

**Tennessee Water Resources Research Center
Annual Technical Report
FY 2012**

Introduction

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.

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

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

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

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

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

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

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 issues.

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.

Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study

Basic Information

Title:	Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study
Project Number:	2011TN78B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	Second, Knox County, Tennessee
Research Category:	Water Quality
Focus Category:	Sediments, Non Point Pollution, Water Quality
Descriptors:	Stormwater Managemnet; Sediment; Infiltration; Bioretention; Water Quality
Principal Investigators:	Andrea Ludwig, Daniel Yoder

Publications

There are no publications.

Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study

Statement of Critical Regional or State Water Problems:

The leading cause of impairment in streams in the US is habitat alteration, which is a direct impact of sedimentation. Sediment pollution from urban areas has been shown to mostly come from failing streambanks that have eroded under increased bank shear stress. This increased shear stress is a result of the flashy hydrology that is characteristic of urban settings and is identified as one of the symptoms of the “urban stream syndrome,” which describes the ecological degradation of streams draining urban landscapes (Walsh, Roy et al. 2005). Other symptoms are elevated concentrations of nutrients and pollutants, altered channel morphology, and reduced biotic richness.

There are over 60,000 stream miles in the State of Tennessee, and of the approximately 30,000 miles that have been assessed, only 54% were supporting all designated uses (Denton, Graf et al. 2010). This indicates that almost half of Tennessee streams exhibit degraded water quality. The leading causes of pollution in Tennessee streams and rivers are sediment/silt, habitat alteration, pathogens, and nutrients. Exacerbating this issue is a 60% loss of wetland areas in Tennessee as determined through historic data (Denton, Graf et al. 2010), which decreases land area that has the capacity to hold and treat flood waters and removes ecosystem services crucial to good water quality.

Statement of Results or Benefits:

The first phase of this project identified the following outcomes from the stated objectives: 1) a characterization of pollutants of concern for ecological function in surface waterways transported by stormwater from a residential development, 2) laboratory data to support recommendations of media layers for bioretention practices, 3) quantity and quality treatment efficiencies based on loading reductions due to BMPs in the Cedar Crossings development, and 4) begin a water quality monitoring database on the capacity of bioretention practices to meet infiltration requirements of permits for use by stormwater professionals.

The second phase will address the needs of the education and BMP adoption goals of the project team for Cedar Crossing neighborhood. The specific outcome will be a Home Stormwater Assessment Tool for assisting homeowners and stormwater professionals in selecting and implementing small-scale stormwater BMPs that will be transferable to other residential communities.

As of December 31, 2011, progress has been made on the stated objectives:

- 1) Characterization of pollutants: Two monitoring stations were installed in the project neighborhood to collect flow-weighted water quality samples and flow data during storm events. The first station is located at a drop inlet storm drain near the common space that is slated for the large-scale bioretention facility and sampling from a drainpipe that carries stormwater from an approximately 4-acre sewershed. This sewershed is representative of the single-family residential neighborhood. The second station is

located at the inlet to the detention basin that receives the majority of the runoff produced from the single-family units and condominiums. Stormwater hydrographs were developed for ten storm events between June and December 2011. Water quality analyses were performed on samples from five of these ten events. Additional sites were identified for grab water sampling in order to characterize stormwater at specific locations throughout the neighborhood.

- 2) Laboratory data for media: A prototype design was created for bioretention mesocosms that would be used in bench-scale experiments. Three different media mixtures and carbon sources were identified as test treatments in experiments and selection of appropriate instrumentation to measure storage volume has begun. A preliminary experiment was conducted to measure the amount of leachable nutrients from commonly used and readily assessable mulches.
- 3) Treatment efficiency determination: Treatment efficiencies will be characterized once BMPs are installed in the project neighborhood, beginning in 2012.
- 4) BMP water quality monitoring database: A database was conceptualized to include the following data on stormwater BMPs in Tennessee: site location (geographic coordinates), picture, stormwater source, inflow water quality data, outflow water quality data, storage, and other pertinent design parameters and site conditions.

This project neighborhood will serve as a long-term study location for urban hydrology and stormwater management research. Additionally, it will be a demonstration of the retrofit of individual lots and neighborhood common spaces with small-scale stormwater practices. This demonstration is timely due to increasing regulations on stormwater from urban areas and the motivation of individual homeowners to minimize their impacts on the environment. The long-term goal of project cooperators is to increase BMP adoption by homeowners and condominium owners to create a model neighborhood community for retrofitting failing or substandard stormwater management controls. In order to accomplish this, residents must be educated on watersheds and stormwater management, potential impacts to water quality due to urban development, and effective solutions. An action plan was created by project cooperators to outline the approach, which is: 1) collect background data and anecdotal information regarding water quality and stormwater management in the area, 2) educate homeowners on the issues and needed solutions, 3) identify external cost-sharing opportunities for homeowners interested in lot-scale BMPs, 4) create a standardized method for assessing the stormwater footprint and appropriate BMPs for individual homes (the Home Stormwater Assessment), 5) identify and train needed professionals for stormwater BMP installations, 6) assist in neighborhood-scale implementations, and 7) continue to monitor hydrology and water quality throughout retrofit.

In October 2011, Cedar Crossing residents attended a 2-hr educational workshop from the *Tennessee Yards and Neighborhoods* team. Participants were given information about their home watershed (Beaver Creek), sources of stormwater in residential settings, and lot-scale BMPs to retain and filter stormwater. In phase two of this project, we will develop a 2-step Home Stormwater Assessment and pilot its use with residents of Cedar Crossing and the condominiums.

As of December 2012, progress was made on the following objectives:

- 1) Characterization of pollutants: Runoff rates and total volume accumulated per storm event were measured as to continue to characterize small-scale residential sewershed response to rainfall events. Water quality analyses for pollutants in stormwater runoff grab samples has been scaled down to specific storm events (approximately once a season).
- 2) Laboratory data for media: Bench-top experimental set-up was assembled to include 16 mesocosms, influent reservoir, effluent sampling hoses, and sample collection reservoirs. Drip diffusers were inserted along tubing running from the influent reservoir, and flow rate calibration was performed. Preliminary tests were conducted to determine the effect of coarse sand material selection (dredged river sand vs. manufactured sand from limestone) on effluent pH. Initial results indicate that effluent from manufactured sand infiltration practices are higher in pH than that coming from dredged river sand applications. Further studies will be conducted on innovative soil amendments for rain garden applications.
- 3) Treatment efficiency determination: Field determination of treatment efficiencies for bioretention practices will be limited due to the fact that only 3 lot-scale practices were implemented in the neighborhood due to grant funding reallocation. While total runoff volume and flow rate will continue to be monitored at the outlet of the 38-acre subdivision, significant change in overall hydrology is not expected due to the limited amount of on the ground practices.
- 4) BMP water quality monitoring database: Principle investigators were successful in obtaining state funding for work towards a green infrastructure design manual. In cooperation with this project, work towards the database continues to occur. The database will be established in 2013 and contribute towards state-sponsored documents.

