Tennessee Water Resources Research Center
Annual Technical Report
FY 2009

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 2007 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. Beginning in 2006 and continuing on through the summer of 2008, 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.

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 101-147. 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 TNWRRC 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 Water Environment Federation, the American Water Works Association, the International Erosion Control Association, the Soil and Water Conservation Society, the Lower Clinch Watershed Council, the ORNL-TVA-UT Research Consortium and the National Institutes for Water Resources (NIWR). 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, TNWRRC 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 Introduction

None.

Effect of Wastewater Strength on Soil Physical Properties when using Subsurface Drip Irrigation

Basic Information

Title:	Effect of Wastewater Strength on Soil Physical Properties when using Subsurface Drip Irrigation
Project Number:	2008TN52B
Start Date:	3/1/2008
End Date:	8/31/2010
Funding Source:	104B
Congressional District:	TN Second
Research Category:	Water Quality
Focus Category:	Waste Water, Treatment, Water Quality
Descriptors:	
Principal Investigators:	John R. Buchanan

Publication

1. Hillenbrand, Boone,2010,An Investigation for the Need of Secondary Treatment of Residential Wastewater when Applied with a Subsurface Drip Irrigation System,"MS Dissertation", Department of Biosystems Engineering and Soil Science, Insitute of Agriculture, the University of Tennessee, Knoxville, TN.,pp 164.

(6) Nature, Scope and Objectives of Research:

The specific objectives of this project were to:

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 nutrients, and organic carbon as water moves through the soil.
e) Publish the new information generated by this project.

(7) Methodology and Accomplishments to Date:

Experimental Setup

A consistent supply of primary and secondary treated domestic wastewater was required for this project. Jackson Bend subdivision, located in Blount County, Tennessee, has a decentralized wastewater management system. Wastewater from each home is collected by a Septic Tank Effluent Pump (STEP) system that transfers effluent to a recirculating media filter for secondary treatment. The highly renovated effluent is then subsurface applied using drip irrigation. This location allowed the P.I to collect primary treated water out of the STEP system and collect secondary treated water out of the recirculating sand filter. Two separate subsurface wastewater drip dispersal fields were established. Each field has 305 m of subsurface drip line. Each drip field is composed of 10 parallel rows that are 15.24 m long. The drip lines were plowed-in 0.6 m on center. Specifications for drip line include pressure-compensated emitters rated at approximately 2.27 L/h with the emitters spaced every 0.6 m along the tubing. One drip field received septic tank effluent (primary treatment) and the second field received secondary quality effluent.

Approximately 1,514 L of domestic wastewater per day is applied each day. This includes 757 L of septic tank effluent and 757 L of secondary quality effluent. The dispersal field is 372 m^2, and thus the application rate was 4 $L/m^2/d$.

Data Collection

As of this writing, four rounds of samples have been collected from the experimental location. With Tennessee Water Resources Research Center Program funding, a graduate student was employed to conduct sampling and analyses. Two-inch diameter soil cores were extracted from selected locations within each field. The soil solution from these cores was analyzed for total organic carbon (TOC), total nitrogen, and total phosphorus. A second set of soil cores were extracted and evaluated for saturated hydraulic conductivity.

Soil core samples were taken at two depths, 0.3 and 0.6 m below the drip emitter elevation. Six sets of cores were pulled. Core 1 was at a emitter, core 2 was along the drip tubing, but between emitters, core 3 was at the emitter but between the drip lines (to the right in the direction of flow), core 4 was at the emitter but between the drip lines (to the left in the direction of flow), core 5 was both between emitters and between the drip tubing to the right, and core 6 was between the emitters and tubing to the left. As controls, two cores with samples

from 0.3 and 0.6 m were taken from the native soil outside of the drip dispersal area. This procedure was repeated in both fields: The field receiving primary quality effluent and the field receiving secondary quality effluent.

The goal of the chemical analysis was not to extract all of the carbon, nitrogen and phosphorus out of the sample. Rather, this was an attempt to simulate saturated soil conditions and determine the constituent concentration that would be expected to percolate through to the groundwater. Soil chemical properties were analyzed by drying and then grinding the soil sample. Thirty grams of dry soil was mixed with 20 g of tap water and placed on a shaker table for 24 hours. This mixture was then centrifuged for 10 minutes at 3,500 rpm. A sample of the supernatant was extracted and subjected to chemical analyses.

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 equally well as the secondary-treated effluent. Statistical analysis was performed on the data to verify this hypothesis.

