Tennessee Water Resources Research Center
Annual Technical Report
FY 2004

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 Tennes5ee 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:

I. 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.

II. 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 TWRRC 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 watt 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, TWRRC 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

Removal of Toxic Heavy Metals from Wastewater Effluents

Basic Information

Title:	Removal of Toxic Heavy Metals from Wastewater Effluents
Project Number:	2004TN12B
Start Date:	3/1/2004
End Date:	6/30/2005
Funding Source:	104B
Congressional District:	TN4
Research Category:	Not Applicable
Focus Category:	Toxic Substances, Water Quality, Waste Water
Descriptors:	heavy metals, toxic substances, wastewater treatment, water quality
Principal Investigators:	Gregory J. Grant

Publication

1. Grant, G J, L L Hill, M L Helm, D G VanDerveer, 2005, Multinuclear NMR Studies on Homoleptic Thioether Complexes of Cadmium(II), J Chem Soc Dalton Trans, submitted.
2. Grant, G J, 2005, Mercury(II) Complexes with Thiacrown Ligands, invited chapter in Structure and Bonding, in preparation.
3. Helm, M L, G P Helton, D G VanDerver, G J Grant, 2005, 199-Hg NMR Chemical Shifts in Thiacrown and Related Macrocyclic Complexes, Inorganic Chemistry, in press.

Problem and Research Objective:
The critical water issue addressed by our research project was water quality. The project dealt with research that can lead to enhanced methods for the treatment, removal, and detection of hazardous and toxic heavy metal contaminants in industrial and municipal wastewater. These heavy metal pollutants are problematic because their presence may not be obvious, and even when present at very low concentrations, they may have insidious effects. Industries present in the state of Tennessee such as mining and smelting can mobilize large quantities of trace metals. Besides industrial sources, solid waste disposal and landfills create another potential source of these heavy metals which can pollute groundwaters. For example, discarded household batteries, inks, paints and dyes, dental amalgams, and pigments can release heavy metals into water supplies. Thus, sewage sludge disposal and landfills can also result in an increase of trace metals in surface or groundwater, and special waste disposal in approved landfill sites has previously been employed for the handing of some toxic heavy metals in the state of Tennessee.

The specific goal of this research project was to examine correlations between X-ray crystal structures and NMR chemical shifts for complexes containing the divalent heavy metal ions Hg(II) and Cd(II). The research project can assist in the further advancement of chemosensors for heavy metal ions by providing key information regarding their solution structures. We are currently focusing on macrocyclic thioether complexes of heavy metal since nuclei like 199Hg and 113Cd are attractive and amenable for study by NMR yet surprisingly little data exist for them.

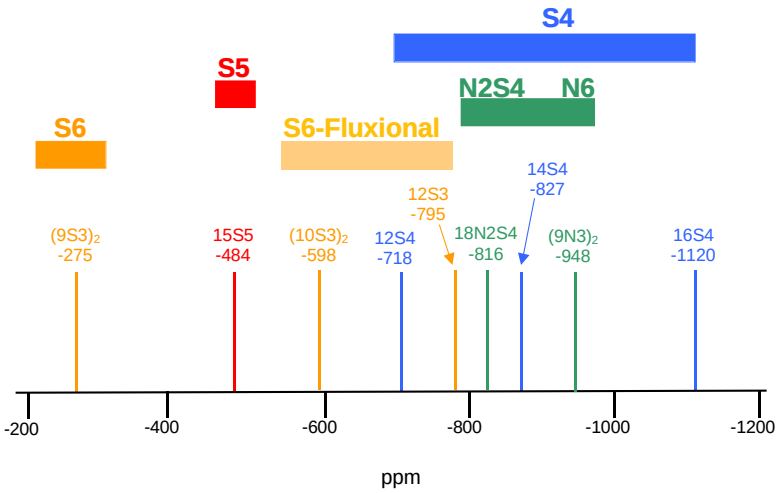
Objectives of Research:
The research objectives of this project were to:

(1) Synthesize novel complexes containing several polythioethers with heavy metal ions such as mercury and cadmium.
(2) To characterize and analyze these complexes using multinuclear nuclear magnetic resonance including 199Hg and 113Cd NMR
(3) To examine the NMR behavior and identify trends in data.

