

Tennessee Water Resources Research Center

Annual Technical Report

FY 2003

Introduction

Water Resources Issues and Problems of Tennessee

Tennessee is fortunate to have what many consider to be an abundant and good quality water supply. Historically, federal government agencies, such as the Tennessee Valley Authority (TVA), Corps of Engineers, Soil Conservation Service, U.S. Geological Survey and others, have been the primary contributors to the management and monitoring of water resources. In recent years, however, the State, through the Tennessee Departments of Environment and Conservation, Wildlife Resources, Agriculture and others, have begun to develop a more active and aggressive role in the management and protection of these resources. The State has moved to establish an integrated and coordinated policy and administrative system for the management of water resources in Tennessee.

While the situation is improving, there remain many of the additional types of water problems. Although the overall supply of water is adequate, the distribution is still not optimal. Local shortages occur during dry periods. The summer of 1980 was a particularly hot and dry one. During this period over 35 water districts out of a total of 671 public systems in Tennessee experienced lesser degrees of difficulty in supply water. The situation continued to worsen in the late 1980's. Beginning in 1985 and continuing on through the summer of 1988, Tennessee experienced another major drought period which severely strained the water supplies of many communities across the state. In recent years, many of the small municipal water suppliers and utility districts that rely on wells, springs, or minor tributaries for their water sources continue to face severe water shortage problems. All across the state many private, domestic, and commercial use wells have become severely strained, forcing users to seek alternative sources of water. Providing an adequate supply of water for industrial, commercial, and domestic uses and the protection of these surface and groundwater resources are of major concern in all regions of the state and vital to the economic development and growth of the state.

Groundwater presents a particular challenge in Tennessee. Over 50% of the population of Tennessee depends on groundwater for drinking water supply. In West Tennessee, nearly all public suppliers, industries, and rural residents use groundwater. However, not enough is known about the quality and quantity of groundwater in the state, and consequently, maximum benefit from and protection of this resource cannot be easily accomplished. More information about the quality of the state's groundwater, particularly about the potential impact of recharge areas, is needed in order to develop an effective management and protection program for this valuable resource.

There is also the problem of potential contamination of groundwater from agricultural and urban non-point sources. The "fate and transport" of agricultural chemicals (herbicides and pesticides) and toxic substances in groundwater is a problem area that must be addressed if the state's groundwater protection strategy is to be effective in protecting this vital resource.

Although the danger of large-scale, main-stem flooding is controlled by mainstream and tributary dams that have been constructed by TVA and the Army Corps of Engineers, localized flooding and even general flooding in unregulated watersheds remain substantial problems across the state. A lack of effective local floodplain management land-use controls is apparent in West Tennessee, where related problems of excessive erosion, sedimentation, drainage, and the loss of wetlands constitutes what many consider to be the greatest single water resource issue in the state from an economic and environmental point of view. Effective regulation of private levee design, construction, maintenance, and safety is needed.

Water quality problems continue to persist from past industrial practices, from the surface mining of coal and other minerals (especially from abandoned mines), from agricultural and urban nonpoint sources and from improperly planned, designed and operated waste disposal sites. As has been the situation in the past, the state program for the construction of municipal wastewater treatment facilities and improved operation and management of the facilities have experienced numerous set-backs due to shortfalls in funding and administrative delays. In major urban areas that have combined storm and sanitary sewers, urban storm water runoff causes increased pollution and, during periods of wet weather, bypasses treatment facilities, which allows raw sewage to enter receiving waters untreated. Tennessee cities, both large and small, are concerned about current (and future) impacts of the new NPDES storm water discharge permit requirements on clean up needs and costs. In certain regions of the state, failing septic fields and the practice of blasting bedrock for new septic fields are serious threats to surface and groundwater resources.

There are existing programs which can address many of these problems. However, some problems do not have easy solutions. Additional research can also play a role in understanding and solving these problems, but the greatest impediments are the lack of agreement between competing interests and a shortage of financial support for existing programs. From the viewpoint of the State government, the legal, institutional, and administrative aspects of water management are major concerns. The state is still working to develop new policy and to refine administrative structure for the effective management of its water resources.

To address the problems and issues of effective water resources management in the state of Tennessee, a truly interdisciplinary and well-coordinated effort is necessary. The Tennessee Water Resources Research Center has the capability and organization that can call upon the diverse set of disciplinary expertise necessary to address the key water issues of the state and region.

The Tennessee Water Resources Research Center: Overview of Program Objectives and Goals:

The Tennessee Water Resources Research Center serves as a link between the academic community and water-related organizations and people in federal and state government and in the private sector, for purpose of mobilizing university research expertise in identifying and addressing high-priority water problems and issues and in each of the respective state regions.

The Tennessee Water Resources Research Center, located at the University of Tennessee, is a federally-designated state research institute. It is supported in part by the U.S. Geological Survey of the U.S. Department of Interior under the provisions of the Water Resources Research Act of 1984, as amended by P.L. 101-397 and 10 I - 1 47. The Act states that each institute shall:

1. plan, conduct or otherwise arrange for competent research that fosters the entry of new research scientists into the water resources fields; the training and education of future water scientists, engineers and technicians; the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and the dissemination of research results of water managers and the public.