(8) Principal Findings and Significance:

The Jackson Bend site has been in operation since June 19, 2006. In that time, just over 6,000 L of effluent per m^2 has been applied. No significant differences have been found in the data concerning the concentrations of total nitrogen, nitrate-nitrogen, and total carbon from the two fields. There does appear to be a difference in saturated hydraulic conductivity.

The hydraulic conductivity differences at Jackson Bend with the primary and secondary treatments were not significantly different however the secondary side did have a significantly lower Ksat than the control. The estimated Ksat values for primary, secondary, and the control are as follows: 0.041, 0.036, and 0.073 cm/day respectively. The Ksat differences for 1-ft and 2-ft depths were not significant (0.049 and 0.050 cm/day respectively).

Jackson Bend shows no significance for nitrate with the primary, secondary, and control treatments. Depth was a significant factor for nitrate concentration with the concentration getting higher nearer the emitter (3.970 mg/kg at 1-ft and 2.602 mg/kg at 2-ft).

The concentration of total carbon for the primary treatment was lower than with the secondary and control treatments but not significant due to the variability in the data. This is counter-intuitive because one would expect there to be significantly more carbon on the primary side. It is speculated that uniform effluent application, and dose and resting cycles allowed by the drip irrigation promoted enhanced organic carbon degradation.

The total nitrogen concentration was not significantly different between the 3 treatments. The treatment means ranged from 6.4 to 8.4 mg/kg. The control at the 1-ft depth has a significantly higher concentration of TN than at the 2-ft depth but these concentrations are not significantly different than the primary and secondary samples at either depth.

The overall treatment differences in TP were not significantly different but there were differences when the trt*depth interactions are examined. The control samples at the 1-ft depth are significantly higher than the primary and secondary samples. The means for secondary are higher than the means for primary but are not significant.

(9) Summary and Conclusions:

The purpose of this study was to evaluate two strengths of wastewater (primary and secondary) being applied by subsurface drip dispersal to determine the need for secondary treatment. The purpose was not to evaluate the performance of subsurface drip dispersal as a whole. The soil has a tremendous ability to treat wastewater but its full potential may be retarded by the use of a costly secondary treatment. Physical and chemical properties of the soil were measured to make the comparison. It was found that the pore water in the soil that had been irrigated with the low strength wastewater was of slightly higher quality than the pore water in the primary treated side. At Jackson Bend, the hydraulic conductivity of the primary side show significant reduction as compared to the secondary and control areas; and within reason, this is beneficial for the treatment of the wastewater – more contact time with the soil. Nitrate and total nitrogen were significantly higher in the primary treated areas but showed a decrease with depth. TC and TP showed no significant differences. The benefits of a secondary treatment are not enough to make it necessary when using subsurface drip dispersal. The soil acts much the same as the secondary wastewater treatment plant and drip irrigation is designed to fully utilize these characteristics.

(10) Publications from this Effort

This work has produced a Master's Thesis. "An Investigation for the Need of Secondary Treatment of Residential Wastewater when applied with a Subsurface Drip Irrigation System" was written by Boone Hillenbrand for the partial fulfillment of the requirement of a M.S. degree in Biosystems Engineering. Boone graduated in August of 2010.

A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables

Basic Information

Title:	A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables
Project Number:	2008TN53B
Start Date:	3/1/2008
End Date:	8/31/2009
Funding Source:	104B
Congressional District:	TN Second
Research Category:	Climate and Hydrologic Processes
Focus Category:	Sediments, Surface Water, Ecology
Descriptors:	None
Principal Investigators:	Qiang He, John S. Schwartz

Publications

1. Keaney,Bart, Qiang He, and John Schwartz,2009. Effects of the Watershed Urbanization on Stream Channel Stability in Knox Count, Tennessee,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2A-26.
2. Keaney, Bart, 2009, Stream Channel Stability and Channel Evolution in a Rapidly Urbanizing,Ridge-and-Valley Watershed,Beaver Creek,Knox County, Tennessee."MS Dissertation", Department of Civil and Environmental Engineering, College of Engineering, The University of Tennessee, Knoxville, TN., pp. 119.

