.0002213805	mg/L	WKU MCC	ICP-TOFMS
Lithium	<0.000290298	mg/L	WKU MCC	ICP-TOFMS
Magnesium	3.4968200000	mg/L	WKU MCC	ICP-TOFMS
Manganese	<0.00034	mg/L	WKU MCC	ICP-TOFMS
Nickel	0.0056414100	mg/L	WKU MCC	ICP-TOFMS
Phosphorus	0.0915120000	mg/L	WKU MCC	ICP-TOFMS
Potassium	1.9382100000	mg/L	WKU MCC	ICP-TOFMS
Selenium	0.0012496800	mg/L	WKU MCC	ICP-TOFMS
Silicon	1.1557020000	mg/L	WKU MCC	ICP-TOFMS
Silver	0.0020841500	mg/L	WKU MCC	ICP-TOFMS
Sodium	4.0230800000	mg/L	WKU MCC	ICP-TOFMS
Strontium	0.1256460000	mg/L	WKU MCC	ICP-TOFMS
Sulfur	50.0000000000	mg/L	WKU MCC	SC-432
Thallium	<0.0000387594	mg/L	WKU MCC	ICP-TOFMS
Tin	<0.001131105	mg/L	WKU MCC	ICP-TOFMS
Vanadium	0.0004819530	mg/L	WKU MCC	ICP-TOFMS
Zinc	0.0072929250	mg/L	WKU MCC	ICP-TOFMS
Acetochlor	<0.00021	mg/L	WKU TraceOrg	GC-MS
Alachlor	<0.00009	mg/L	WKU TraceOrg	GC-MS
Atrazine	<0.00004	mg/L	WKU TraceOrg	GC-MS
Chloroneb	<0.00014	mg/L	WKU TraceOrg	GC-MS
Linuron	<0.0001	mg/L	WKU TraceOrg	GC-MS
Metolachlor	<0.00004	mg/L	WKU TraceOrg	GC-MS
Metribuzin	0.00757	mg/L	WKU TraceOrg	GC-MS
Pendimethalin	<0.0001	mg/L	WKU TraceOrg	GC-MS
Propachlor	<0.00014	mg/L	WKU TraceOrg	GC-MS
Propazine	<0.0002	mg/L	WKU TraceOrg	GC-MS
Simazine	<0.00011	mg/L	WKU TraceOrg	GC-MS
Trifluralin	0.00265	mg/L	WKU TraceOrg	GC-MS

Guthrie Demonstration Site, April 16, 2002

Analyte	Results	Units	Lab Name	Analytical Method
Conductivity	424	microSiemens	field	meter
pH	6.72	pH_units	field	meter
Temperature	18.3	degC	field	meter
Aluminum	<0.000784506	mg/L	WKU MCC	ICP-TOFMS
Antimony	<0.0001837764	mg/L	WKU MCC	ICP-TOFMS
Arsenic	<0.00730614	mg/L	WKU MCC	ICP-TOFMS
Barium	0.0345476000	mg/L	WKU MCC	ICP-TOFMS
Beryllium	<0.001208658	mg/L	WKU MCC	ICP-TOFMS
Boron	<0.011	mg/L	WKU MCC	ICP-TOFMS
Cadmium	0.0012083530	mg/L	WKU MCC	ICP-TOFMS
Calcium	73.1369500000	mg/L	WKU MCC	AA-3100
Chromium	0.0118813000	mg/L	WKU MCC	ICP-TOFMS
Cobalt	0.0764123000	mg/L	WKU MCC	ICP-TOFMS
Copper	0.0011893900	mg/L	WKU MCC	ICP-TOFMS
Iron	0.1539800000	mg/L	WKU MCC	ICP-TOFMS
Lead	<0.0000553881	mg/L	WKU MCC	ICP-TOFMS
Lithium	0.0018056900	mg/L	WKU MCC	ICP-TOFMS
Magnesium	3.7351100000	mg/L	WKU MCC	ICP-TOFMS
Manganese	<0.00034	mg/L	WKU MCC	ICP-TOFMS
Nickel	0.0005463340	mg/L	WKU MCC	ICP-TOFMS
Phosphorus	0.0933240000	mg/L	WKU MCC	ICP-TOFMS
Potassium	0.5992840000	mg/L	WKU MCC	ICP-TOFMS
Selenium	0.0020301700	mg/L	WKU MCC	ICP-TOFMS
Silicon	1.0884920000	mg/L	WKU MCC	ICP-TOFMS
Silver	0.0020655400	mg/L	WKU MCC	ICP-TOFMS
Sodium	2.4031200000	mg/L	WKU MCC	ICP-TOFMS
Strontium	0.2077440000	mg/L	WKU MCC	ICP-TOFMS
Sulfur	<10	mg/L	WKU MCC	SC-432
Thallium	<0.0000387594	mg/L	WKU MCC	ICP-TOFMS
Tin	<0.001131105	mg/L	WKU MCC	ICP-TOFMS
Vanadium	0.0004474660	mg/L	WKU MCC	ICP-TOFMS
Zinc	0.0030406650	mg/L	WKU MCC	ICP-TOFMS
Acetochlor	<0.00021	mg/L	WKU TraceOrg	GC-MS
Alachlor	<0.00009	mg/L	WKU TraceOrg	GC-MS
Atrazine	<0.00004	mg/L	WKU TraceOrg	GC-MS
Chloroneb	<0.00014	mg/L	WKU TraceOrg	GC-MS
Linuron	<0.0001	mg/L	WKU TraceOrg	GC-MS
Metolachlor	<0.00004	mg/L	WKU TraceOrg	GC-MS
Metribuzin	0.00547	mg/L	WKU TraceOrg	GC-MS
Pendimethalin	<0.0001	mg/L	WKU TraceOrg	GC-MS
Propachlor	<0.00014	mg/L	WKU TraceOrg	GC-MS
Propazine	<0.0002	mg/L	WKU TraceOrg	GC-MS
Simazine	<0.00011	mg/L	WKU TraceOrg	GC-MS
Trifluralin	0.00105	mg/L	WKU TraceOrg	GC-MS