2. cooperate closely with other colleges and universities in the state that have demonstrated capabilities for research, information dissemination, and graduate training, in order to develop a statewide program designed to resolve state and regional water and related land problems.

In supporting the federal institute mandate, the TWRRRC is committed to emphasizing these major goals:

1. To assist and support all the academic institutions of the state, public and private, in pursuing water resources research programs for addressing problem areas of concern to the state and region.

2. To provide information dissemination and technology transfer services to state and local governmental bodies, academic institutions, professional groups, businesses and industries, environmental organizations and others, including the general public, who have an interest in water resources matters.

3. To promote professional training and education in fields relating to water resources and to encourage the entry of promising students into careers in these fields.

4. To represent Tennessee in the Universities Council on Water Resources, the American Water Resources Association (including Tennessee Section), the Ohio River Basin Consortium for Research and Education, the Clinch-Powell River Basin Consortia, the South Atlantic-Gulf regional grouping of state water resources research institutes, the ORNL-TVA-UT Research Consortium and the National Institutes for Water Resources (NIWR) Directors. To work with these and other associations and with state, local and federal government agencies dealing with water resources in identifying problems amenable to a research approach and in developing coherent programs to address them. Particularly, to cooperate with the other state institutes and their regional groupings for assisting the U.S. Geological Survey in developing a national water resources strategy.

In fulfilling the Center's major goals indicated previously, TWRRRC emphasizes the application of Section 104 grant and required matching funds for primarily supporting the research and training/education needs of the state. While the information dissemination and technology transfer portion of the Center's overall program does not receive direct or significant section 104 funding, this is accomplished primarily from the research and training activities of the Center from other funding sources--state, private, or non-profit. The Center recognizes that education and training, research, and information transfer are not independent objectives or are not mutually exclusive. Instead these goals are achieved through the administration of a coordinated, fully- integrated program within the limitations of the resources available to the Center.

Research Program

Acid Catalyzed Hydrolysis of Wastewater Activated Sludge for Removal and Possible Conversion to Products

Basic Information

Title:	Acid Catalyzed Hydrolysis of Wastewater Activated Sludge for Removal and Possible Conversion to Products
Project Number:	2002TN3B
Start Date:	3/1/2001
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	TN2
Research Category:	Not Applicable
Focus Category:	Treatment, Waste Water, Models
Descriptors:	Activated sludge, data analysis, economics, energy use and conservation, mathematical models, optimization, pollution control, waste disposal
Principal Investigators:	Paul R. Bienkowski, Robert M. Counce

Publication

1. Perkins, L W; K T Klasson, P Bienkowski, R M Counce, 2003, Preliminary Investigation of Nitro-Hydrolysis for Wastewater Sludge Treatment, Separation Science and Technology for Energy Applications, 38 (12 & 13), 3273-3288.
2. Perkins, L W; K T Klasson, R M Counce, P Bienkowski, 2003, Development of Nitrolysis for Excess Sludge Treatment - A Factorial Study, Industrial and Engineering Chemistry Research, 42, 3544-3548.
3. Perkins, L W; R M Counce, P R Bienkowski, C Perilloux, K T Klasson, 2003, Production and Separation of Organic Acids from Waste Biosolids, Separation Science and Technology for Energy Applications, 38 (12 & 13), 3273-3288.
4. Perkins, L W; K T Klasson, R M Counce, P R Bienkowski, Development of Nitrolysis for Excess Sludge Treatment II: A Factorial Study for Industrial Wastes, Industrial and Engineering Chemistry Research, (in press).
5. Perkins, L W; T Klasson, RM Counce, P R Bienkowski, Development of Nitrolysis for Excess Sludge Treatment II: A Factorial Study of Industrial Wastes, Ind. and Eng. Chem. Res. (in Press).
6. Bienkowski, P R; R M Counce, 2002, Nitrolysis as a Sludge Treatment Alternative,

Kentucky-Tennessee Water Environment Association Conference, Marriott Hotel, Knoxville, TN, May 13-17, 2002.

7. Bienkowski, P R; R M Counce, 2002, Preliminary Investigation of Nitrolysis To Treat Biosolids from Wastewater Treatment, American Nuclear Society Spectrum 2002: 9th Biennial International Spectrum Conference, Reno, NV, August 4-8, 2002.
8. Bienkowski, P R; R M Counce, 2002, Preliminary Investigation of Nitro-Hydrolysis for Wastewater Sludge Treatment, 2002 AIChE Annual Meeting, Indianapolis, IN, November 3-8, 2002.
9. Bienkowski, P R; R M Counce, 2003, Design and Development of a Process for Acid Hydrolysis of Excess Sludge, University of Tennessee, Chemical Engineering Dept. Seminar, March 25, 2003.
10. Bienkowski, P R; R M Counce, 2003, Development of Nitrolysis As An Alternative For Treatment Of Excess Sludge Produced During Industrial Wastewater Treatment Activities, 2003 AIChE Annual Meeting, San Francisco, CA, November 16-21, 2003.