(6) Problem and Research Objectives:

The State of Tennessee contains many waterbodies that have been identified on the 303(d) list as impaired or threatened, by which they do not meet designated beneficial uses including biological integrity [40 CFR Part 130; TCA §69-3-101 and TDEC Rules Chapter 1200-4]. By far, the majority of streams listed are impacted by excessive sedimentation in channels causing physical habitat degradation, which reduces biological integrity. The Tennessee Department of Environment and Conservation (TDEC) is required by statutes to produce total daily maximum loads (TMDLs) for 303(d) listed streams impacted by siltation and habitat alteration. TDEC has produced sediment TMDLs for the Beaver Creek watershed, Knox County (Lower Clinch HUC). Field observations and output from a completed AnnAGNPS model suggest that bank erosion is a significant contributor.

The nature of this research is to investigate impacts from urbanization on watershed-scale patterns of channel instability. In addition, the proposed research studies how variables associated with force and resistance play into the development of a predictive model for bank erosion potential. The scope of the project is to intensively survey Beaver Creek and major tributaries for bank erosion problems by conducting RGAs. The number of RGAs conducted will be between 50 and 100.

The objectives for this research are:

(a) Evaluate AnnAGNPS model output with respect to identifying locations with bank erosion problems, and

(b) Develop a predictive model for bank erosion potential based on variables associated with channel force and resistance.

(7) Methodology and Accomplishments to Date:

The research being reported here, sponsored in part by the TNWRRC with FY08 and FY09 funding, is to evaluate the AnnAGNPS model output for Beaver Creek, which identified areas with potentially high bank erosion. The field survey carried out in this project using the Rapid Geomorphic Assessment (RGA) technique in Beaver Creek provides the BCTF on prioritization of proposed bank stability projects.

Methodology:

The field survey of bank erosion in the Beaver Creek watershed was performed with three key metrics for each site. These were a Channel Stability Index, water surface slope, and a Modified Wolman Pebble Count. If the bed material at the site was composed entirely of bedrock or of sand or smaller particles, a pebble count was not performed. The latitude and longitude for each site were recorded with a Global Positioning System receiver accurate to 5 meters.

I. Channel Stability Index

The Channel Stability Index is obtained with the Rapid Geomorphic Assessment (RGA) technique developed by Andrew Simon, of the National Sedimentation Laboratory in Oxford, MS, as a tool to allow a quick evaluation of reach-scale stream bank stability to be made in the field. RGA sites were selected using a detailed map of all streams, swales and water conveyances in the Beaver Creek Watershed that was provided by the Knox County Stormwater Department. Channelization was inferred by visual estimation of sinuosity. An effort was made to ensure that sites were somewhat evenly spaced along the length of the stream, to provide data for sites ranging from the headwaters to mouth. Field visits were made to determine whether access to the stream was available and whether there existed a baseflow adequate to perform an RGA.

The Rapid Geomorphic Assessment ranked stream channel stability on a scale from 0 to 36, as measured by a series of 9 quantitative and semi-qualitative metrics. The scores assigned to each metric were summed to obtain the total RGA score. This total score is also termed the "Channel Stability Index". The nine metrics are:

1. Primary bed material. A score between 0 and 4 was given based on the stability of the bed material. 0 was given to bedrock, 1 to boulder/cobble, 2 to gravel, 3 to sand and 4 to silt/clay.
2. Bed/bank protection. A score of 1 was given if no bed or bank protection was present. Two points were given if one bank was protected and 3 points if both banks were. Thus, if a reach had an unprotected bed and two banks protected, the score would be 4. If the bed was protected, the score would be 3.

3. Degree of incision. A score of 0 to 4 was awarded based on the ratio of the bank height (from the toe to the top bank) to the depth of flow at the deepest part of the reach. 0-10% incision was scored 4, 11-25% incision was scored 3, 26-50% incision was scored 2, 51-75% incision was scored 1 and 76-100% incision was scored 4.
4. Degree of constriction. A score of 0 to 4 was awarded based on the ratio of channel width at the head of the reach to the width at the bottom of the reach. 0-10% incision was scored 0, 11-25% constriction was scored 1, 26-50% constriction was scored 2, 51-75% constriction was scored 3 and 76-100% constriction was scored 4.
5. Stream Bank Erosion. Each bank was considered separately. If no erosion was present, it was scored 0. If fluvial erosion was the dominant process, it was scored 1. If mass wasting was the dominant process, it was scored 2.
6. Stream bank instability. If mass wasting was present, whether or not it was the dominant process, the percentage of each bank in the reach on which it appeared was assessed. 0-10% failing was scored 0, 11-25% failing was scored 0.5, 26-50% failing was scored 1, 51-75% failing was scored 1.5 and 76-100% failing was scored 2. This assessment was performed separately for each bank.
7. Established riparian woody-vegetative cover. The percentage of each bank on which woody vegetation was present was considered separately. 0-10% covered was scored 2, 11-25% covered was scored 1.5, 26-50% covered was scored 1, 51-75% covered was scored 0.5 and 76-100% covered was scored 0.
8. Occurrence of bank accretion. The percentage of each bank upon which fluvial deposition was present was considered separately. 0-10% covered was scored 2, 11-25% covered was scored 1.5, 26-50% covered was scored 1, 51-75% covered was scored 0.5 and 76-100% covered was scored 0.
9. Stage of channel evolution. A score between 0 and 4 was awarded based on the stage of channel evolution. Stage 1 was scored 0, Stage 2 was scored 1, Stage 3 was scored 2, Stage 4 was scored 4, Stage 5 was scored 3 and Stage six was scored 1.5.