In 2012, three lot-scale bioretention practices (rain gardens) were designed and implemented in the test neighborhood through state funding. Through this part of the project, we were able to pilot our homeowner educational tool, "Rainwater: Your Liquid Asset. A Home Stormwater Exercise." This tool is a 6-page Extension publication that steps a homeowner through an activity that maps the flow of stormwater on their property while educating them on how runoff is generated, where it goes, and how they can use lot-scale practices to minimize their footprint. This tool is currently in press at the UT Extension Communications Department. This will be a web publication that is accessible by anyone online and marketed for use specifically through county Extension offices and local Tennessee municipal governments. We have also used this publication as a pre-workshop activity for homeowners that enroll in our rain garden workshops. Participants are invited to map their pervious and impervious surfaces, downspouts, and stormwater conveyances, and then bring this to the workshop in order to help guide them towards successful designs and implementation.

Nature, Scope and Objectives of Research:

The nature of this research is to investigate the composition of stormwater runoff from an urban residential development and into an impaired waterway. In addition, the proposed

research will study how variables associated with the media of bioretention practices will affect performance and evaluate field-scale practices. The scope of the project is bench-scale experimentation with controlled variables and field-scale monitoring of engineered solutions for stormwater management. Field data collection will be limited to a single neighborhood; however, this will begin the formation of a database of infiltration BMP monitoring data. Since success of the overall project hinges on the involvement and commitment of property owners in the study development, we reserve the right to change the location to another development in the face of currently unforeseen barriers in Cedar Crossings. If necessary, the new location would be selected based on the potential for technology transfer to other developments and pollutant reduction to Beaver Creek.

The objectives of this research are to 1) characterize stormwater volume and concentrations of pollutants of concern being transported from Cedar Crossings residential neighborhood and into Beaver Creek; 2) determine the effects of bioretention design variables (layer media composition, layer thickness, and saturation hydroperiod) on BMP performance through bench-scale laboratory column studies; 3) monitor the effectiveness of field-scale bioretention practices for peak flow and pollutant attenuation in Cedar Crossings; and 4) evaluate the effectiveness of selected bioretention practices for meeting infiltration requirements of new municipal stormwater management permits and demonstrate potential stormwater retrofit design. The larger project that is funding the BMP installations requires that technology transfer to other parts of the state be achieved, and therefore, we will adapt these broad objectives to the project as specific BMP designs are identified as practical for residential neighborhood stormwater retrofit.

Methods, Procedures, and Facilities:

The methods employed for this study on bioretention stormwater practices include: 1) sampling stormwater conveyances through grab samples during storm events and analyzing for sediment, nutrients, and other pollutants of concern; 2) a bench-scale factorial study using laboratory columns and simulated storm events (Hsieh, Davis et al. 2007) to examine the effects of bioretention design variables (layer media composition and thickness, and internal storage zones) on BMP performance; 3) field monitoring of BMPs with automated samplers for capturing timed and flow-composited samples and analyzing for load reduction of pollutants of concern; and 4) measurement of BMP outlet hydrograph and total precipitation to evaluate feasibility of practices to infiltrate 100% of the first inch of rainfall following a 72-hr dry period. Pollutant and runoff volume reductions will be determined through field water quality sampling for pollutant removal and flow measurements based on load estimations (Johnes 2007).

As the field-scale components of the study develop through the anticipated adoption of infiltration practices at the home-owner level, the contributing impervious surface area will decrease over the project timeline. This is expected to have an effect on the outflow from the development. To understand the hydrologic impact of BMP adoption, we will monitor stormwater flow in the storm sewer system and relate this to the changing *retention capacity* of the development. The *retention capacity* is the degree of connection of impervious surfaces to streams (Walsh, Roy et al. 2005). We will examine the relationship between stormwater hydrology and retention capacity over time.

Additionally, total suspended solids and turbidity data will be collected simultaneously during variable size storm events. Regression analysis will be performed to create a relationship between TSS and turbidity as to allow for future loading estimates from turbidity in disturbed urban soils in Eastern Tennessee.

The second phase of this project will engage homeowners and facilitate the adoption of lot-scale stormwater BMPs through the development and use of a Home Stormwater Assessment tool. This tool will be created through the work with Cedar Crossing residents and it's use piloted throughout the neighborhood. The overall goal is to create an easy-to-use tool that will be transferable to residential areas across the state (and region). The tool will have two steps: I) identifying the stormwater flow path, imperviousness, and potential pollutants (to be completed by homeowner), and II) on-site analysis for appropriate BMP selection and placement (to be completed by stormwater professional). Step I will not only build the capacity of the homeowner to understand the link between their home and water quality in their watershed, but also

Related Research:

Bioretention is an emerging stormwater best management practice for runoff reduction and peak attenuation and an element of better site design for residential developments (Johnes 2007). The mechanisms for stormwater management and treatment through bioretention are infiltration, evapotranspiration, media filtration, increase groundwater recharge, vegetation uptake of nutrients, media sorption of pollutants, and microbial conversion of nutrients. Secondary pollution reduction benefits are experience through reducing streambank erosion by reducing total runoff volume and peak flows.

In published studies, bioretention was an effective management practice for reducing runoff volume (Cosgrove and Bergstrom 2001; Davis 2008), attenuating heavy metal (Mason, Ammann et al. 1999; Davis, Shokouhian et al. 2001), and decreasing sediment loading in receiving waterways (Davis, Shokouhian et al. 2006); (Hsieh and Davis 2005). However, there is great variability in results reported for nutrient retention through bioretention (Table 1). Much of the variation may be attributed to design characteristics, such as hydraulic loading, media composition, and outlet design. Bioretention practices without underdrains (usually referred to as rain gardens) have also shown great hydraulic and pollution retention potential when designed to capture the first inch of runoff (typically required by state stormwater permits). Saturation zones in bioretention without underdrains decreased redox potential, which increases nitrate attenuation through denitrification (Davis, Shokouhian et al. 2006). Bioretention soil media has also shown to effect pollutant removal efficiencies (Johnes 2007). More research needs to be conducted to understand the effect of bioretention media mix, design layer depths, and internal storage zone hydroperiod on treatment performance for nutrient reduction.

Study Location	Bioretention Layers*	Nutrient Species	Average Inlet Concentration (mg/L)	Reported Mass Removal Efficiency (%)	Citation
Lab	Mulch, sand, sandy loam	TP	3.06	63-85	(Hsieh, Davis et al. 2007)
Lab	Mulch, topsoil, sandy loam	DP TKN NO ₃	0.6 4.0 2.0	81 68 24	(Davis, Shokouhian et al. 2001)
Lab	Mulch, sandy loam	TP TKN NO ₃	0.44 3.5 0.39	70-85 55-65 <20	(Davis, Shokouhian et al. 2006)
CT	Mulch, sandy loam, underdrain	NO ₃ NH ₃ TKN TP TN	0.9 0.04 0.6 0.015 1.6	67 82 26 -108 51	(Dietz and Clausen 2006)
NC	Mulch, soil, underdrain	TN NO ₃ TKN TP OP	1.27 0.5 1.0 0.11 0.09	40 75 -4.9 -240 -9.3	(Hunt, Jarrett et al. 2006)

* TN – total nitrogen; TP – total phosphorus; OP – orthophosphate; NH₃ – ammonia; NO₃ – nitrate; DP – dissolved phosphorus; TKN – total kheldal nitrogen.