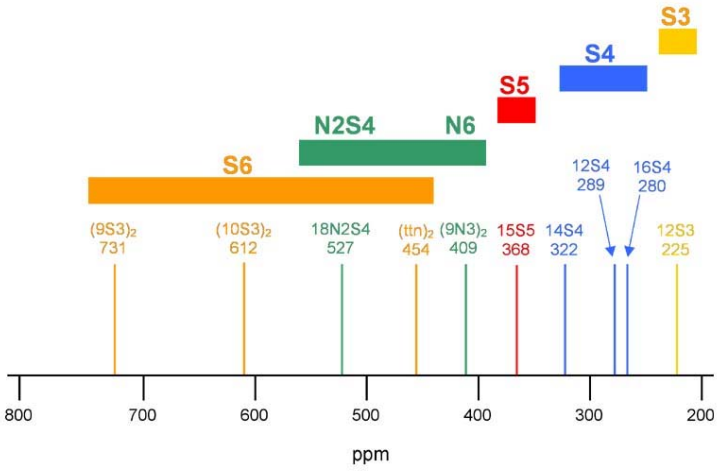
Research Results and Findings:
We have now prepared many complexes containing several polythioethers with two heavy metal ions, mercury, and cadmium. Additionally, these mercury and cadmium complexes have been characterized and analyzed using nuclear magnetic resonance spectroscopy. We wish to report our NMR results for a series of Hg(II) and Cd(II) complexes containing thiacrown ligands as well as some related azacrowns and mixed nitrogen-sulfur donor ligands.

We observe 113Cd NMR chemical shifts in the range of 730 to 225 ppm and 199Hg NMR chemical shifts in range of –275 to –1120 ppm for the series of macrocyclic complexes. Graphical summaries of our data with both nuclei appear on the following page.

199Hg NMR chemical shift data



$^{113}Cd\{^{1}H\}$ NMR Shifts of Various Thioether Complexes

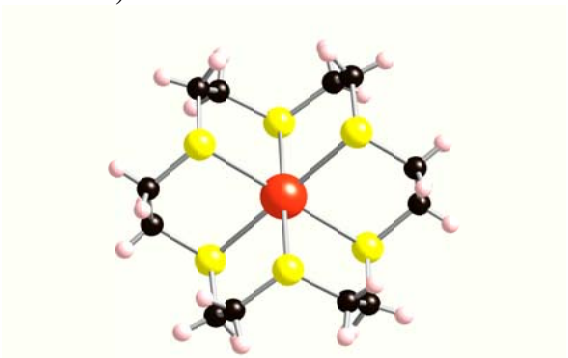


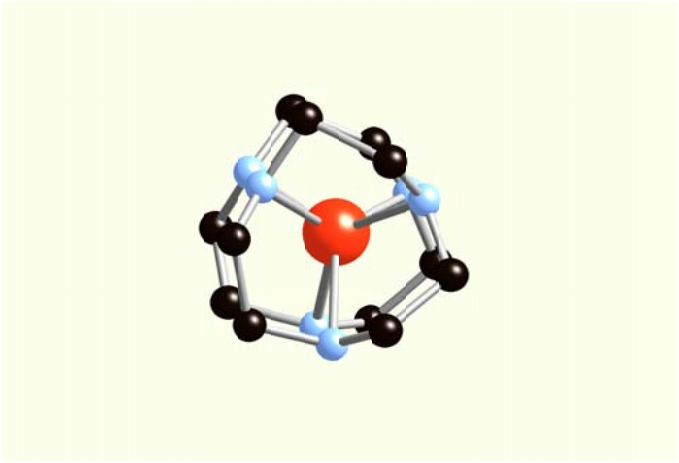
To summarize these data -- Upfield chemical shifts in the NMR spectra of either nucleus are seen whenever:

1. the number of thioether sulfur donors in the complex is decreased.
2. a thioether sulfur donor is replaced by a secondary nitrogen donor.
3. the size of the macrocycle ring increases without a change in the nature or number of the donor atoms.

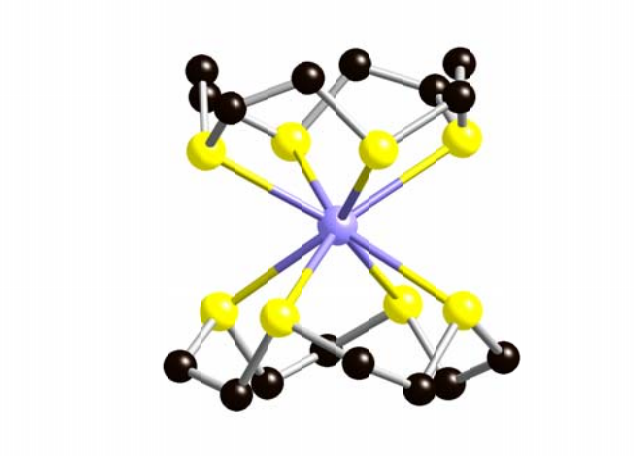
Thus, we have developed a novel means of clearly identifying the surrounding ligand environment for mercury or cadmium in solution.

We report the crystal structures of the mercury(II) complexes with the crown thioether 18S6 as well as the bis complex with azacrown 9N3. The two structures are shown below. An interesting structural result that we have obtained is complexes with six sulfur donors bonded to mercury(II) have an octahedral structure while complexes with six nitrogen donors have a trigonal prismatic structure as shown for the 9N3 complex (2nd structure) below.