II. Water surface slope

Slope was measured with a Pentax AL-M4c Autolevel. Frequently, the reach of interest was less than or equal to 100 ft in length, so the slope was measured from points 50 ft upstream and 50 ft downstream of the level, in order to ease calculations. At certain downstream sites, longer reaches were surveyed, to account for the fact that a reach length of six to ten channel widths would be longer than 100 ft. In these instances, the measurements were corrected to provide a percent slope.

III. Modified Wolman Pebble Count

The pebble count procedure was modified from Wolman (1954). A fiberglass tape measure was stretched across a riffle to such a distance that 50 feet were covered (since most reaches would not accommodate a 50ft length of tape directly across the stream, several transects across the same riffle were often used.) Every 0.5 ft the operator lowered his finger straight down and selected the first object he touched. If it was a pebble between 2 mm and 125mm, its size was recorded. If it was a finer particle, it was categorized as clay, silt or sand, depending on feel. If it was larger, it was categorized as cobble, boulder or bedrock, based on visual estimation.

Spatial Analysis:

A digital elevation model of the Beaver Creek watershed area was obtained from the United States Geological Survey National Map Seamless Server. The hydrology toolset incorporated in ESRI's ArcMap 9.3 was used to delineate flow paths as a raster image based on flow accumulation. The latitude / longitude location of each geomorphic assessment site was then plotted onto this map as a point shapefile. The points representing the assessment sites were fitted to the flow accumulation raster so that upstream catchments could be developed. The degree of urbanization in each catchment was determined by overlaying the map with a layer containing the NLCD 2001 Land Cover Classification. "Urbanization" was defined as areas that were labeled 21: Developed, Open Space; 22: Developed, Low Intensity; 23: Developed, Medium Intensity and 24: Developed, High Intensity. The percentage of each catchment that was forested was determined by summing the total of 41: Deciduous Forest and 42: Evergreen Forest. Due to the difficulty of combining the NCLD 2001 Impervious Surfaces raster with the watershed rasters, the area of impervious surfaces was estimated using the "averaging-by-land-use" system used previously in Knox County in the Second Creek watershed and developed by Camp, Dresser & McKee, an environmental consulting firm (Castle, 1996).

Statistical Analysis:

The scores for each metric at each site, as well as the total Rapid Geomorphic Assessment score, the slope, the d50 of the pebble count, the percentage of developed land in the local upstream area and total upstream catchment, the percentage of each catchment that was forested and the percentage of each catchment that was covered by impervious surfaces were used as the input for multivariate statistical analysis using SAS's JMP 7.0.1. The dataset was input as 15 independent and semi-dependent variables and 1 dependent variable. The overall RGA score was taken to be the dependent variable in most analyses, although most of the metrics used to compute the RGA are also controlled, to varying extents, by the same processes as overall channel stability. In particular, the Stage of Channel Evolution, percent of bank failing, degree of incision, bed material and presence of bank accretion were the variables that should have most closely correlated with the overall stability score. Correlations between these variables would not convey information as useful as those between metrics that gave approximations of the processes that control stream channel morphology.

Water surface slope was expected to be a controlling factor for incision, bank accretion, and bed particle size, so these factors were analyzed independently. The presence of vegetation on stream banks was expected to have a strong influence on bank stability, and the RGA allows for each bank to be assessed separately, so the scores for overall stream bank woody vegetation and percentage of stream banks failing, as well as the scores for the left and right banks for both those metrics were analyzed.

Accomplishments:

In total, full assessment were conducted in 57 sites in Beaver Creek watershed with Rapid Geomorphic Assessment (RGA) as well as the slope measurement and pebble count. In addition, there were 34 sites at which only the RGA was conducted.