An Evaluation of Floodplain Forest Land Use Dynamics, Ecosystem Services and Conservation Policies in West Tennessee Watersheds

Basic Information

Title:	An Evaluation of Floodplain Forest Land Use Dynamics, Ecosystem Services and Conservation Policies in West Tennessee Watersheds
Project Number:	2011TN79B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	Second, Knox County, Tennessee
Research Category:	Social Sciences
Focus Category:	Wetlands, Economics, Ecology
Descriptors:	Ecosystem Services; River Restoration, Floodplain Forest
Principal Investigators:	Donald Hodges

Publication

1. Hodges, Donald; and Donald Grebner, 2013, Dealing with uncertainty and risk in uneven-aged hardwood management in the southern Appalachians of the United States, "in" International Symposium on Socio-economic Analyses of Sustainable Forest Management, International Union of Forestry Research Organizations, Prague, Czech Republic, pp. 35-42.

An Evaluation of Floodplain Forest Land Use Dynamics, Ecosystem Services and Conservation Policies in West Tennessee

Statement of Critical Regional or State Water Problems:

The watersheds of West Tennessee contain a significant number of streams that have been listed by the Tennessee Department of Environment and Conservation on the 303(d) list as impaired, meaning they do not meet designated beneficial uses including biological integrity [40 CFR Part 130; TCA §69-3-101 and TDEC Rules Chapter 1200-4]. Due to historic channel alteration and riparian habitat alteration associated land use change over the past century, a large number of these impaired streams have been impacted by excessive siltation. In addition to local stream restoration and floodplain reforestation initiatives planned to support Total Maximum Daily Load implementation and watershed restoration, significant local attention is being devoted to developing ecosystem restoration strategies and sustainable management plans for West Tennessee rivers.

Most notably, the State of Tennessee submitted a formal request to the U.S. Army Corps of Engineers to reevaluate management options to control flood risk in the Obion and Forked Deer watersheds. This led the Corps of Engineers to publish a Notice of Intent in the National Register in May 2009 to prepare a Draft Supplement No. 2 to the Final Environmental Impact Statement for the West Tennessee Tributaries Project General Reevaluation. While the National Environmental Policy Act scoping process was initiated in late 2009, a number of local and national organizations voiced concern for the project and its potential implications for the west Tennessee ecosystem. Therefore, empirical evaluation of floodplain forest dynamics in West Tennessee watersheds can serve both to inform the scientific community as to the landscape-scale changes that have taken place throughout the region in past decades, and to guide public policies regarding land management and water resource planning throughout the region.

Statement of Results or Benefits:

While previous studies have explored the theoretical alternatives for restoring ecosystem services in agricultural watersheds, fewer studies have evaluated actual land use dynamics and how these are related to the provision of ecosystem services. Great potential exists for applying similar techniques to other agricultural watersheds throughout the Southeast. Therefore, this project will produce a methodology that incorporates economic values into estimating spatial and temporal changes in floodplain ecosystem service provision.

Given recent progress made by ecologists in recognizing the role of floodplain forests for river sustainability (Stanturf et al. 2009), appropriate attention must be placed on evaluating natural resource policies and developing management strategies that support floodplain restoration. Additionally, emerging interest in large-scale restoration of fluvial ecosystems is dependent upon the analysis of how past policies have influenced West Tennessee floodplains. Perhaps more importantly, the proposed re-conceptualization of the West Tennessee Tributaries Project by the US Army Corps of Engineers has increased focus on understanding how policies have impacted

floodplain ecosystems in the region, and how management strategies can be successfully adapted to ensure the sustainability of river systems for multiple uses. Thus, the results provided by this study will hold a number of practical implications for floodplain ecosystem restoration in West Tennessee, and for river conservation policies throughout the world.

Nature, Scope and Objectives of Research:

In order to develop a more complete understanding of the functions, distribution, and dynamics of floodplain forests in West Tennessee, a multi-faceted study of the legal, political, and biophysical framework must be initiated (King et al. 2009). Rather than simply focusing on one component of regional floodplain ecosystems, this study will explore the relatively recent evolution of management paradigms, with particular focus on how shifts in natural resource policies have impacted the distribution of floodplain forests in West Tennessee, and subsequently how these land use dynamics are connected to the flow of ecosystem services from both public and private lands in the region. Therefore, a comprehensive research approach is proposed which incorporates multiple methodologies to better understand west Tennessee floodplain management issues, and to aid in developing conservation policies that promote ecosystem restoration and sustainable management of natural resources throughout the region.

Objective #1: Develop a comprehensive inventory of geospatial data documenting the distribution of floodplain ecosystems in West Tennessee.

Both Defries & Eshleman (2004) propose the integration of multiple disciplines into the emerging study of landscape change, particularly focusing on the implications of land use dynamics on hydrological function. As demonstrated by Hodges et al. (1998), integrating multiple modeling methodologies can aid in projecting future land use scenarios. Additionally, previous research by Carver et al. (2006) reveals the immense potential for applying spatial analysis techniques to evaluate specific forest policy initiatives, revealing meaningful information for restoration planning and natural resource decision-making in channelized watersheds in Southern Illinois.

A comprehensive geospatial database will be constructed that incorporates existing data sources on regional hydrography, stream quality, biodiversity and wildlife habitat, vegetation classification, land use, soil resources and other relevant data. The data also will be developed to include information needed to assess the level of ecosystem services in the watershed.

Progress To Date: The geospatial database for the study area has been completed, including the data related to different ecosystem services, which have been gathered and processed. The data requirements for the InVEST model have been assessed and the data for each model have been compiled and processed. Carbon storage and sequestration, habitat quality and rarity, nutrient retention, water quality regulation, and timber production will be considered to assess the distribution of floodplain ecosystems using the InVEST model. For carbon storage and sequestration model, the land use and land cover raster dataset was obtained from National Land Cover Database. The carbon pools for aboveground, belowground, soil, and dead organic matter for each land uses and the current harvesting rate have been collected from available literature. The digital elevation

model and soil depth, precipitation, evaporation, land use, and watershed data have been collected for the nutrient retention model. The digital elevation model is available for sediment retention model and rainfall erosion index and soil erodibility are other additional data required to run the model.

In order to assess the changes in the land use due to channelization, the available land use data for the year 1992, 2001, and 2006 have been obtained from the National Land Cover Database. Landsat images were obtained from U.S. Geological Survey (USGS)'s Global Visualization Viewer) to identify the changes in the land after the channelization before 1990s. Those Landsat images were classified into different land use categories applying Maximum likelihood classification in ArcGIS 10.

Objective #2: Evaluate the political and legal factors that have influenced West Tennessee river system management.