Problem and Research Objective:

Both municipal and industrial treatment of wastewater using an activated sludge process generates large quantities of biosolids referred to as sludge. Currently the Knoxville Utility Board (KUB) generates 65 tons/day of these solids (dry basis) from their activated sludge wastewater treatment facilities. This material is concentrated from 4.2 wt % up to 35 - 40 wt % via filtration and disposed off-site by trucking it over 70 miles for disposal through land farming. Every year the distance becomes greater due to KUB's inability to find acceptable sites for land farming. At least several industries (DuPont and Tennessee Eastman) have similar problems with sludge disposal. Eastman currently produces 55 dry tons/day of sludge which is incinerated.

On-site destruction of the excess biosolids is preferred from both an economic and environmental standpoint. Currently both Dupont and Tennessee Eastman use on-site incineration and would prefer a more environmentally benign process which uses less energy. A nitric acid catalyzed hydrolysis process can convert most of the sludge into a biodegradable material suitable for recycle. There is also a possibility that the sludge could be converted into acetic acid for commercial sale. The major products from this hydrolysis are organic acids. It may be possible to optimize production of these acids to the point where it is economically feasible to convert the waste activated sludge stream into a commercial product. If it is not economically feasible to recover the organic acids the stream can be recycled back to the waste treatment unit where the organic acids will biodegrade.

This proposal will consist of a batch scale kinetic study using activated sludge from KUB's Kuwahee treatment facility, employing a factorial experimental design. The variables consist of residence time, reaction temperature, solids concentration, and nitric acid concentration; with percent conversion and acetic acid concentration as the dependent variables. The concentration of the sludge can have a significant impact on the economics of any potential process and must be investigated. The sludge stream from KUB's activated sludge treatment process is 4.2 wt % and is concentrated to 35 - 40 % by filtration prior to land farming. A feed sludge concentration in the range of 4.2 - 40 wt % will be investigated. The data will be analyzed and a mathematical model will be developed for the reaction kinetics over the range of the input variables. The form of the model will depend on the experimental data. If significant quantities of organic acids are obtained a complex model will likely be required; if the organic compounds are not produced in sufficient quantity a much simpler model describing destruction kinetics will be employed. The model will be utilized to evaluate the economics of the process and to develop a preliminary process design. A continuous pilot scale unit will be designed and built. This unit will be used at KUB's Kuwahee treatment facility in the second year of the project.

The First Year Objectives for this research were:

1. A complete data set on the reaction kinetics and development of a mathematical model from this data set for design and optimization
2. Development of a process flowsheet for evaluation of economics
3. Economic potential for recovery of products
4. Complete construction of a 2.0 gph pilot plant capable of continuous operation at the optimum batch reactor conditions.

The Second Year Objectives for this research were:

1. Conduct Corrosion test on three different catalyst (nitric and sulfuric acids and sodium hydroxide) at normal operating conditions.
2. Evaluate the economic for this process for KUB sludge and for Eastman Chemical sludge
3. Develop a process design for a one ton per day demonstration unit at Eastman's Kingsport plant site.

Methodology and Accomplishments to Date:

During the first year of this project a factorial experimental design was developed for conducting batch kinetic experiments on activated sludge effluent obtained from KUB. The objective of the experiments was two fold; 1) to hydrolyze the biosolids to CO₂ and organic material which is biodegradable via recycle to the waste treatment unit and 2) investigate the possibility of producing organic acids that maybe recovered commercially. Four variables were used in the experimental design; 1) reaction temperature, 2) residence time, 3) acid concentration and 4) biosolids concentration in the feed. The feed solids range was already been fixed by the sludge availability at KUB (4.2 - 40 wt %). The other three variables are all interrelated. The idea of a factorial experimental design is to set up a four dimensional matrix covering the anticipated range of each of the four control variables, but to only run selected experiments. It would be prohibitive to run all of the possible experiments, instead some initial experiments will be conducted and based on these results (percent reduction of biosolids and/or quantity of organic acids produced) the direction for future experiments will be determined. This direction can be determined either by numerical regression of the experimental data or by fitting the data to a predetermined kinetic model. Obviously what we want to find is that combination of these four variables that leads to high percentage destruction of biosolids and possibly high conversion to organic acids. After several experiments were conducted it was determined that it was more useful to combine acid concentration and sludge concentration into one variable, acid/sludge ratio. A process design was developed for a demonstration unit during the second year and the economics were evaluated for a full scale unit. The pilot plant was used to demonstrate continuous process and develop design data (mainly corrosion testing).

Principal Findings and Significance:

The volume and viscosity of both municipal and industrial sludge can be significantly reduced with an acid based hydrolysis at 160 to 180 C with a residence time of 5 to 10 minutes. The effluent stream is suitable for recycle to the wastewater treatment facility. Kinetics have been developed for this process based on batch reactor data. Production of an acetic acid product requires considerably longer residence times and results in a product concentration so dilute as to make recovery uneconomical. Several process flow sheets have been developed to convert the bench scale experiments into a viable process. A continuous pilot plant with a capacity of 2.0 gph of a 4 wt% sludge has been designed and constructed for the purpose of demonstration. Using a subsequent DOE grant a much larger unit was constructed at Kingsport capable of processing 16 wt% sludge at much higher flow rates. The results of this work are documented in the publications listed below plus Larry Perkins's PhD dissertation. Currently four students, two masters and two undergraduates are working on this project.