We also report the crystal structure for the bis cadmium(II) complex with the tetrathiacrown 12S4. An unusual octakis(thioether) coordination of Cd(II) with a square anti-prismatic geometry is exhibited by [Cd(12S4)2](ClO4)2is shown.



Summary

We have established clear trends in how changes in the ligand environment around a mercury or cadmium center affect its NMR chemical shift. This information will be invaluable for the design of ligand systems which can selectively bind these heavy metals and in chemosensors that are used to detect them.

Presentations at Conferences and Universities Resulting from the Project.

This work has resulted in six presentations at conferences and Universities during the past twelve months. The presentations are listed below, and the name of the author is underlined. These all acknowledge the generous support of the Tennessee Water Resources Research Center. Presentation #1 was an invited paper in a special Symposium on Mercury Immobilization in Soil and Water that was part of a regional chemistry meeting in November of 2004. Paper #3 was presented at an international chemistry conference in Australia.

1. Gregory J. Grant, Monte L. Helm, Gregory P. Helton, Lensey L. Hill "Applications of 199Hg NMR Spectroscopy in Heavy Metal Complexes of Thiacrown Ligands" presented at the 56th Southeastern Regional Meeting of the American Chemical Society, Research Triangle, NC, November 10-13, 2004. Symposium on Mercury Immobilization in Soil and Water, Environmental Chemistry and Public Health Issues. Paper Number 742.

2. Maikel E. Botros, Gregory J. Grant, "Synthesis of the Mixed Donor Macrocycle, 9S2N, 7-aza-1,4-dithiacyclcononane" presented at the 56th Southeastern Regional Meeting of the American Chemical Society, Research Triangle, NC, November 10-13, 2004. Undergraduate Research Poster Session, Division of Chemical Education Paper Number 874.

3. Gregory J. Grant, Monte L. Helm, Gregory P. Helton, Lensey L. Hill; "199Hg and 113Cd NMR Analysis of Macrocyclic Thioether Complexes" presented at the 29th International Symposium on Macrocyclic Chemistry; Cairns, Queensland, Australia, July 4–8, 2004. Paper Number P18.

4. Gregory J. Grant; "Lords of the Thioether Rings: Mercury(II) and Platinum(II) Complexes of Thiacrown Ligands"; invited departmental seminar; presented to the Department of Chemistry, Clemson University Clemson, SC April 28, 2005.

5 Gregory J. Grant, Monte L. Helm, Gregory P. Helton, Lensey L. Hill; "199Hg and 113Cd NMR Analysis of Macrocyclic Thioether Complexes" presented at the 229th National Meeting of the American Chemical Society, San Diego, CA, March, 13-17, 2005. Division of Inorganic Chemistry, Paper Number 705.

6. Maikel E. Botros, Gregory J. Grant, "Synthesis of the Mixed Donor Macrocycle, 9S2N, 7-aza-1,4-dithiacyclcononane" presented at the 229th National Meeting of the American Chemical Society, San Diego, CA, March 13-17, 2005. Undergraduate Research Poster Session, Division of Chemical Education Paper Number 545.

Student Involvement in the Research:
Two UTC students were funded through the project, Greg Helton and Maikel Botros. Both presented their work at professional meetings and were included as co-authors on presentations made by Dr. Grant. Helton is a co-author on one paper (Paper #2) that has already been accepted for publication, and the two students will be co-authors on at least two additional papers. Both students are interested in medical school, and Greg Helton is currently applying to the University of Tennessee at Memphis medical school.

An Investigation of Surface-Ground Water Connections at Nonconnah Creek: A Source of Recharge and Potential Contamination for the Memphis Aquifer in Shelby County Tennessee

Basic Information

Title:	An Investigation of Surface-Ground Water Connections at Nonconnah Creek: A Source of Recharge and Potential Contamination for the Memphis Aquifer in Shelby County Tennessee
Project Number:	2004TN13B
Start Date:	3/1/2004
End Date:	8/31/2005
Funding Source:	104B
Congressional District:	TN9
Research Category:	Not Applicable
Focus Category:	Non Point Pollution, Groundwater, Surface Water
Descriptors:	ground-water hydrology, ground-water movement, age dating, ground-water recharge, urban hydrology, ground-water quality
Principal Investigators:	Daniel Larsen, Jerry Anderson, Stephanie Ivey, Brian Waldron

Publication

1. Larsen, D, R W Gentry, D K Solomon, 2003, The geochemistry of mixing of leakage in a semi-confined aquifer at a minicipal well field, Memphis, Tennessee, USA, Applied Geochemistry, 18, 1043-1063.
2. Larsen, D, J Morat, B Waldron, S Ivey, J Anderson, A Owen, C Garner, 2005, Hydrologic assessment of leakage from Nonconnah Creek to the shallow aquifer in the vicinity of the Sheahan well field, Memphis, Tennessee, "in" Proceedings of the Fifthteenth Tennessee Water Resources Symposium, April 13-15, 2005, Burns, TN, 2B-15.