Because regional river management strategies have a long and complex history (Smith et al. 2009), it is necessary to develop both a background as to the public policies that have guided floodplain management in West Tennessee, and a deep understanding of the legal guidance that has directed river conservation strategies in the past few decades. Therefore, this study will include an analysis of the policies that have directed river management, including the Flood Control Act of 1948, the Fish and Wildlife Coordination Act, the National Environmental Policy Act and the Clean Water Act; as well as the legal cases that have influenced management activities and subsequent mitigation efforts such as *National Ecological Foundation v. Alexander, et al.*, Civil Action No. 78-2548-H, and *Akers v. Resor, et al.* Civil Action No. C-70-349.

The implications of recent federal and state policies designed to support stream ecosystem restoration must also be considered as an essential element of floodplain forest conservation policy. Farm Bill programs impacting private lands management, such as the Conservation Reserve Program and the Wetland Reserve Program, obviously play a great role in private land management in West Tennessee (Bridges 2010). Additionally, state stream and wetland protection legislation and associated watershed restoration initiatives will also be examined along a temporal gradient to examine how river management paradigms have evolved in West Tennessee over the past few decades. The evolution of the West Tennessee River Basin Authority's strategies for environmentally-sensitive stream maintenance and floodplain restoration, which differ significantly from earlier support for channelization (Johnson 2007), will also be examined as part of this objective.

A wide variety of data are available detailing the early scoping phases for the development of an additional supplement to the Environmental Impact Statement that would allow for the reformulation of the West Tennessee Tributaries Project as a flood control initiative. Scoping documents, proposed resource management plans and written comments received during the scoping process will be examined to better understand the complexities of floodplain management in West Tennessee.

Progress To Date: Most of the publicly available documents have been obtained and currently are being reviewed to develop a comprehensive assessment of the role that past and current federal and state policies have played in river management and stream ecosystem restoration. All aspects of the work proposed for year 1 will be completed by the end of the project period.

Remaining 2 Objectives: To build upon the lessons learned from the document analysis, key informant interviews will be administered to individuals knowledgeable about West Tennessee rivers issues in Year 2. Results of the Year 1 analyses will be provided to the interviewees prior to and during the interviews to validate the results as well as to guide the interviews.

Objective #3: Explore spatial and temporal changes in the distribution and flow of ecosystem services derived from West Tennessee floodplain forests and wetlands.

Smith & Rosgen (1998) identified several questions for future researchers to explore as a means of informing West Tennessee river conservation policies, including the societal values associated with alternative floodplain management systems. Because of the immense ecological, economic and social values placed upon floodplain forests, the development of a methodology that quantifies the values associated with land use change in west Tennessee floodplains will provide much-needed guidance for restoration planning. Consequently, a key objective of this study is to examine the spatial and temporal changes in ecosystem service production associated with West Tennessee floodplain land use dynamics. Tremendous spatial variability is exhibited in the ecological characteristics of West Tennessee floodplains.

Progress To Date: As described for Objective 1 Progress above, the data for Objective 3 has been collected and processed. The remaining task for this objective is to develop the economic values associated with the various ecosystem services. Some work has begun on this, specifically the values related to timber production. This resulted in a presentation at the International Union of Forest Research Organizations, Working Group 4.05.00 in May 2013 (Hodges and Grebner 2013).

Additional Year 2 Objectives: Once all ecosystem service quantities and values have been completed, a facilitated group discussion will be conducted in the study area to present the results, discuss their validity and implications, and identify next steps in developing a means of addressing the results.

Methods, Procedures, and Facilities:

Multiple studies have identified compiling geospatial data as an essential step in identifying watershed restoration planning (Yuan et al 2006), particularly regarding the design of riparian forest filter strip systems to reduce nonpoint-source pollution (Endreny 2002) (Schulz et al. 2004) (Berry et al. 2003). While a preliminary inventory of riparian forests in Tennessee has

been developed (Bridges 2008), a focus on floodplain ecosystems, rather than riparian buffers associated with fluvial systems, should yield data that is more useful for restoration planning in West Tennessee.

Key informants will be identified through state and organizational directories and will include representatives from some or all of the following: pertinent state/federal resource management agencies, local planning agencies, local economic development agency, local environmental groups, regional and/or national environmental groups, business community, and local agricultural and forestry interests. When participation of the identified informants cannot be obtained, alternative respondents will be selected. Responses will be aggregated following a procedure that eliminates idiosyncratic answers and respondent error (see Schwartz et al. 2001). The interview will cover: (1) awareness of past and proposed management activities; (2) the range of values associated with the river ecosystems; (3) perception of the role of public policy on river ecosystems in the study area, and (4) potential ecological, economic, and social effects of proposed policies for restoration. Findings from these key informant interviews will be incorporated in the next phase of this study.

Quantifying and valuing changes in ecosystem service levels will be conducted by utilizing the geospatial database developed in Year 1 with the valuation program InVEST, a software package developed to value ecosystem services and tradeoffs (Tallis et al. 2011). InVEST has been used in a number of similar assessments, including some conducted in the Lower Mississippi Alluvial Valley (Jenkins et al. 2010, Murray et al. 2009).

A synthesis of the key informant data and the results of the InVEST analysis will be presented a facilitated group discussion to contribute to a better understanding of the strengths, weaknesses, opportunities, and threats associated river ecosystem restoration. Facilitated groups are similar to the more commonly used focus group approach in qualitative research. Such groups are designed to determine perceptions, feelings, concerns, and manners of thinking about particular products, services, and/or opportunities. Unlike focus groups, which are generally homogeneous and involve seven to ten people, facilitated groups can be larger and do not hinge upon homogeneity of participants – rather, these people must share an interest in the subject and willingness to engage in dialogue about the issues raised. The purpose of the group is to focus on and provide information about the study area and the associated values they hold. Our focused discussion will target the same types of individuals interviewed earlier – the major difference is the focus on “group think” as opposed to individual responses to core questions.

Related Research:

Multiple researchers associated with the University of Tennessee have applied a variety of expertise to the analysis of water resources and associated floodplain ecosystem research in West Tennessee over the past few decades. Early evaluation of the implications of river channelization throughout the Obion and Forked Deer systems helped to inform local decision-makers as to the cost of natural resource management alternatives (Smith & Badenhop 1975). More recent research projects have also included multiple evaluations of the influence of excess sediment loading on floodplain forest composition (Pierce & King 2008), and also the implications of

forest habitat dynamics on wildlife communities (Summers & Gray 2009). Additionally, the geomorphological research of Smith, Diehl et al. (2009) is also helping to guide river restoration throughout the region.

While great attention has been placed regionally on the integration of ecosystem services (Lant et al. 2005) and associated economic implications into river resource management planning (Lockaby 2009), significant opportunity remains to explore the implications of natural resource policies on West Tennessee rivers and floodplains. Additionally, by building upon previous river ecosystem studies in the region, this project will serve to integrate multiple-objective conservation planning to ensure the sustainability of West Tennessee watersheds.