Future Research and Funding:

Eastman Chemical Company and The University of Tennessee have received a \$982,500.00 NICE3 grant from DOE (DE-FG44-03R410870) for a commercial demonstration of this technology at the Tennessee Eastman plant site in Kingsport. The grant is for 3 years, 6/23/03 to 6/22/06 with \$480,000 from DOE and the remained in matching from Eastman and UTK. A one ton per day demonstration unit was constructed on the Kingsport plant site and turned over to UTK on May 10, 2004.

Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration

Basic Information

Title:	Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration
Project Number:	2003TN7B
Start Date:	3/1/2003
End Date:	9/30/2004
Funding Source:	104B
Congressional District:	TN 2nd
Research Category:	Not Applicable
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	water quality, water quality management, pollution control, regulatory permits, watershed management, pollutants
Principal Investigators:	John F. McCarthy, Randall Wilson Gentry, Alice Layton, Larry D. McKay

Publication

1. Gentry, R W; J McCarthy, A Layton, L Mckay, G S Sayler, Fecal Bacteria Occurrence at Basal Conditions in a Karst Dominated Watershed in East Tennessee, (in preparation).
2. Layton, A D; V Williams, L Garrett, R McKay, R Gentry, G. Sayler, Development of Bacteroides 16srRNA gene TaqMan PCR assays for the quantification of fecal source pollution in water samples, Submited to Applied and Environmental Microbiology in 2004, (currently in revision).
3. Gentry, R W; J McCarthy, A Layton, L McKay, S Koirala, 2004, Evaluating microbial water quality and potential sources of contamination in a small rural watershed in karstic terrain, Groundwater Quality 2004-4th International Conference, July 19th - 22nd, 2004, University of Waterloo, Ontario, Canada.
4. Gentry, R W; 2004, Assessing Ground Water and Surface Water Interaction through Tracer Observation, ASCE-EWRI, 2004 World Water & Environmental Resources Congress, June 27 July 1, 2004, Salt Lake City, Utah.
5. Gentry, R W; J McCarthy, A Layton, L McKay, S Koirala, 2004, A Hydrologic Investigation into the Occurrence and Causation of Pathogen Indicators in the Stock Creek Watershed, Knoxville,

Tennessee, TN Section American Water Resources Association, Thirteenth Annual Tennessee Water Resources Symposium, March 31 April 2, 2004, Burns, TN.

6. Gentry, R W; J McCarthy, A Layton, L McKay, S Koirala, 2004, A hydrologic investigation into the occurrence and causation of pathogen indicators in the Stock Creek watershed, Knoxville, TN, AWRA 14th Annual Tennessee Water Resources Symposium, Burns, TN, March 31-April 2, 2004.
7. Layton, A; D Williams, V Garrett, L McKay, R Gentry, J McCarthy, G Sayler, 2004, Development of real-time PCR assays for the detection of Bacteroides sp. as a method to quantify fecal contamination, TN Section American Water Resources Association, Thirteenth Annual Tennessee Water Resources Symposium, March 31 April 2, 2004, Burns, TN.
8. Layton, A; L McKay, D Williams, V Garrett, R Gentry, J McCarthy, G Sayler, 2004, Development of real-time PCR assays for the detection of Bacteroides sp., KY/TN Water Environment Association, Pollutant Source Identification Specialty Conference, Murfreesboro, TN, May 20, 2004.
9. Layton, A; D Williams, V Garrett, L McKay, 2004, Development of real-time PCR assays for the detection of Bacteroides sp. as a method to quantify fecal contamination, AWRA 14th Annual Tennessee Water Resources Symposium, Burns, TN, March 31-April 2, 2004.
10. McKay, L: A Layton, T Baldwin, G Sayler, 2004, Development and testing of real-time PCR assays for detecting pathogens and related microbial indicators in karst settings, GQ2004 Conference, Waterloo, Ontario, Canada, July 19-22, 2004.

Problem and Research Objective:

This proposal focuses on the Stock Creek Watershed, which is part of the Little River Watershed in Knox and Blount Counties. Stock Creek, which is on the 303(d) list because of elevated levels of pathogens, represents a small watershed that can serve as a “research watershed” to explore and evaluate strategies for holistic approaches to watershed remediation. The principal goal is an evaluation of pathogen occurrence and causation within the creek that will eventually lead to the restoration of the Stock Creek Watershed. The project is testing and demonstrating holistic watershed assessment protocols that can serve as a model for restoration of other impaired waterbodies. We are testing innovative monitoring techniques to distinguish between human- and animal sources of pathogens, and evaluate the effectiveness of integrated stream assessment tools in watershed restoration. The project will achieve a secondary goal of using the process knowledge of the watershed to restore it to the condition fully supporting its designated uses, and lead to the removal of Stock Creek from the 303(d) list before a TMDL is required.