- Five sites in the Plumb Creek watershed were assessed completely, with one site rated as unstable.
- Four sites in the Meadow Creek watershed were fully assessed, with two sites rated as unstable.
- Eight sites in the Grassy Creek watershed were evaluated fully, with 6 sites rated as unstable
- Eight sites were fully assessed in the Knob Fork watershed, with three sites rated as unstable
- Five sites were fully assessed along Hines Branch, with 1 site rated as unstable
- Fifteen sites were evaluated in the headwaters area, covering several small streams including North Fork, Mill Branch, Willow Fork, Lammie Branch, Kerns Branch, Cox Creek and a stretch of Beaver Creek. Fives sites were rated as unstable.
- Eleven sites were evaluated on the main stem of Beaver Creek downstream of the headwaters area, with 6 sites rated as unstable.

(8) Principal Findings and Significance:

Many rivers and streams in our nation have been identified on the 303(d) list as impaired or threatened as a result of siltation and habitat alteration, and commonly occurring in urbanizing watersheds. Urbanization creates more impervious surfaces that alter the hydrologic regime causing increased storm flow peaks and duration that can lead to excessive stream bank erosion in some locations. Beaver Creek in Knox County, Tennessee has been identified on the state 303(d) list and a sediment TMDL has been proposed by the Tennessee Department of Environment and Conservation (TDEC). In addition, state 319 funds have been awarded to the Beaver Creek Task Force (BCTF) to address the siltation problems. A sediment model for the Beaver Creek watershed completed by the University of Tennessee in 2005, in which the model found bank erosion to significantly contribute to stream sediment loads. However, the model output was never evaluated with a field study to confirm its findings. This study surveyed the extent of bank erosion in the Beaver Creek watershed to evaluate the extent of bank erosion problem. The Rapid Geomorphic Assessment (RGA) developed by the USDA National Sedimentation Laboratory was used to quantify channel stability and bank erosion potential.

RGA analysis found no clear spatial relationship between a study site's position along the stream reach and its stage of channel evolution in this study. Nor was there a clear correlation between the degree of watershed development and channel stability. Previous studies have shown that the presence of vegetative growth on and near stream banks can be one of the dominant controls of bank stability, but this was not the case in this study. Another expected relationship that was not apparent in the data was an influence of slope on

channel incision. Notably, none of the stream channels in the sub-watersheds in the Beaver Creek watershed showed discernable patterns in the stages of channel evolution observed along their courses of flow. The main stem of Beaver Creek did appear to show a pattern of adjustment. The results from this study suggest that the Rapid Geomorphic Assessment is simply not suited to measuring system-wide stream channel stability on the watershed scale under a condition of rapid urbanization. That said, it remains a valuable tool for comparing channel stability at reach-scale sites within a watershed.

Of the 57 sites surveyed for bank stability, 24 were classified as unstable. The study results will provide the BCTF with useful information on prioritization of proposed bank stability projects.

Furthermore, the impact of hydrological events on water quality was also evaluated. The dynamics of carbon export from the Beaver Creek Watershed as represented by dissolved organic carbon revealed distinct carbon transport mechanisms as a function of storm intensity, with organic carbon input dominated by overland runoff during the largest storms while organic carbon transported with groundwater was shown as a more important source during smaller storms. Further characterization of the dissolved organic matter in different storms confirmed that humic substances derived from terrestrial organic materials may be the main source of carbon export during high storm flows. Nutrient export was also linked to carbon transport as phosphorus transport was associated with terrestrial sources and overland runoff. However, the lack of correlation between the transport of nitrate and storm flow suggests that the main sources of nitrate was likely groundwater, which was not impacted by storm events in the short term. Storm events also impacted the export of the microbiological indicator *E. coli*, which could be attributed to two sources related to sediment transport: overland runoff and sediment resuspension.

Educational opportunities from the research included support and training of a graduate student, who has graduated with a Master's thesis.

Publications and Presentations Resulting from this Research:

F. B. Keaney, J.S. Schwartz, and Q. He, "Effects of Watershed Urbanization on Stream Channel Stability in Knox County, Tennessee," Proceedings of the 19th Tennessee Water Resources Symposium, Burns, TN, 2009: pp 2A-26.

Platform presentation at the 19th Tennessee Water Resources Symposium, April 15-19, 2009, Montgomery Bell State Park, TN: F. B. Keaney, J.S. Schwartz, and Q. He, "Effects of Watershed Urbanization on Stream Channel Stability in Knox County, Tennessee."