Problem and Research Objectives:

This project investigates the potential of surface water from an impaired watershed (Nonconnah Creek, Fig. 1) to infiltrate into a shallow aquifer system that recharges an aquifer (Memphis aquifer) used for a municipal water supply. This project is an expansion of a long-term study to investigate the potential for modern water to enter the Memphis aquifer in the Sheahan well field, Memphis, Tennessee (Fig. 2). Published results of our previous research indicate that water pumped from shallow production wells in the Memphis aquifer contains as much as 30% of a chemically distinct modern water (15 to 20 year residence time) that is entering the upper part of the Memphis aquifer near the Sheahan well field. The shallow aquifer overlying the upper Claiborne confining unit and Memphis aquifer is almost unsaturated near the Sheahan pumping station, but becomes progressively saturated toward Nonconnah Creek, 2.7 miles south of the pumping station. Previous investigators determined that Nonconnah Creek loses water to the shallow aquifer in the Memphis area, although no quantitative information is available. Most recently, lumped parameter tracer models have been coupled with inverse computational methods and geochemical data to determine fluxes of modern water to individual well and a location of leakage from the shallow aquifer in the center of the well field. Unpublished finite-difference flow modeling results and model calibration further suggest that various wells in the Sheahan well field receive water from the shallow aquifer, most likely ultimately derived from Nonconnah Creek. Considering that Nonconnah Creek receives urban and agricultural runoff and contains significant pollutant loadings and that the shallow aquifer beneath Nonconnah Creek contains agricultural pollution, it is important to assess shallow aquifer contributions to the urban water supply. The results of the project have the potential to influence ground-water exploitation strategies, watershed management, and source-water protection policies in the Memphis area and surrounding region.

The prime objective of this study is to determine whether Nonconnah Creek is a losing stream in the region south of the Sheahan well field and, if so, how much of that water could be contributing to recharge of the Memphis aquifer at the Sheahan well field. The water loss from Nonconnah Creek to ground water is assessed using four types of methods: (1) hydraulic data and ground-water flow modeling (stream gaging and head measurements), (2) water chemistry (major and minor solutes) and organic chemical analysis, (3) environmental tracers ($^{3}H/^{3}He$ and CFC's), and (4) groundwater flow modeling.

Methods and Accomplishments:

The project is designed to determine the flux and quality of water from Nonconnah Creek to the shallow aquifer during a one-year period (Spring 2004 –Spring 2005). Currently, most of our installation, sampling, and modeling milestones in the project development have been met. Three monitoring wells (NC-1, -2, and -3) were installed and developed in the shallow aquifer in the vicinity of Nonconnah Creek and Getwell Road during April 2004. The boreholes were drilled using a hollow-stem and the returns were described and sampled in the field. The samples are being analyzed for their grain-size distributions. In addition, a stilling well was installed at the same location in August 2004. All well locations and elevations were surveyed using a nearby survey point. Pressure transducers were installed in two of the monitoring wells and in the stilling well. As part of a larger transducer network in Shelby County, pressure transducers are also installed in three existing monitoring wells in the Sheahan well field. Water levels in the wells are being taken quarterly (May and August, 2004) along with discharge measurements in Nonconnah Creek and Johns Creek, a major tributary upstream from the Getwell Road site. Slug testing (for estimating hydraulic conductivity) of 5 wells has been completed: 3 wells (NC-1, SH:K-75, and MLGW 99s) were tested during July 2004 and 2 additional wells (NC-2 and –3) were tested during class projects for a Field Methods in Hydrology course in

October 2004. Water quality samples were also taken from 6 wells and Nonconnah Creek during May, August, and November 2004 and March 2005. In addition to field analysis using calibrated probes, titration, and spectrophotometric techniques, lab analysis of anion concentrations by ion chromatography and cation concentrations by flame source atomic absorption spectrometry have been completed on all but the March 2005 samples (only cation analysis remains). The three monitoring wells at Nonconnah Creek and three shallow monitoring wells in the Sheahan well field were sampled for tritium, noble gases (including ^{3}He) and Chlorofluorocarbons (CFC's) during August 2004; a tritium sample was also taken from Nonconnah Creek as well. In regard to model development, boundary conditions and hydraulic head data have been estimated from existing hydraulic data. A geologic structure was estimated from well-log data and was transformed into a 55-layer model; however, the model would not calibrate due to dry cells. A less complex model comprising fewer layers is currently being calibrated and tested.