Hodges, Donald G., and Donald Grebner. 2013. Dealing with uncertainty and risk in uneven-aged hardwood management in the southern Appalachians of the United States. Presented at: Socio-economic Analyses of Sustainable Forest Management, International Symposium of International Union of Forestry Research Organizations, Unit 4.05.00. Prague, Czech Republic. May 16.

USGS Award No. G11AP20135 Development of Water Quality Model for Regional Loadings

Basic Information

Title:	USGS Award No. G11AP20135 Development of Water Quality Model for Regional Loadings
Project Number:	2011TN86S
Start Date:	4/13/2011
End Date:	7/31/2013
Funding Source:	Supplemental
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Water Quality, Conservation, Models
Descriptors:	
Principal Investigators:	Timothy Gangaware, Carol P Harden

Publications

1. Tran, Liem T., Robert V. O'Neill, Elizabeth R. Smith, Randall J.F. Burns, and Carol Harden, 2013, Application of Hierarchy Theory to Cross-Scale Hydrologic Modeling of Nutrient Loads, *Water Resources Management*. Springer, New York, NY, 1:1-17.
2. Tran, Liem T., and Robert V. O'Neill, 2013, Detecting the Effects of Land Use/Land Cover on Mean Annual Streamflow in the Upper Mississippi River Basin, USA. *Journal of Hydrology*, "in preparation".
3. Tran, Liem T., and Robert O'Neill, 2013, Hierarchy and Cross-Scale Hydrologic Modeling, "in" Annual Meeting of Association of American Geographers, Los Angeles, CA., pp.236-243.
4. Tran, Vi, and Liem Tran, 2013, Geospatial Regression Models for Regional and Sub-Regional Mean Annual Streamflow, "in" Annual Meeting of Association of American Geographers, Los Angeles, CA., pp.244-251.
5. O'Neill, Robert and Liem Tran, 2013, Cross-Scale Hydrologic Modeling for Annual Sediment Load, "in" Annual Meeting of Association of American Geographers, Los Angeles, CA., pp. 252-261.

Development of Water Quality Model for Regional Loadings

Below is the progress report for the EPA Interagency Agreement IA 95796201-0 for the first year, May 2011-July 2012:

Task 1. Compile and analyze available data

The following datasets have been collected and compiled to have them ready for subsequent modeling tasks.

Population data

Population data at block group level from 1990 Census, 2000 Census, and 2010 Census have been allocated to the catchments in the NHDplus dataset for the whole conterminous U.S.

Land use

The National Land Cover Dataset (NLCD) of 1992, 2001, and 2006 from the Multi-Resolution Land Characteristics (MRLC) initiative have been allocated to the catchments in the NHDplus dataset for the whole conterminous U.S.

Annual instream nitrogen load

Data of from NASQAN National Stream Quality Accounting Network were downloaded, processed, and geocoded to have them ready for the Regional Hydrologic Modeling for Environmental Evaluation (RHyME²) model developed during the first phase.

We are in the process of preparing data for dissemination through a server bought from the project fund.

Task 2. Set up model

RHyME² has been prepared/coded to run for Nitrogen flux and Phosphorous flux for the Upper Mississippi River Basin (UMRB) and the Future Midwest Landscape (FML) study area.

Task 3. Calibrate/validate model

RHyME² for Nitrogen flux has been calibrated for FML. RHyME² for Nitrogen flux has been calibrated for UMRB.

Regarding theoretical model development, we have developed a regional streamflow model to use along with RHyME².

In term of a tangible product, we have submitted one manuscript of RHyME² to *Water Resources Management*. Two more manuscripts will be submitted to peer-reviewed journals by the end of July 2012.

In general, the project is on time or ahead of the schedule. Furthermore, we closely follow the project's QAPP. We are more than happy to answer any question you might have about this report and the project.

Rainwater Harvesting as part of a Sustainable Urban Water Management Strategy

Basic Information

Title:	Rainwater Harvesting as part of a Sustainable Urban Water Management Strategy
Project Number:	2012TN90B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Second
Research Category:	Engineering
Focus Category:	Surface Water, Conservation, Management and Planning
Descriptors:	Rainwater harvest, Potable water conservation, Cooling tower
Principal Investigators:	Kevin G Robinson, Kevin G Robinson

Publications

There are no publications.

9. Problem and Research Objectives:

The use of lower quality water for appropriate applications is a water conservation strategy for improving water use efficiency. The exploration of rainwater harvesting as a water management strategy is motivated by the goal of reducing energy and natural resource demands. In 2010, the University of Tennessee consumed over 500,000,000 gallons of potable water which amounted to a cost of about 1.5 million dollars. Water conservation strategies, such as installing water efficient faucets, have been explored on the campus by a student-formed group, *Make Orange Green*, but the initiatives can only have a small impact without implementing additional strategies. There are approximately 56 cooling towers in operation on the University of Tennessee campus and supplementing the make-up line for even a few of these towers would further the effort of reducing the potable water demand of the campus.

The overall objective of this project is to reduce the potable water demand of the University of Tennessee campus. While a combination of reuse and water capture strategies will be needed to attain the goal of a sustainable water infrastructure, this project focuses on a specific water capture strategy for a specific water use application. The utilization of rainwater has been suggested as a supplementary water source to the local water utility (Knoxville Utility Board, KUB) for make-up cooling water in campus cooling towers. A feasibility study on supplementing a single campus cooling tower with rainwater must first be conducted to ascertain whether the idea can become a campus-wide water-saving strategy. The rainwater will essentially provide a second make-up water line to the designated cooling tower in addition to the already-installed KUB make-up line. Key objectives of the project include:

- (a) examine the quality of collected rainwater to determine if any additional chemical treatment is necessary to maintain efficient cooling tower operation;
- (b) quantify the amount of potable water that can be saved by the providing a rainwater make-up line; and
- (c) evaluate project feasibility based on costs associated with reduced tap water use and wastewater generation during annual cooling tower operations on campus.

10: Methods, Procedures and Results:

Figure 1 outlines the experimental approach utilized in this investigation. The research was divided between water quality and quantity assessments. The quality analysis included a comparison of specific water parameters (conductivity, pH, total dissolved solids (TDS), alkalinity, total hardness, and calcium hardness) that were designated for their ability to indicate the fouling potential of the rainwater and tap water samples. This comparison was used to assess the advantages and disadvantages of using the rainwater as a cooling tower makeup water source. While the dissolved solids content of the rainwater was the most prevalent water quality parameter with regards to cycles of concentration (COC) calculations, it was important to characterize the rainwater to ascertain the potential for scaling or corrosion.

Silica and conductivity measurements were taken for cooling water samples, collected from a campus tower to calculate the number of COC under current operating conditions. The other water quality parameters were also measured for the cooling water samples to verify that the samples were representative of typical operating conditions by comparing the measured values to those recommended by the manufacturer of the cooling tower.