Drought Variability in Reconstructed Streamflow

Basic Information

Title:	Drought Variability in Reconstructed Streamflow
Project Number:	2009TN61B
Start Date:	3/1/2009
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	Second
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Climatological Processes, Hydrology
Descriptors:	Climate, Drought, Streamflow Reconstruction, Atmospheric/Oceanic Influences, Tree-rings,
Principal Investigators:	Glenn A Tootle, Henri D Grissino-Mayer

Publications

There are no publications.

(6) Problem and Research Objectives:

The recent drought in the southeast U.S. (e.g., Lake Lanier, GA) has greatly stressed the water supply and availability of many systems. This has resulted in increased interest in re-evaluating the various agreements and compacts for water deliverability. The proposed two-year research project will use proxy records derived from tree rings to examine climatic controls on streamflow and assess how natural interdecadal variability might impact streamflow. The proposed research will initially review existing tree-ring chronologies in and around watersheds in the State of Tennessee. Next, unimpaired or naturalized streamflow records will be identified for streams of interest. Finally, an investigation of long-term streamflow variability, focusing on extreme events such as mega-droughts, will be performed. This investigation includes evaluating the influence of various atmospheric – oceanic influences [e.g., El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO)] on streamflow. This analysis will also address how large-scale climatic drivers affect the spatial distribution of droughts and the results of the research will be used to develop probabilistic drought forecasts. These forecasts would utilize both empirical probabilities for drought risk derived from the tree-ring record and links between streamflow and climatic drivers like ENSO and the PDO.

(7) Methodology and Accomplishments to Date:

Unimpaired streamflow data was obtained from the USGS NWIS website and tree-ring chronology data was obtained from the International Tree-Ring Database. Stepwise multiple linear regression was selected to develop the reconstructions.. A forward and backward stepwise regression process entered and removed
predictors with a threshold F significance of 0.05. The statistical strength and fit of the resulting regression
models are summarized by the following statistics: r^2, r^2 adjusted, r^2 predicted, F statistic, root-mean-square error, cross-validated standard error, variance inflation factor, Mallows' C-p, the predicted error sum of
squares, and the Durbin-Watson statistic. The regression models were evaluated using two techniques. A regression model was first calibrated on the first half of the data and validated on the second half of the data. This procedure is then reversed by calibrating on the second half of the data and validated on the first half. A second approach, leave-one-out cross validation, was also applied. Leave-one-out cross validation creates a validation series by omitting 1 year, creating a new regression equation, and then predicting the value
for the dropped year. The process is repeated for all the years in the series.

Two master's students (Tate Geren and Ross Ogle) are currently completing streamflow reconstructions for (11) unimpaired gages in the Southern Appalachians. Additionally, one Ph.D. student (Cody Moser) is currently completing precipitation reconstructions for eastern Tennessee and western North Carolina. We anticipate the reconstructions being completed in October 2010. Upon completion, Amanda Bowen (master's student) will complete the proposed research by evaluating climate signals and drought variability in the reconstructed datasets.

(8) Principal Findings and Significance:

Seasonal (three, four and six month averages) of streamflow were evaluated to determine which season results in the highest correlation value with the tree-ring chronology data. Previous research efforts of scientists at the Oak Ridge National Lab resulted in the late-spring / early-summer season being the best. The current research efforts identified the May-June-July streamflow season as the best for reconstruction skill. Of the (11) streamflow gages identified, it appears three to four of the gages will provide statistical results that are strong enough to be considered as a successful streamflow reconstruction. The reconstructions extend back to approximately 1700. It appears the 1700's has the highest variability while the 1800's had the highest number of droughts. During the observed record (mid 1900's to present), streamflow was generally wetter. Thus, if water management is based on observed records, this could result in over allocation of resources.

Two peer-reviewed publications are currently being developed. Cody Moser plans to submit to the Journal of the American Water Resources Association a manuscript entitled "Reconstruction of Tennessee Valley Precipitation Using Tree Rings" in October 2010. He has also submitted an abstract for presentation at the American Geophysical Union Fall 2010 Meeting in San Francisco, CA. Ross Ogle and Tate Geren plan to combine their research efforts into one peer-reviewed publication (Streamflow Reconstructions in the Southern Appalachians).