This project objectives are to (1) devise and implement a monitoring plan to obtain information on water quality (water chemistry, pathogens, sediment load, biological integrity), (2) further develop biomolecular tools that will provide real-time data on levels of pathogen indicators and of pathogenic *E. coli* and that will directly help to (3) distinguish between human- and animal-derived pathogens, and potential “pathogen reservoirs” which could be persistent sources of pathogen inputs to the Creek, and (4) the role of storm events, seasonal changes in hydrologic conditions, and groundwater inputs to water quality and pathogen levels. The new fundamental knowledge of pollutant sources and watershed processes can be used by partnering agencies to develop recommendations for BMPs, and support efforts to obtain Grant Pool funds to perform the BMPs. The success of the integrated watershed remediation and management tools developed within this project can be demonstrated by the restoration of the Stock Creek Watershed to its designated uses, and its removal Stock Creek from the 303(d) list.

Methodology and Accomplishments to Date:

The Stock Creek Watershed has been evaluated based on sampling from 16 locations that were selected to monitor water quality at several locations within the stream, as well as at locations where major tributaries draining sub-watersheds enter Stock Creek. We obtained data on water quality, stream flow rate and pathogens at the sampling locations at approximate monthly intervals for a year. The sampling locations are shown in Figure 1. The data are being used in several ways.

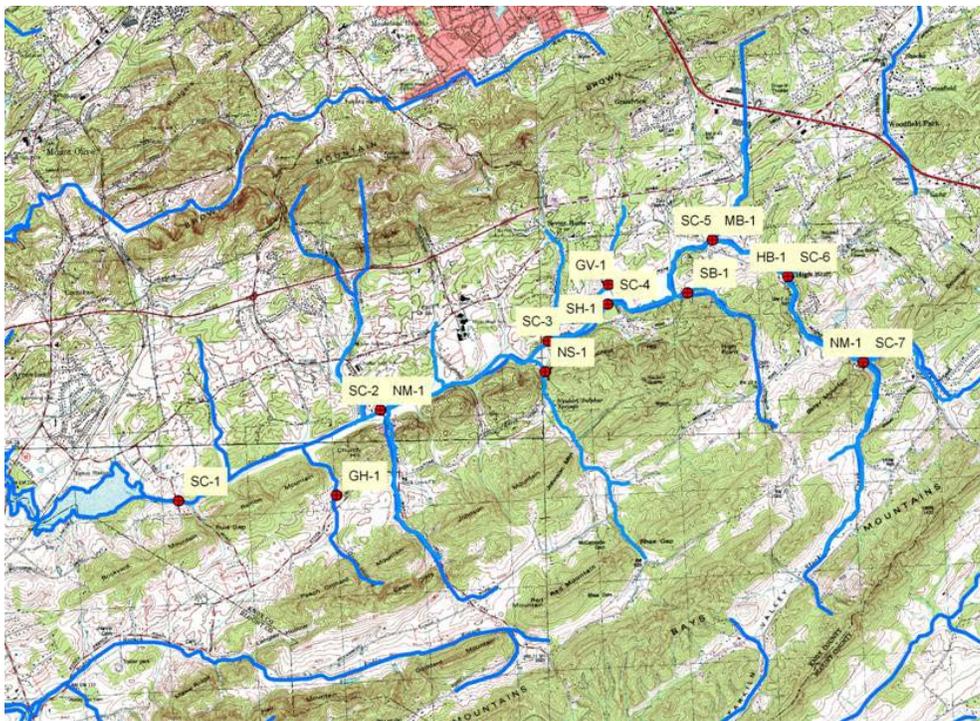


Figure 1. Stock Creek and associated sample locations.

Data are being made available in Access format to use by TDEC or for incorporation into GIS layers for use by other agencies such as TVA and Knoxville-Knox County to assist in identifying potential pollution sources. The types of data that have been collected include categories of pathogens, water quality, and hydrology.

Pathogen indicators have been quantified at each of the sampling locations using “standard” analyses for total coliforms and fecal coliforms by the TDEC laboratory in Knoxville. In addition, two alternative methods have been compared. The EPA-approved Hack pathogen test kit involves filtration of water samples and incubation of the filters. Dyes in the kit identify lactose utilizing and glucuronidase-containing organisms to provide information on levels of total coliforms and *E. coli*. We have developed real-time PCR assays for the differentiation and quantification of fecal anaerobic bacteria within the genus *Bacteroides*. This research was performed in conjunction with two other projects monitoring the Stock Creek Watershed. Data collected in this research project is expected to provide information regarding the sources of fecal contamination (cattle versus human) necessary for the development of a TMDL for pathogens in the Stock Creek Watershed.

Water chemistry and hydrology of Stock Creek is being analyzed to evaluate the sources of the pathogens and to help design effective BMPs. Water chemistry of the water samples has been analyzed by TDEC. Both base flow and storm monitoring of the Creek provides information to parameterize a hydrologic flow model of the watershed. This effort helps link pathogen loading to storm events and to sediment resuspension processes. An important aspect of this work will also include an analysis of overland flow travel times. The evaluation will attempt to correlate the concentration of pathogens to the time of concentration of sub-basin catchments.