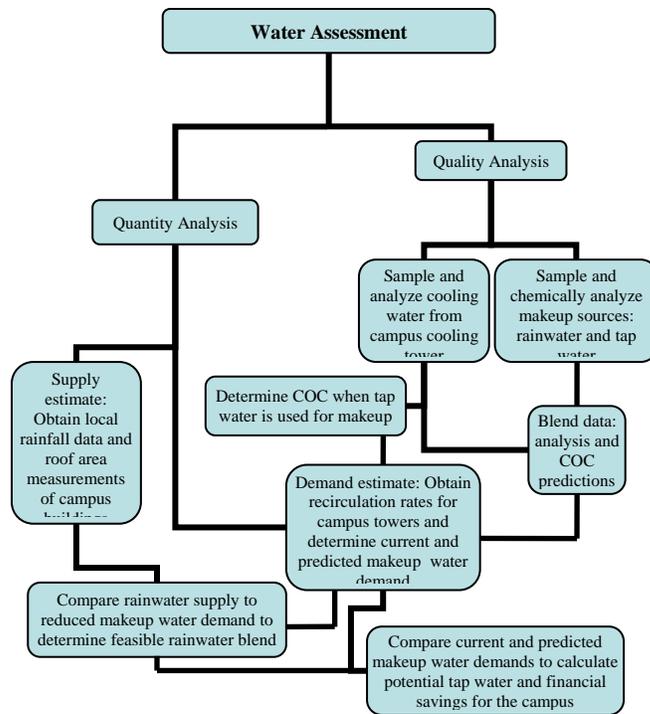


Figure 1 – Flow diagram of the experimental approach.

Since it is highly unlikely that the supply of rainwater can completely replace tap water as the makeup water source due to climate-imposed limitations, blends of rainwater and tap water were prepared and analyzed. In addition to characterizing each of the blends with the designated water quality parameters, predictions were made for the number of COC that could be achieved by consistently using a makeup water source of the same blend proportions. A back-calculation from the lab-predicted number of COC for each blend was then performed to estimate the new and reduced makeup water demand of the campus if all of the campus cooling towers were using the blended makeup water supply. The predicted makeup water demand of the campus was then compared to the current makeup water demand, using only tap water as the makeup supply, to calculate the potential tap water and financial savings of using rainwater blends.

Results

Table 1 displays the results of the water quality analysis on the tap water and the rainwater samples. Four distinct rainfall events were used for the quality analysis to obtain representative samples. A comparison of the TDS and conductivity values between the rainwater and tap water samples indicated that significantly lower levels were measured for the rainwater. These reduced concentrations would be advantageous when considering rainwater for cooling tower makeup water use because a higher number of COC would be achievable with a makeup source containing fewer solids. The rainwater also appeared as a favorable cooling water medium due to the lower values reported for alkalinity, total hardness, and calcium hardness, compared to those measured for the tap water. Since the dissolved components measured in alkalinity and hardness are typically chemical constituents of scale, lower values for each of these parameters were the desired results. However, some alkalinity is required in cooling water to buffer the pH to prevent corrosion; and calcium may be required in the water to bind with, and thereby activate, the corrosion inhibitor that is included as part of the cooling tower’s chemical treatment package. It has been suggested that the use of a more dilute water source for cooling tower makeup water will reduce the amount of chemical treatment

required to control fouling inside the cooling tower. The lower limits of these parameters would therefore need to be identified for the chemical treatment package that is currently in use, and consideration of possible modifications to this package would need to be explored if rainwater was to completely replace tap water as the cooling tower's makeup water source.

Table 1. Makeup source comparison between tap water and rainwater.

Parameter	Tap Water (<i>Measured</i>)	# of Tests	Rainwater (<i>Measured</i>)	# of Events
pH	7.19 ± 0.13	18	6.91 ± 0.25	4
TDS (ppm)	150.5 ± 24.1	18	12.72 ± 6.64	4
Conductivity (μ S/cm)	230.8 ± 35.2	21	20.31 ± 10.52	4
Alkalinity (as mg/L CaCO ₃)	67.6 ± 11.7	18	< 10	4
Total hardness (as mg/L CaCO ₃)	87.8 ± 13.6	18	< 10	4
Calcium (as mg/L CaCO ₃)	63.9 ± 9.0	18	< 10	3

Blends of collected rainwater and tap water were prepared in the lab in specific volumetric ratios. Each chemical parameter measured decreased with increasing blends of rainwater due to dilution (except pH which remained relatively constant). Silica and conductivity measurements of the rainwater and tap water blends were used to predict the number of COC that would be achievable in a cooling tower that consistently used a makeup supply of a specific percentage of rainwater. The overall trend of the results was that the number of predicted COC increased with an increasing volume of rainwater in the blend (Figure 2) which is significant since blowdown (diversion of cooling water to the sewer) is reduced with increasing COC.

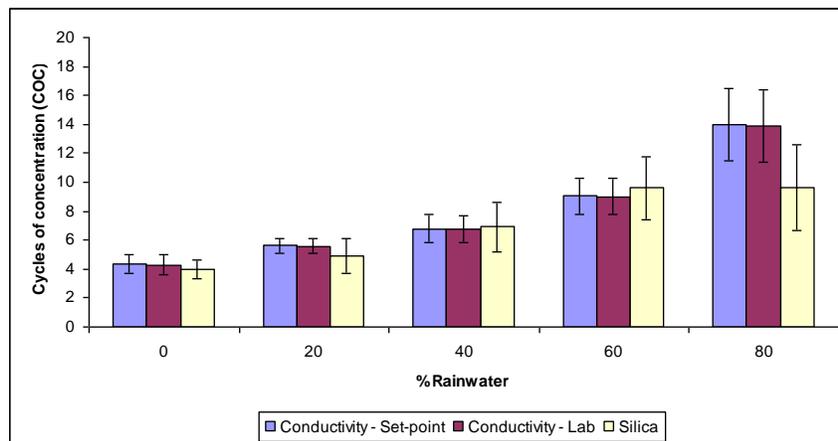


Figure 2. Cycles of concentration (COC) for various tap/rainwater blends.

Based on a 50% collection efficiency for rainwater falling on University of Tennessee building rooftops, an estimated 20% makeup blend can be achieved on campus. The potential water

volume resulting from the use of a 20% rainwater/tap water blend makeup for every campus cooling tower was calculated to be 108 ± 20 million gallons. The annual financial savings were determined to be approximately \$100,000 based on current potable water rates. Since increasing the number of COC decreases the frequency of blowdown, as well as makeup, a reduction in wastewater charges for the 20% blend was also calculated. The cost savings associated with reduced wastewater discharges resulting from the utilization of rainwater in campus cooling towers was calculated to be approximately \$155,000 per year. Thus, the total estimated financial savings for the 20% rainwater/tap water blend was estimated to be \$255,000 annually for the University of Tennessee. Higher tap/rainwater blends would result in additional savings.