Marion Demonstration Site, April 15, 2002

Analyte	Results	Units	Lab Name	Analytical Method
Conductivity	134.5	microSiemens	field	meter
pH	6.48	pH_units	field	meter
Temperature	21.7	degC	field	meter
Aluminum	0.062	mg/L	WKU MCC	ICP-TOFMS
Antimony	<0.0001837764	mg/L	WKU MCC	ICP-TOFMS
Arsenic	<0.00730614	mg/L	WKU MCC	ICP-TOFMS
Barium	0.026	mg/L	WKU MCC	ICP-TOFMS
Beryllium	<0.001208658	mg/L	WKU MCC	ICP-TOFMS
Boron	<0.011	mg/L	WKU MCC	ICP-TOFMS
Cadmium	<0.0000452802	mg/L	WKU MCC	ICP-TOFMS
Calcium	10.96	mg/L	WKU MCC	AA-3100
Chromium	0.001	mg/L	WKU MCC	ICP-TOFMS
Cobalt	0.020	mg/L	WKU MCC	ICP-TOFMS
Copper	0.016	mg/L	WKU MCC	ICP-TOFMS
Iron	0.108	mg/L	WKU MCC	ICP-TOFMS
Lead	0.0003682	mg/L	WKU MCC	ICP-TOFMS
Lithium	<0.000290298	mg/L	WKU MCC	ICP-TOFMS
Magnesium	2.108	mg/L	WKU MCC	ICP-TOFMS
Manganese	<0.00034	mg/L	WKU MCC	ICP-TOFMS
Nickel	0.006	mg/L	WKU MCC	ICP-TOFMS
Phosphorus	0.094	mg/L	WKU MCC	ICP-TOFMS
Potassium	1.568	mg/L	WKU MCC	ICP-TOFMS
Selenium	0.002	mg/L	WKU MCC	ICP-TOFMS
Silicon	0.356	mg/L	WKU MCC	ICP-TOFMS
Silver	0.002	mg/L	WKU MCC	ICP-TOFMS
Sodium	3.208	mg/L	WKU MCC	ICP-TOFMS
Strontium	0.039	mg/L	WKU MCC	ICP-TOFMS
Sulfur	<10	mg/L	WKU MCC	SC-432
Thallium	<0.0000387594	mg/L	WKU MCC	ICP-TOFMS
Tin	<0.001131105	mg/L	WKU MCC	ICP-TOFMS
Vanadium	0.000410158	mg/L	WKU MCC	ICP-TOFMS
Zinc	0.059	mg/L	WKU MCC	ICP-TOFMS
Acetochlor	<0.00021	mg/L	WKU TraceOrg	GC-MS
Alachlor	<0.00009	mg/L	WKU TraceOrg	GC-MS
Atrazine	<0.00004	mg/L	WKU TraceOrg	GC-MS
Chloroneb	<0.00014	mg/L	WKU TraceOrg	GC-MS
Linuron	<0.0001	mg/L	WKU TraceOrg	GC-MS
Metolachlor	<0.00004	mg/L	WKU TraceOrg	GC-MS
Metribuzin	0.00467	mg/L	WKU TraceOrg	GC-MS
Pendimethalin	<0.0001	mg/L	WKU TraceOrg	GC-MS
Propachlor	<0.00014	mg/L	WKU TraceOrg	GC-MS
Propazine	<0.0002	mg/L	WKU TraceOrg	GC-MS
Simazine	<0.00011	mg/L	WKU TraceOrg	GC-MS
Trifluralin	<.00071	mg/L	WKU TraceOrg	GC-MS

APPENDIX 4-1

Database Management and Information Tools:

Two CD-ROM set with the program

Software Tools for Drinking Water Providers:
ArcExplorer Watershed Mapping Utility
Kentucky Edition

Version 2, 2002

Software Tools for
Drinking Water Providers:
ArcExplorer Watershed Mapping

CD 1 ver. 2
of 2 2002

Kentucky edition

Technical Assistance Center for Water Quality
Center for Water Resource Studies, Western Kentucky University
http://water.wku.edu/
Dr. Ouida Meier and Jake Lyon
Funded by the U.S. EPA

Software Tools for
Drinking Water Providers:
ArcExplorer Watershed Mapping

CD 2 ver. 2
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