Principal Results and Significance

The data collected thus far indicate substantial leakage from Nonconnah Creek to the alluvial aquifer and potential for ground-water flow from the alluvial aquifer to the Memphis aquifer. Downstream stream losses have been determined during each series of discharge measurements and average 0.66 million gallons per day (MGD)(Fig. 1). Vertical downward gradients are consistently measured in the stilling well and three wells constructed in the alluvial aquifer at Nonconnah Creek and Getwell Rd. Water table maps for the four water-level measurements indicate a consistent gradient from Nonconnah Creek to the center of the Sheahan well field (Fig. 2). Using hydraulic characteristics of the shallow aquifer, a resulting flow of 0.4 MGD from the alluvial aquifer near the creek to the fluvial aquifer beneath the well field. Geochemical data indicate that water quality generally varies with distance from Nonconnah Creek; however, water compositions in Nonconnah Creek are similar to those in MLGW 99s and production wells sampled in the Sheahan well field in 2002 (Fig. 3). The latter observations suggest that a preferential flow path may exist between Nonconnah Creek and the Sheahan well field, possibly an ancient paleochannel in the shallow aquifer as suggested in previous studies (Larsen et al., 2003). Tritium-^{3}He ground-water ages from shallow aquifer wells vary from approximately 14 to 29 yrs, generally increasing with distance from the creek to the center of the aquifer. An exception to the increasing age trend is observed in well MLGW 96s (14 yrs), which lies close to the trend of the ancient paleochannel. The CFC data are still being evaluated.

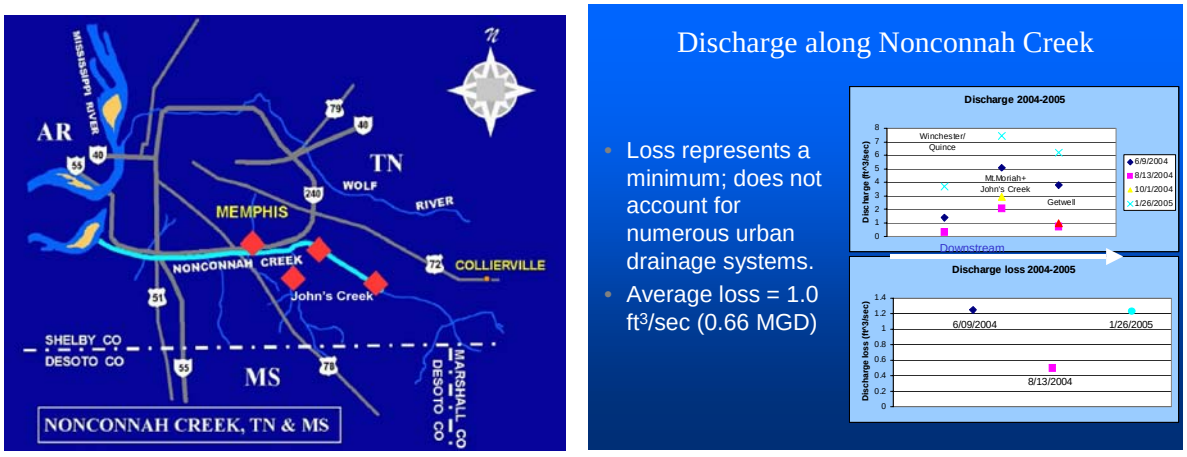


Fig. 1. (A) Location of discharge measurement locations along Nonconnah Creek. (B) Discharge data and calculation of average loss (MGD = million gallons per day).

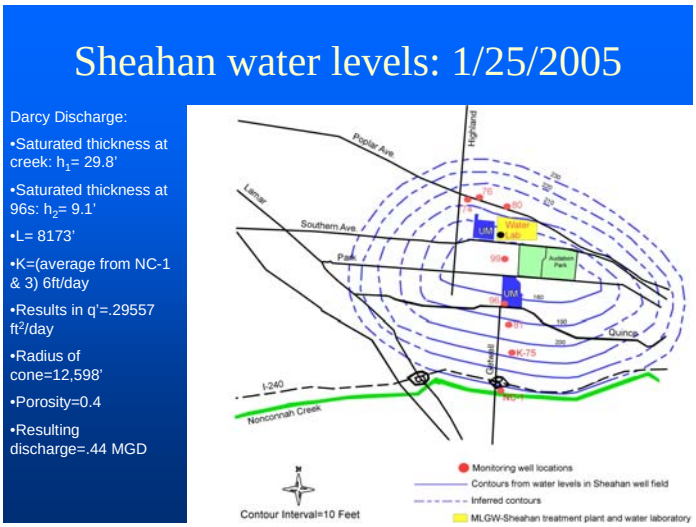


Fig. 2. Water table map and calculated loss from Shallow aquifer to Memphis aquifer.