11. Principle Findings and Significance

The use of rainwater as a supplementary water source for cooling water makeup was explored in an effort to reduce the potable water demand of the University of Tennessee's Knoxville campus. A water quality analysis involving the measurement of parameters relevant to cooling tower operation was conducted on tap water currently used for makeup supply and rainwater collected from the roof of a campus building. In anticipation of limited rainwater supplies due to issues of catchment surface area, collection efficiency, storage capacity, and climatic conditions, blends of rainwater and tap water were also analyzed. The dissolved solids concentration of the rainwater was significantly lower than in tap water, which indicated that a higher COC could be achieved should rainwater be used in the makeup water source. Predicted COC values for the rainwater/tap water blends were calculated based on silica and conductivity measurements and were higher than the 4 ± 0.6 COC at which the campus towers were operating at during the investigation. A back-calculation using the blended COC values was used to determine potential makeup demand reductions. The replacement of tap water with rainwater in the makeup supply was found to contribute to the total tap water savings to a greater extent however, than increasing COC. Based on a rainwater supply estimate of 116 million gallons, it is possible that anywhere from a 20-60% blend may be utilized in each of the campus cooling towers if the average annual heat load is between 50-100%. At the current price of water and wastewater, the maximum cost savings associated with these results is about \$343,000 for the case in which a 40% blend is used for cooling towers operating at a 75% heat load.

11. Publications and Presentations Resulting from this Research:

None to date

Determining Channel Protection Flows in Urban Watersheds Through Effective Strategies for Stormwater Management and Stream Restoration

Basic Information

Title:	Determining Channel Protection Flows in Urban Watersheds Through Effective Strategies for Stormwater Management and Stream Restoration
Project Number:	2012TN92B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Ecology, Surface Water, Sediments
Descriptors:	TMDLs; Stormwater Management; Urbanization, Bank Erosion; Urban Stream Restoration
Principal Investigators:	John S. Schwartz, John S. Schwartz

Publications

There are no publications.

Methods, Procedures, and Facilities:

1. Pilot Site Sampling and Setup:

Rainfall and flow monitoring equipment will be set up at each pilot. Composite samplers to capture water samples at different stages will be installed to evaluate suspended sediment. Continuous stage and weather data will be monitored at each site. Four automated composite samplers with flow measurement sensors will be purchased with USGS grant.

Field surveys will be performed on the channel and floodplain of each pilot stream. The initial survey will be used to describe the baseline geometry of the stream and prepare inputs to the hydrologic and channel erosion models. Erosion pins will be installed on the banks of 3 cross-sections at each site. Pins will be measured every 6 months and following rainfall events greater than 1.0 inches. Additionally, Rapid Geomorphic Assessment (RGA) and Modified Wolman Pebble Count will be conducted at each site (Simon and Klimetz, 2008). Detailed soil and vegetation characterization will be performed at each pilot site. Soils at each of these pilot streams will be characterized from *in-situ* shear strength testing with Torvane testers, field samples utilizing geotechnical laboratory analyses (e.g., bulk weight, particle size distribution), and using a submerged jet device to measure *in-situ* critical shear and erosion rates for cohesive material.

Progress To Date: Composite samplers have been purchased, and set up at two locations to obtain baseline sediment yield estimates. Mini submerged jet devices have been constructed and are currently being tested to measure *in-situ* shear strength of cohesive bank materials. The study design has changed in order to estimate properties of channel resistance to erosion. Using the mini submerged jet devices, a geostatistical approach to characterize flow resistance has been developed, and site selection is in progress. A second approach will use the Rapid Geomorphic Assessment (RGA) and Modified Wolman Pebble Count surveying roughness element densities along a longitudinal profile - selection of study sites for this approach is in progress.

2. Pilot Model Creation:

The project team will create detailed hydrologic/hydraulic and erosion models for each pilot stream so that model output can be incorporated into the SUSTAIN model. The model software will be public domain, approved by the EPA, and accepted by the professional community. For example, the hydrologic/hydraulic model recommended is EPA SWMM (EPA, 2008) or the Hydrological Simulation Program- Fortran (HSPF) model, and the geotechnical bank failure models will be USDA's Dynamic BSTEM. We will assume at this time that SWMM will be used. These models will be used in later tasks to evaluate the channel erosion, baseflow and water quality impacts of alternative stream protection options. The SWMM models includes rainfall, runoff, infiltration, evaporation, groundwater, hydraulic and baseflow components. Each model will be run to determine flow rates over the length of each pilot stream. Bank Stability and Toe Erosion Model (BSTEM) spreadsheets will be set up for continuous simulation to evaluate bank stability and toe erosion on each of the pilot streams. Dynamic BSTEM is a public-domain model developed by the USDA National Sedimentation Laboratory (USDA, 2009). Flow rates from the SWMM models will be introduced to the dynamic BSTEM spreadsheets at the appropriate locations. Soil and survey data will be used to describe the bed and bank materials and channel geometry in the model.

Progress To Date: Robert Woockman, a graduate student is in training learning the use of the EPA SWMM and SUSTAIN models. Paul Simmons, a second graduate student on the project is learning Dynamic BSTEM. In part of the study design change is to work with Dr. Bill Lucus, Pennsylvania, to utilize existing calibrated SWMM models for watersheds, in which we can focus on applications of channel characterization of flow resistance. The objectives have not changed, but through collaboration with other national leaders in the water resources area, research outcomes will be improved. We have arranged to work with Dr. Lucus and utilize 2-4 watersheds he has completed modeling with various LID scenarios. Robby Woockman is working on the details to implement field campaign to survey bank and bed resistance properties.

3. Pilot Model Calibration:

The SWMM models will then be run with the recent rainfall data collected by the nearby rain gauge. Relatively uncertain watershed characteristics of the model will be calibrated so that flow results match recorded flows as closely as possible. This calibration will reduce uncertainty and increase the reliability of the modelled flows. Flow results from these models will be entered into the BSTEM spreadsheets to drive the channel erosion analysis. Erosion results will be compared to those gathered by the yearly field surveys. The soils parameters of the BSTEM model will then be calibrated to match the observed measurements as closely as possible. This approach was similarly used by Simon and Klimetz (2008). The calibrated SWMM and BSTEM models can then be used to test any number of stream protection options or land use changes for their effect on long term stream health.

Progress To Date: See above statement in Task 2.

Shear Strength Guidance Creation:

The soils data calibrated in BSTEM will then be analyzed to determine which field-measured parameters (such as Torvane tester values, root density, etc.) are accurate predictors of shear strength. Relationships between the key parameters and shear strength will be determined. The project team will publish a simplified method for determination of bank and bed shear strength. Proper use of inexpensive Torvane shear strength testers will be combined with field observations to determine a valid shear strength.

Progress To Date: See above statement in Task 2.

Evaluation of Potential Channel Erosion for Pilot Streams:

The SWMM models for the reference streams will be altered by changing the land uses to residential and commercial and applying the long-term rainfall record. The increased flow hydrographs determined from SWMM will be fed into BSTEM until the channel geometry stabilizes for each stream. The progression of channel geometries will be compared to the geometries of the newly and historically urbanized pilot streams. The BSTEM models may be further calibrated based on this comparison, which will provide insight into the evolution of urban stream degradation. Several similar model runs will be performed after varying the stream channel characteristics in BSTEM for each pilot stream. The effects of several critical factors such as channel shear strength, bank angle and vegetation on sediment load will be

determined. The total erosion load potential will then be tabulated for a range of stream and watershed conditions.