Principal Findings and Significance:

1. In conjunction with two other Stock Creek projects, a real-time PCR assay was developed to differentiate and quantify fecal anaerobic bacteria within the genus *Bacteroides*.
2. It appears that bovine-specific *Bacteroides* are present throughout the Stock Creek Watershed and are at high levels at some sites. This suggests that a portion of the *E. coli* contamination in Stock Creek may be attributable to cattle. Additional data analysis is needed to determine if there is a link between the levels of bovine-specific *Bacteroides* and *E. coli*
3. Frequency analysis was performed on several main channel sites. The analysis provided a probabilistic model for the occurrence of general and bovine specific fecal loading within the watershed. This is a potentially valuable statistical approach for risk-based modeling and establishment of regulatory limits within the TMDL process. The methodology may also be useful for post-BMP audits for evaluating BMP performance in varying watershed types.

Future Research and Funding:

A hydrologic model of the watershed is being developed based on flow monitoring of the Creek. These efforts will continue as part of Shesh Koirala's Ph.D. research in the Department of Civil and Environmental Engineering.

Information Transfer Program

Tennessee Water Resources Research Center Information Transfer Program

Basic Information

Title:	Tennessee Water Resources Research Center Information Transfer Program
Project Number:	2003TN5B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	TN2
Research Category:	Not Applicable
Focus Category:	Education, Non Point Pollution, Water Quality
Descriptors:	training, nonpoint source pollution, technology transfer
Principal Investigators:	Timothy Gangaware

Publication

1. Tschantz, B.A., Timothy Gangaware, and Robert Morgan, 2003, Guide to the Selection and Design of Stormwater Best Management Practices (BMP): A Guide for Phase II MS4 Communities for Protecting Post-construction Stormwater Quality and Managing Stormwater Flow, Tennessee Water Resources Research Center, The University of Tennessee, Knoxville, TN. pp. 228.
2. Buchanan, J.R., B.A. Tschantz, and T.R. Gangaware, 2003, Design Principles for Erosion Prevention and Sediment Control for Construction Sites: EPSC Level II Training Manual, Tennessee Water Resources Research Center, University of Tennessee, Knoxville, TN., pp 138.
3. Haden, J., R.A. Hanahan, and T.R. Gangaware, 2003, Tennessee Growth Readiness: Leadership Training for Planning and Public Works Officials Manual and CD-ROM, Tennessee Water Resources Research Center, University of Tennessee, Knoxville, TN., pp 168.

The major emphasis of the information transfer program during the FY 2003 grant period focused on technical publication support, conference planning/development, and improvement in the information transfer network. The primary purpose of the program was to support the objectives of the technical research performed under the FY 2003 Water Resources Research Institute Program.

The primary objectives, as in previous years, of the Information Transfer Activities are:

- To provide technical and structural support to water researchers performing research under the WRRIP.
- To deliver timely water-resources related information to water researchers, agency administrators, government officials, students and the general public.
- To coordinate with various federal, state, and local agencies and other academic institutions on program objectives and research opportunities.
- To increase the general public's awareness and appreciation of the water resources problems in the state.
- To promote and develop conferences, seminars and workshops for local and state officials and the general public which address a wide range of issues relating to the protection and management of the state's water resources.

During the FY 2003 grant period, a major focus of the information transfer activities was on the participation of the Center staff in the planning and implementation of several statewide conferences and training workshops.

As co-sponsor, the Center was involved in the planning and implementation of the Thirteenth Tennessee Water Resources Symposium, which was held on April 9-11, 2003 at Montgomery State Park in Burns, Tennessee. The purposes of the symposium are: (1) to provide a forum for practitioners, regulators, educators and researchers in water resources to exchange ideas and provide technology transfer activities, and (2) to encourage cooperation among the diverse range of water professionals in the state. As with previous symposia, the thirteenth symposium was very successful with over 260 attendees and approximately 65 papers and 20 posters being presented in the two-day period. The event received a good deal of publicity across the state.

The Center also participated in several meetings and workshops across the state that were held to address water related problems and issues such as stormwater management, water quality monitoring, non-point source pollution, water supply planning, TMDL development, watershed management and restoration, multiobjective river basin management and lake management issues and environmental education in Tennessee.

The following is a brief listing of formal meetings, seminars and workshops that the Center actively hosted, supported and participated in during FY 2003:

- Tennessee Watershed Roundtable, March 27-28, 2003, Sheraton Hotel, Nashville, TN.
- Knox County Site Planning Roundtable Monthly meetings of the Roundtable subcommittees were held on March 6, 19 & 26, 2003; April 2, 7, & 22, 2003; May 8, 13, 15, 22 & 27, 2003.
- Adopt-A-Watershed National Development Training March 14-15, 2003, Ijams Nature Center, Knoxville, TN.
- Tennessee Wetlands Technical Advisory Task Force meeting, April 1-2, 2003, Nashville, Tennessee. Meeting of government agency staff and technical experts to advise to the State on issues related to the Tennessee Wetlands Management Plan.
- Adopt-A-Watershed Southeast Leadership Retreat, April 30 – May 3, 2003, Rockfish Outdoor Center, Fayetteville, NC.
- WaterFest, May 9, 2003, Knoxville, TN. An annual community-wide event sponsored by the Water Quality Forum that highlights the importance of our water resources and the activities of the WQF partners to protect and manage those resources.
- Kids-In the-Creek, April 17, 2003 Bonnie Kate Elementary School; April 29, 2003, Halls Middle School, Knoxville, TN. A watershed experience sponsored by Tennessee Valley Authority, TNWRRC and the CAC AmeriCorps Water Quality Team. An all day event for approximately 75 3rd & 5th grade students introducing them to watershed science including biological and chemical monitoring and land use impacts on water quality.
- Fundamentals of Erosion Prevention and Sediment Control Level I Training workshops, sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. A one day course for developers, contractors, road builders and others involved with construction activities across the State. The course was offered on the following dates in 2003: April 15, Nashville, TN.; May 13, Chattanooga, TN.; May 14, Cookeville, TN.; June 3, Memphis, TN.; June 4, Jackson, TN.; September 30, Nashville, TN.; October November 14, Chattanooga, TN.(TDOT); November 18, Knoxville, TN.; November 19, Chattanooga, TN.; November 24, Knoxville, TN.(TDOT); December 10, Johnson City, TN.; December 16, Jackson, TN. (TDOT); February 10, 2004, Nashville, TN.; and February 26, 2004, Knoxville, TN.