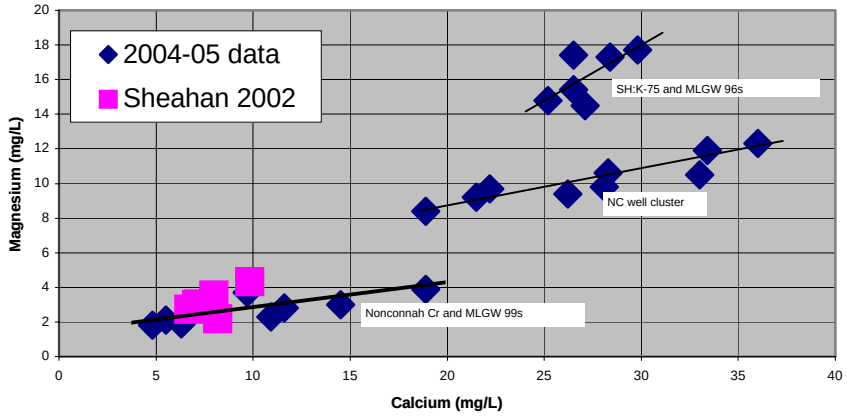


Fig. 3. Example of geochemical results from 2004-2005 Nonconnah Creek project in comparison to Sheahan well field data from 2002.

The study serves as the Masters thesis project for Jason Morat, a student in the Department of Earth Sciences at the University of Memphis. Jason has been trained in all measurements, sampling protocols, and analytical methods associated with the project, and is conducting much of the work with other graduate students and myself. Jason presented preliminary results of the study at the Tennessee section of the American Water Resources Association in April 2005. As many as 7 or 8 students working at the Ground Water Institute during the Spring, Summer, and Fall 2004 have been involved with various aspects of the project, including well construction, stream gaging, water-level measurements, water sampling, and chemical analysis. Several of the field projects conducted in Field Methods in Hydrology, taught by Dr. Larsen during the fall semester 2004, have taken place at the Nonconnah Creek and Getwell Rd. well cluster or in Nonconnah Creek itself. The ten students in the

class measured stream discharge and water quality, and conducted slug testing of wells associated with the Nonconnah research project.

Future Research and Funding:

- A study to re-evaluate the water table in Shelby County has received funding from TDEC and Shelby County for 2005-2006.

- A study to evaluate the presence of modern water in municipal well field in Shelby County is currently being funded by the Shelby County Department of Health.

In-Field Comparison of Drip Distribution Dosed with Septic Tank Effluent vs. Secondary Quality Effluent

Basic Information

Title:	In-Field Comparison of Drip Distribution Dosed with Septic Tank Effluent vs. Secondary Quality Effluent
Project Number:	2004TN14B
Start Date:	3/1/2004
End Date:	9/30/2005
Funding Source:	104B
Congressional District:	TN2
Research Category:	Not Applicable
Focus Category:	Waste Water, Non Point Pollution, Water Quality
Descriptors:	drip dispersal, domestic wastewater, decentralized wastewater management
Principal Investigators:	John R. Buchanan, Jennifer Brogdon

Publication

1. Buchanan, J R, 2005, Comparison of primary and secondary treated wastewater in drip dispersal, Tennessee Section ASAE Annual Meeting, Crossville, TN, June 16, 2005.
2. Buchanan, J R, J T Watson, 2005, Subsurface wastewater drip irrigation design workshop, Tennessee Onsite Wastewater Association Annual Meeting, Spring Hill, TN, February 22, 2005.
3. Buchanan, J R, J N Brogdon, 2004, Comparison of primary and secondary treated wastewater in drip dispersal, National Onsite Wastewater Recycling Association Annual Meeting, Alburquerque, NM, November 7-10, 2004.

Problem and Research Objectives:
The 2002 draft of the U. S. EPA 303(d) list for Tennessee shows 32 stream segments that are impaired due (in part) to failing or leaking septic systems. Systems fail because the design, installation, operation and/or maintenance were not compatible with the limitations of available soil resources. Domestic onsite wastewater treatment systems have two basic functions. The first is to minimize human contact with wastewater and the second is to remove the pollutants from wastewater. Soil is a highly-reactive medium and is used to renovate more than 25% of the domestic wastewater generated in the United States. Life-sustaining elements are cycled by the physical, chemical and biological activities that take place in the soil. These cycling processes allow for the degradation of pollutants contained within domestic wastewater. If onsite renovation systems are not appropriate for the available soil, the result is poorly treated wastewater and the subsequent contaminant loading of surface and ground water reservoirs.

Designers of onsite wastewater management systems need new information about how to renovate wastewater in areas with marginal soil resources. Drip irrigation technology has the potential to optimize the soil's ability to remove pollutants from domestic wastewater. However, the engineering literature provides very little design guidance for using drip irrigation technologies to disperse wastewater into the subsurface soil.

The specific objectives of this project are:

a) Determine whether biomat forms around drip tubing, and to determine whether the quality of the wastewater influences biomat formation around drip tubing.
b) Determine the extent of soil moisture saturation (if any) around the drip tubing.
c) Determine the renovation of the water at various depths below the point of application.
d) Determine the reduction in coliform bacteria as water moves through the soil.
e) Publish the new information generated by this project.