Information Transfer Program Introduction

The major emphasis of the information transfer program during the FY 2009 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 2009 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 2009 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 Eighteenth Tennessee Water Resources Symposium, which was held on April 15-17, 2009 at Montgomery State Park in Burns, Tennessee. The goals 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 sixteenth symposium was very successful with over 320 attendees and approximately 53 papers and 14 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 2008:

- Tennessee Department of Environment and Conservation, Tennessee Stormwater Association and TNWRRC sponsored quarterly meetings of local government officials, TN Home Builders Association and other stakeholders to establish a process by which local MS4 stormwater programs could assume responsibility for issuing the TN General Construction Permit in their jurisdiction. These meeting were held in Nashville on the following dates: April, 2009; August 21. 2009; December 8, 2009.

- Tennessee Department of Agriculture, Nonpoint Source 319 Program Workshop, Ellington Agriculture Center, Nashville, TN. March 19, 2009.

- Tennessee Wetlands Technical Advisory Task Force meeting, April 22-23, 20098, Nashville, Tennessee. Meeting of government agency staff and technical experts to advise to the State on issues related to the Tennessee Wetlands Management Plan.

- WaterFest, May 1, 2009, 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. Over 1,100 elementary school age students from the Knox County school systems and schools from the surrounding region attended.

- 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 FY 2009: March 3, 2009, Cookeville, TN.; March 12, 2009, Knoxville, TN.; April 30, 2009, Jackson; May 19, 2009, Nashville, TN.; June 9, 2009, Chattanooga, TN.; June 16, 2009, Knoxville, TN.; August 20, 2009, NRSC staff, Murfreesboro, TN.; September 10, 2009, Nashville, TN.; September 17, 2009, Knoxville, TN.; October 7, 2009, NRCS staff, Jackson, TN.; October 13, 2009, Chattanooga, TN.; October 21, 2009, Cookeville, TN.; November 3, 2009, Johnson City, TN.; November 12, 2009, Memphis, TN.; December 2, 2009, Nashville, TN.; December 15, 2009, Knoxville, TN.; February 10, 2010, Nashville, 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: May 6-7, 2009, Nashville, TN.; May 13-14, 2009, Knoxville, TN.; October 28-29, 2009, Chattanooga, TN.; November 18-19, 2009, Nashville, TN.

- Construction Site Inspection as Required by Tennessee s Construction Stormwater General Permit Level I Recertification course sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. This is a half day course which focuses on inspection requirement under the current TNCGP. This course is required for all inspectors of construction sites that have coverage under the TNCGP and serves as a recertification course for those that have completed the Level I Fundamentals course. The course was offered on the following dates: March 24, 2009, Knoxville, TN.; April 21, 2009, Nashville, TN.; May 5, 2009, Knoxville, TN.; May 21, 2009, Memphis, TN.; June 4, 2009, Lebanon, TN.; June 10, 2009, Cleveland, TN.; June 11, 2009; Murfreesboro, TN.; October 7, 2009, Jackson, TN.; November 4, 2009, Johnson City, TN.; November 6, 2009 TDOT Region 3, Nashville, TN.; November 10, 2009, Knoxville, TN.; November 11, 2009, Nashville, TN.; December 1, 2009, Chattanooga, TN.; December 7, 2009, Sevierville, TN.; December 9, 2009, Nashville, TN.; December 10, 2009, Memphis, TN.

- Southeast Watershed Forum Blueways Conference, October 29-31, 2009, Chattanooga, TN. TNWRRC staff exhibited at the conference attended by over 180 water resource professionals and watershed groups from across the southeast.

- Knoxville Water Quality Forum, Quarterly meetings, May, July and October 2009 and January 2010. 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 2009 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.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	7	0	0	0	7
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	11	0	0	0	11