- Design Principles for Erosion Prevention and Sediment Controls for Construction Sites Level II workshops sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. A two day training workshops for engineers and other design professionals responsible for the development of Storm Water Pollution Prevention Plans for construction activities. The course was offered on the following dates: April 3-4, 2003, Knoxville, TN.; June 17-18, 2003 Nashville, TN.; August 5-6, 2003, Memphis, TN.; August 26-27, 2003, Chattanooga, TN.; October 1-2, 2003, Nashville, TN.; January 29-30, 2004, Knoxville, TN.; and February 5-6, 2004, Nashville, TN.
- Nonpoint Source Program Education Working Group, June 12, 2003, Nashville, TN.
- Urban Runoff Working Group, July 15, 2003, Nashville, TN.
- Adopt-A-Stream training workshop June 14, 2003, Knoxville, TN. The kick off training of a new program sponsored by TNWRRC, City of Knoxville, Knox County and the Town of Farragut . The AAS encourages local citizens and community organizations to adopt and monitor sections of streams in the region. Additional AAS training were held on September 13, 2003; October 18, 2003 and January 24, 2004.
- Tennessee Growth Readiness Leadership training workshops. A series of half day workshops sponsored by TNWRRC, Tennessee Valley Authority and the Tennessee Department of Agriculture Nonpoint Source Program. The TGR was developed to provide local planners and public works officials with a tool box of materials that could be used to educate local elected officials about the impacts of land use decisions on water quality. The TGR program was patterned after the University of Connecticut' s NEMO program. The workshops were held on the following dates: July 30, Nashville, TN.; September 10, Jackson, TN.; September 16-17, Nashville, TN.; September 22, Cookeville, TN.; September 23-24, Knoxville, TN.; October 3, Chattanooga, TN.; October 8, Johnson City, TN.; December 17, Columbia, TN.; and January 14, 2004, Memphis, TN.
- Twelfth Annual SAMAB Conference, November 5-7, 2003, Gatlinburg, TN. Sponsored by the Southern Appalachian Man and the Biosphere. TNWRRC staff made several presentations on watershed assessment projects.
- Knoxville Water Quality Forum, Quarterly meetings, May, July and October 2003 and January 2004. Meeting of government agencies and other organizations to share information and discuss water quality issues in the Tennessee River and it's tributaries in Knox County.
- Little River , French Broad River, Bull Run Creek, Beaver Creek Stock Creek and Emory River Watershed Associations, monthly meetings. Agency staff and community leaders working towards protection of the Little River, lower French Broad, the Emory/Obed and smaller tributaries watersheds.

- Joint UT-TVA-ORNL Water resources Consortium Seminar Series on timely water resources topics, issues and projects of common interest to the three organizations.

Other principal information transfer activities which were carried out during the FY 2003 grant period focused on the dissemination of technical reports and other water resources related reports published by the Center as well as other types of information concerning water resources issues and problems. A majority of the requests for reports and information have come from federal and state government agencies, university faculty and students, and private citizens within the state. The Center also responded to numerous requests from across the nation and around the world.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	3	0	0	3
Masters	2	2	0	0	4
Ph.D.	0	2	0	0	2
Post-Doc.	0	1	0	0	1
Total	2	8	0	0	10

Notable Awards and Achievements

Tennessee Water Resources Research Center staff, Ruth Anne Hanahan, Senior Research Associate and Timothy Gangaware received awards from the Knoxville/Knox County Water Quality Forum in recognition of their Outstanding Support and Contribution to Water Quality Improvement Activities in Knox County. The awards were presented at the July 13, 2003 quarterly meeting of the WQF.