Methods and Accomplishments:
Consolidated Utilities of Rutherford County, Tennessee, has 21 housing developments that utilize decentralized collection, aerobic treatment, and drip dispersal. Crescent Glen subdivision was selected to serve as a wastewater source for this project. Southeastern Environmental Engineers, Inc. is a private utility that maintains several decentralized systems (with aerobic treatment and drip dispersal) in East Tennessee. Jackson Bend subdivision, in Blount County, was selected as a replicate site for this project.

At each location, two separate drip fields have been established. Each field has 1000 feet of drip line installed. The drip lines have been plowed-in 24 inches on center. Specifications for drip line include pressure-compensated emitters rated at approximately 0.6 gph and are spaced 24 inches on-center. At each location, one drip field receives septic tank effluent and the second field receives secondary quality effluent. Approximately 600 gallons of domestic wastewater per day is required at each site - 300 gallons of septic tank effluent and 300 gallons of secondary quality effluent. At each location, an interceptor line has been installed to extract septic tank effluent prior to the aerobic treatment device. This water is transferred to a dose tank used to pressurize the septic tank effluent drip field. Each location already had dose tanks to pressurize their drip fields; we were able to utilize these tanks as a source of secondary quality water.

An intensive soil survey was conducted by registered soil scientists. From that information, the loading rates (gallons per day per square foot) were determined. The Crescent Glen site is being loaded at 0.15 gallons per day per square foot, and the Jackson Bend site is being loaded at 0.20 gallon per day per square foot. All four experimental units are loaded at the design rate each day.

Weather stations have been installed at the sites. Measured weather parameters include solar radiation, precipitation, relative humidity, air temperature, and wind speed. These are the parameters that are required by the Penman-Monteith evapotranspiration estimation model. A crucial component of this effort is being able to create a water balance at each location. By measuring precipitation, soil moisture, and evapotranspiration, deep percolation of effluent can be estimated.

Before installation, each emitter was identified and checked for discharge uniformity. As the dripperlines were installed, the location of each group of emitters was documented for future disinterment.

Installation

Each subdivision has a recirculating sand filter (aerobic treatment) that provides secondary quality effluent. Sump pumps have been installed to intercept wastewater from each subdivision both before and after the aerobic treatment devices. Dose tanks have been installed to receive the intercepted fluid. Each experimental drip field will has individual control stations. Each control station consists of a time-based pump controller, flow meter, filtration system, and a datalogger. Pumps within the dose tanks pressurize the drip fields four times per day.

The dripperlines have been plowed-in using a vibratory plow. Each drip field is composed of 20 parallel rows that are 50 feet long. In each drip field, a portable time domain reflectometry (TDR) probe will be used to measure the volumetric moisture content at nine locations. At each location, the profile moisture content will be measured from the surface to the bedrock in 10-cm intervals. Ceramic cup suction lysimeters will be positioned at 16 locations within each drip field. These lysimeters are used to extract soil-moisture samples.

Data Collection

Every two weeks, water samples will be collected from the lysimeters and dose tanks tanks. These samples will be analyzed for total organic carbon (TOC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogenous compounds, and total phosphorus.

On a monthly basis, small segments of dripperline will be removed. The condition of the soil adjacent to the line will be evaluated and the emitters will be tested for any reduction in emission rate. Soil samples will be taken for total coliform and fecal coliform bacteria. Additionally, undisturbed soil cores will be extracted to determine any changes in hydraulic conductivity and redox conditions. A new segment of dripperline will be reinstalled and the soil will be replaced.

Data Analysis

All of these samples will be analyzed to look for differences in soil solution quality and water movement as the two types of effluent pass through the soil profile. The null hypothesis is that the soil will be able to renovate and move the septic tank effluent as well as the secondary-treated effluent. Statistical analysis will be performed on the data to verify this hypothesis.

The Biosystems Engineering and Environmental Science Department has a modern wastewater laboratory. The laboratory has a full-time Research Associate assigned to prepare and analyze wastewater constituents. All assays will follow the current edition of the Standard Methods for the Examination of Water and Wastewater.

Principal Findings and Significance:
It is expected to take several years of operation for the soil system to mature and express differences between the two strengths of wastewater.

To date, the investigators have learned much about the installation of drip tubing for subsurface wastewater application. Much of the equipment that is available for drip irrigation was developed for "clean water" and "crop irrigation." Wastewater, even with aerobic treatment, is not clean. Further, wastewater dispersal systems have to work every day, not just during the growing season. Valves and fittings that work well for clean water will not survive the more aggressive wastewater. As the investigators make these observations, these small "hands-on" discoveries are added to our educational program. The University of Tennessee Center for Decentralized Wastewater Management has conducted four drip design workshops.

Publications and Presentations Resulting from this Research:
Presentations at Conferences

Buchanan, J. R. 2005. Comparison of primary and secondary treated wastewater in drip dispersal. Tennessee Section ASAE Annual Meeting, Crossville, Tennessee, June 16.