Notable Awards and Achievements

Publications from Prior Years

1. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Conference Proceedings - Cantrell, William,John Schwartz,and Ken Berry.2009,Effects of Watershed Urbanization on Bedload Characteristics,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2A-26.
2. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Conference Proceedings - Schwartz,John, Andrew,Simon,and Lauren,Klimetz.2009, Use of Fish Autecology Data to Link Impairment to Stream Siltation,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2B-4.
3. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Articles in Refereed Scientific Journals - Schwartz,J.S.,M. Dahel,and R.B. Robison.2008. Concentration-frequency-duration curves for streamturbidity:possibilities for use assessing biological impairment. Journal of the American Water Resources Assocation 44(4):879-886.
4. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Other Publications - Schwartz,J.S., A.Simon and L.Kimetz. (in review) Use of fish functional traits to associate in-stream suspended sediment transport metrics with biological impairment. Ecological Applications.
5. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Conference Proceedings - Cantrell,W.R., J.S. Schwartz, and W.K. Barry.2009. Development of 2D stream sediment model for stream restoration design applications in urbanizing watersheds. ASCE/EWRI World Water & Environment Resources Congress, Kansas, MO. May 17-21, 2009.
6. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Dissertations - Cantrell, William, 2009, Method of Evaluation for Bed Shear Stress and Sediment Transport Capacity in Urbanizing Watersheds: Implications for Stream Restoration. "MS Dissertation," Department of Civil and Environmental Engineering, College of Engineering, the University of Tennessee, Knoxvile, TN.pp 157.
7. 2003TN7B ("Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration") - Articles in Refereed Scientific Journals - Layton, L.A.,L.D. McKay,D.Willliams,G.S. Sayler and R.W. Gentry.2009, Factors influencing the persistence of fecal Bacteroides in streamwater, Journal of Environmnetal Quality, v38,n3,pp1224-1232.
8. 2000TN3B ("An Investigation to 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 - Ivey,S.S, R.W Gentry, D. Larsen, and J.L. Anderson.2008. Inverse application of age-distribution modeling using environmental tracers 3H/3He, ASCE Journal of Hydrologic Engineering, v13, n11,pp 1002-1010.
9. 2000TN3B ("An Investigation to IdentifySources and Quantities of Modern Recharge to the memphis Aquifer in the Sheahan Well Field in Shelby County, Tennessee") - Articles in Refereed Scientific Journals - Ivey,S.S., R.W. Gentry, D. Larsne, and J.L. Anderson.2008. Case study of the sheahan wellfiled using 3H/3He field data to determine localized leakage areas, ASCE journal of Hydrologic Engineering, v13,n11, pp1011-1020.
10. 2005TN16B ("Macropores and Colloids: Their Influence on the Quantity and Quality of Recharge") - Articles in Refereed Scientific Journals - Zhaung,J., J.S. Tyner, and E. Perfect.2009. Colloid transport and remoblization in porous media during infiltration and drainage. Journal Hydrology Doi:10.1016/j.hydrol.2009.08.011.

11. 2005TN16B ("Macropores and Colloids: Their Influence on the Quantity and Quality of Recharge") - Articles in Refereed Scientific Journals - Cihan,A.,J.S. Tyner, and E. Perfect.2009. Predicting relative permeability from water retention: A direct approach based on fractal geomerty. Water Resources Research, 45, W04404.doi:10.1029/2008WR007038.
12. 2007TN58B.confused ("Strucruring of an Information Transfer and Outreach Strategy for TNWRRC Under a new Organizational FRamework") - Conference Proceedings - Baughaman,Doug, Roy Arthur, Lisa Bacon, and Rick Brownlow.2009, Ecological Credit Trading Pilot Study in the Beaver Creek Watershed,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 3A-1-9.
13. 2007TN58B.confused ("Strucruring of an Information Transfer and Outreach Strategy for TNWRRC Under a new Organizational FRamework") - Conference Proceedings - Dodson,Andrew and Michael Hamrick.2009. Site Selection, Modeling and Design of Sub-Catchment Retrofits for Water Quality and Downstream Channel Protection,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 3A-11.
14. 2003TN7B ("Evaluation of Pathogen Occurrence and Causation withing the Stock Creek Watershed (Knox County) as a Model for Watershed Restoration") - Conference Proceedings - DiClaudio,Melanie, Dan Williams, John Sanseverino, Alice Layton, James Easter,and Gary Sayler.2009. Fecal and Hormonally Active Compound Inputs Into and East Tennessee Watershed,"in" Proceedins of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2C-16.
15. 2004TN13B ("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") - Conference Proceedings - Bradshaw, Elizabeth, and Dan Larsen.2009. Assessment of Groundwater Leakage Through the Upper Claiborne Confining Unit to the Memphis Aquifer in the Allen Well Field, Memphis, Tennessee,"in" Proceedings of the Nineteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. P-4.
16. 2007TN58B.confused ("Strucruring of an Information Transfer and Outreach Strategy for TNWRRC Under a new Organizational FRamework") - Water Resources Research Institute Reports - Mawhorter, Julie, Tim Gangaware,and Margo Fransworth. 2009, Understanding Watershed Management Priorities, Activities, and Needs in Tennessee:Final Needs Assessment Report, Tennessee Water Resources Research Center, The University of Tennessee, Knoxville, TN. pp. 27.