Publications from Prior Projects

- 1999TNTN-03 ("Field-Testing of Krypton-85 as an Emerging Tool for Age-Dating Groundwater: II") - Conference Proceedings - Lavastere, V., B. Lavielle, T. Bertrand, E. Gilabert, N. Thonnard, and J. Gilmour, 2003, Dation du Transport d'Eaux Souterraines dans l'Oxfordianet le Dogger (Site Meuse/Haute-Marne) par la Metode du 81Kr, In GdR FORPRO Colloque 2003, La Grande-Motte, 22-24 September.
- 1999TNTN-03 ("Field-Testing of Krypton-85 as an Emerging Tool for Age-Dating Groundwater: II") - Other Publications - Gentry, R.W., L.D. McKay, D. Larsen, J.K. Carmichael, D.K. Solomon, N. Thonnard, and J.L. Anderson, 2003, Inter-aquifer Dynamics in and near a Confining Unit Window in Shelby County, Tennessee, USA, Eos Trans. AUG, 84(47), Fall Meet. Suppl., Abstract H21D-0868, 2003.
- 1999TNTN-02 ("High-rate Anaerobic Pretreatment of Animal Wastewater: Impact on Traditional Anaerobic Animal Waste Treatmnet System Performance and Economics") - Dissertations - Pinto, Alexandra, M., 2003, Fuzzy-logic Control of High-rate Anaerobic Gigestion Processes, PhD Dissertation, Department of Biosystems Engineering, The University of Tennessee, Knoxville, TN.
- 2000TNB-03 ("An Investigationto Identify Sources and Quantities of Modern Recharge to the Memphis Aquifer in the Sheahan Well Field in Shelby County, Tennessee.") - Articles in Refereed Scientific Journals - Larsen, D., R.W. Gentry, and D.K. Solomon, 2003, The Geochemistry And Mixing Of Leakage In A Semi-Confined Aquifer At A Muniiciapl Well Field, Memphis, Tennessee, Applied Geochemistry, V18, n7, pp 1043-1063.
- 2000TNB-03 ("An Investigationto Identify Sources and Quantities of Modern Recharge to the Memphis Aquifer in the Sheahan Well Field in Shelby County, Tennessee.") - Articles in Refereed

Scientific Journals - Gentry, R.W., D. Larsen, and S. Ivey, 2003, Efficacy Of Genetic Algorithm To Investigate Small Scale Aquitard Leakage, ASCE Journal of Hydraulic Engineering, V129,n7,pp. 527-535.

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7. 2001TN4101B ("Constructed Wetland Cleanup of Pirtle's Container Nursery Runoff") - Articles in Refereed Scientific Journals - Stearman, G.K., D.B. George, K. Carlson, and S. Lansford, 2003, Pesticide Removal from Container Nursery Runoff in Constructed Wetland Cells, Journal of Environmental Quality. (accepted for publication).
8. 2001TN4101B ("Constructed Wetland Cleanup of Pirtle's Container Nursery Runoff") - Conference Proceedings - Stearman, G.K., D.B. George, and L.B. Hutchings, 2003, Constructed Wetland Cleanup of Pirtle's Container Nursery Runoff: Removal of Nitrogen Phosphorus and Prodiamine from Subsurface Flow Constructed Wetland at 1, 2, and 3 day Hydraulic Retentions Times. In: The Thirteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Burns, TN., April 9-11, 2003, pp. 28-32.
9. 2001TN4101B ("Constructed Wetland Cleanup of Pirtle's Container Nursery Runoff") - Other Publications - Stearman, G.K., D.B. George, H.G. Spratt, and C.W. Robinson. 2003, Simazine and Metolachlor Removal in Subsurface Flow Gravel Constructed Wetlands, Agronomy Abstracts, American Society of Agronomy Annual Meeting, Denver, CO., November 4, 2003.
10. 2001TN4101B ("Constructed Wetland Cleanup of Pirtle's Container Nursery Runoff") - Articles in Refereed Scientific Journals - Stearman, G.K., D.B. George, and L.D. Hutchings, 2004, Removal Of Nitrogen, Phosphorus and Prodiamine From A Container Nursery By A Subsurface Flow Constructed Wetland, in review, Ecological Engineering.
11. 2001TN4041B ("Investigation of Factors Controlling Transport of Microbial Pathogens in Saprolite Soils") - Articles in Refereed Scientific Journals - McCarthy, J.F., L.D. McKay, and D.D. Burner, 2002, Influence Of Ionic Strength And Cation Charge on Transport Of Colloidal Particles In Fractures Shale Saprolite: Environmental Science Technology, v.36, p.3735-3743.
12. 2001TN4041B ("Investigation of Factors Controlling Transport of Microbial Pathogens in Saprolite Soils") - Articles in Refereed Scientific Journals - McKay, L.D., A.D. Harton, and G.V. Wilso, 2002, Influence Of Flow Rate On Transport Of Phage In A Highly Weathered And Fractured Shale: Journal of Environmental Quality, 31, 1095-1105.
13. 2001TN4041B ("Investigation of Factors Controlling Transport of Microbial Pathogens in Saprolite Soils") - Articles in Refereed Scientific Journals - Driese, S., and L.d. McKay, 2003, Epi-fluorescence Micromorphology Of Saprolite Reveals Evidence For Colloid Retention In Microscale Pore Systems, Geoderma, In-press.
14. 2000TN3B ("Spherical Cavity Ring-down Spectroscopy of Water") - Conference Proceedings - Ivey, S., D. Larsen, J. Anderson, and R. Gentry, 2003, Use of Lumped Parameter Models for Wellhead Protection Delineation, In: Proceedings of the Thirteenth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Burns. TN., pp 2C-8-2C-14.