Buchanan, J. R. and J. T. Watson. 2005. Subsurface wastewater drip irrigation design workshop. Tennessee Onsite Wastewater Association Annual Meeting, Spring Hill, Tennessee, February 22.

Presentation with Published Abstract

Buchanan, J. R. and J.N. Brogdon. 2004. Comparison of primary and secondary treated wastewater in drip dispersal. National Onsite Wastewater Recycling Association Annual Meeting, Albuquerque Conference Center, Albuquerque, NM, November 7-10.

Future Research and Funding:
This project will last much longer than the original funding period. This funding allowed for the development and construction of the experimental apparatus. Soil and water sampling will take place for at least the next three years. Additional funding will be needed to pay for these analyzes. Potential funding sources are the Tennessee Valley Authority, The Tennessee Department of Environment and Conservation, the Nonpoint Source Program of the Tennessee Department of Agriculture, and the Tennessee Water Resources Research Center.

Information Transfer Program

The major emphasis of the information transfer program during the FY 2004 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 2004 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 2004 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 Fourteenth Tennessee Water Resources Symposium, which was held on March 31-April 2, 2004 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 fourteenth symposium was very successful with over 300 attendees and approximately 60 papers and 22 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 2004:

- Southeast Chapter IECA Sediment and Erosion Control Conference, Charlotte, N.C. March, 17-19, 2004.

- Knox County Site Planning Roundtable meeting held on March 24, 2004.

- Tennessee Department of Agriculture, Nonpoint Source 319 Program Workshop, Ellington Agriculture Center, Nashville, TN. March 25, 2004.

- Tennessee Wetlands Technical Advisory Task Force meeting, April 13-14, 2004, Nashville, Tennessee. Meeting of government agency staff and technical experts to advise to the State on issues related to the Tennessee Wetlands Management Plan.

- Kids-In the-Creek, April 23, 2004 Powell 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 6th grade students introducing them to watershed science including biological and chemical monitoring and land use impacts on water quality.

- WaterFest, May 7, 2004, 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.

- 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 2004: March 10, 2004, Jackson, TN.; May 14, 2004, Knoxville, TN. (AMEC); May 25, 2004, Nashville, TN.; June 16, 2004, Cleveland, TN.; August 26, 2004, Nashville, TN.; September 8, 2004, Memphis, TN.; September 14, 2004, Chattanooga, TN.; September 28, 2004, Knoxville, TN.; October 14, 2004, Ft. Campbell, KY.; November 4, 2004, Johnson City, TN.; November 9, 2004, Knoxville, TN. (Knoxville Utilities Board); December 9, 2004, Nashville, TN.; January 27-28, 2005, Nashville, TN. (TDOT); February 17, 2005, 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: March 11-12, 2004, Jackson, TN.; June 24-25, 2004, Knoxville, TN.; September 9-10, 2004, Nashville, TN.; October 6-7, 2004, Memphis, TN.; November 17-18, 2004, Chattanooga, TN.; December 1-2, 2004, Knoxville, TN.

- NWQMC National Monitoring Conference 2004, Chattanooga Convention Center, Chattanooga, TN. May 17-20, 2004.

- Nonpoint Source Program Education Working Group, June 2, 2004, Nashville, TN.

- Urban Runoff Working Group, June 29, 2004, Nashville, TN.

- EPA National Low Impact Development Conference, University of Maryland, College Park, MD. September 21-23, 2004.

- Citizen Environmental Monitoring in Appalachia Conference, Bristol Conference Center, Bristol, VA., November 4-6, 2004.

- Knoxville Water Quality Forum, Quarterly meetings, May, July and October 2004 and January 2005. Meeting of government agencies and other organizations to share information and discuss water quality issues in the Tennessee River and its 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 2004 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	12	0	0	0	12
Masters	5	0	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	17	0	0	0	17

Notable Awards and Achievements

None to note for the FY 2004 period.

Publications from Prior Projects

1. 2003TN7B ("Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration") - Conference Proceedings - Gentry,R.W., J. McCarthy, A. Layton, L. McKay and S. Koirala, 2004, A Hydrologic Investigation into the Occurrence and Causation of Pathogens Indicators in the Stock Creek Watershed, Knoxville, Tennessee, In: proceedings of the Fourteenth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Burns, TN., pp 2B-2-2B-5.
2. 2003TN7B ("Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration") - Conference Proceedings - Layton, A.C., D. Williams, V. Garrett and L.D. McKay, 2004, Development of Real-Time Assays for the Detection of Bacteriodes SP. as a method to Quantify Fecal Contamination, In: Proceedings of the Fourteenth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Burns, TN., pp 2C-39.
3. 2002TN5B ("Water Quality monitoring in two 303(d)-listed East Tennessee streams") - Conference Proceedings - B.A. Jolly, The Effects of Carbonate Geology on Water Quality Land Use Linkages in Urban Watersheds - Knoxville, Tennessee, In: Proceedings of the Fourteenth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Burns, TN., pp 2B-40.