Progress To Date: See above statement in Task 2.

Relationship Between RGA Score and Erosion Potential:

The Rapid Geomorphic Assessment (RGA) technique developed by the USDA National Sedimentation Laboratory (Simon and Klimetz 2008) will be used to score each of the pilot stream reaches. The RGA provides an overall rating for the susceptibility of a channel to erosion. Erosion loads for the pilot streams will then be tabulated based on RGA score and hydrologic area to determine the relationship between these factors. This task is key in developing simplified field protocols that MS4s can implement, and optimally target BMPs for channel protection. This RGA datasheet will be designed for easy incorporation into existing stream assessment protocols such as the “Maryland Protocol” (Yetman, 2001) that are currently being used across the country by MS4 staff.

Progress To Date: See above statement in Task 1.

Information Transfer Program Introduction

The major emphasis of the information transfer program during the FY 2012 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 2012 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 2012 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 TNWRRC was involved in the planning and implementation of the Twentieth Second Tennessee Water Resources Symposium, which was held on April 11-13, 2012 at Montgomery Bell 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 368 attendees and approximately 71 papers and 19 posters being presented in the two-day period. The event received a good deal of publicity across the state.

The following is a brief listing of formal meetings, seminars and workshops that the Center actively hosted, supported and participated in during FY 2012:

East Tennessee MS4 Stormwater Management Working Group, July 18, 2012, October 26, 2012, January 25, 2013 at Knox County Stormwater Department, Knoxville, TN. TNWRRC and the Tennessee Department of Environment and Conservation sponsored a quarterly meeting of local government officials responsible of implementing local stormwater programs under the MS4 Phase II permit. These meeting are designed to provide local officials with information that will add them in development of their local stormwater management programs.

Tennessee Department of Agriculture, Nonpoint Source 319 Program Workshop, Ellington Agriculture Center, Nashville, TN. March 20, 2012.

Information Transfer Program Introduction

Tennessee Wetlands Technical Advisory Task Force meeting, May 1-2, 2012, 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 4, 2012, 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 2012: March 1, 2012, Knoxville, TN.; April 4, 2012, Jackson, TN.; May 3, 2012, Chattanooga, TN.; May 15, 2012, Memphis, TN.; May 17, 2011, Nashville, TN.; May 31, 2012, Knoxville, TN.; September 5, 2012, Nashville, TN.; September 20, 2012, Knoxville, TN.; October 9, 2012, Jackson, TN.; October 16, 2012, Chattanooga, TN.; October 24, 2012, Cookeville, TN.; November 8, 2012, Johnson City, TN.; November 15, 2012, DOD, Ft. Campbell, TN.; November 27, 2012, Nashville, TN.; November 28, 2012, Knoxville, TN.; December 12, 2012, Memphis, TN.; January 15, 2013, Army Corps of Engineers, Memphis, TN.; February 21, 2013, Nashville, TN. For this time period over 14,025 persons obtained Level I certification.

Design Principles for Erosion Prevention and Sediment Controls for Construction Sites Level II workshops sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. A two day training workshops for engineers and other design professionals responsible for the development of Storm Water Pollution Prevention Plans for construction activities. The course was offered on the following dates: April 24-25, 2012, Knoxville, TN.; May 9-10, 2012, Nashville, TN.; June 12-13, 2012, Memphis, TN.; October 3-4, 2012, Nashville, TN.; October 31 - November 1, 2012, Knoxville, TN.; December 5-6, 2012, Chattanooga, TN.; January 15-16, 2013, Army Corps of Engineers, Memphis, TN. For this time period over 215 persons obtained Level II certification.

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: May 3, 2012, Knoxville, TN.; May 16, 2012, Memphis, TN.; May 24, 2012, Chattanooga, TN.; September 11, 2012, NRCS Murfreesboro, TN.; September 12, 2012, Nashville, TN.; September 13, 2012, MLGW, Memphis, TN.; September 26, 2012, Knoxville, TN.; October, 10, 2012, Jackson, TN.; October 11, 2012, Murfreesboro, TN.; October 27, 2011, Jackson, TN.; November 9, 2012, Johnson City, TN.; November 13, 2012, Chattanooga, TN.; November 14, 2012, Nashville, TN.; November 29, 2012, Memphis, TN.; December 3, 2013, Blalock Construction, Sevierville, TN.; December 10, 2013, Blalock Construction, Sevierville, TN.; December 12, 2012, Knoxville, TN. For this time period over 1,275 persons obtained Level I Recertification.

Tennessee Hydrologic Determination Training (TN-HDT) program. This new training program was developed and is being offered to meet the requirements of Tennessee Code Annotated, Section 69-3-105 which establish standard procedures for making stream and wet weather conveyance determinations in Tennessee. The three day course was developed by staff from the Tennessee Department of Environment and Conservation (TDEC) and faculty from the University of Tennessee and Tennessee Technological University. TNWRRC is responsible for administration of the TN-HDT program and works with TDEC and university faculty to deliver the course three to four times each year at selection location across the State. The course was

Information Transfer Program Introduction

offered on the following dates: June 4-6, 2012, Oak Ridge, TN.; August 6-8, 2012, Montgomery Bell State Park

Partnered with faculty for Auburn University and North Carolina State University, University of Tennessee and the City of Chattanooga to host the 2012 Watershed Academy: Water Resource Management from Downspout to River Mouth. The two day workshop targeted staff from MS4 communities in Tennessee and UT Extension county agents with a focus on watershed management basics and how to engage community partners in watershed restoration activities. The Academy included tours of LID stormwater management practices and urban stream restoration projects. Over 30 persons attend the Academy in Chattanooga on June 27-28, 2012.

Adopt-A-Watershed teacher training workshop, June 7-9 2012, Knoxville, TN. This four day workshop sponsored by TNWRRC and partners of the Water Quality Forum trains middle and high school science teachers on how to work with their students to conduct watershed investigations and develop watershed improvement service projects and part of their classroom curriculum. Eleven new teachers completed the training course in 2012.

Environmental Compliance and EPSC Management for Right-of-Way Inspectors Training Course, June 14, 2012, Jackson, TN.; June 21, 2012, Knoxville, Tn.; June 22, 2012, Nashville, Tn.; and June 26, 2012, Chattanooga, TN. TNWRRC, Tennessee Department of Transportation and CEC, Inc. developed and conducted this 1 day training TDOT ROW staff.

West Tennessee Research and Education Center, Jackson, TN. Summer Celebration Field days, July 15-16, 2012. TNWRRC staff and UT Extension staff had a Tennessee Yards and Neighborhoods exhibit at the field day event. TNWRRC staff also conducted a four hour workshop on how to a rain garden for participants.

Tennessee Stormwater Association Conference, October 17-19, 2012, Chattanooga, TN. TNWRRC is a charter member of TNSA and assisted with conducting one day workshop on Green Infrastructure stormwater management practices for conference attendees.

Knoxville Water Quality Forum, Quarterly meetings, May, July and October 2012 and January 2013. 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 2012 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	5	0	0	1	6
Ph.D.	2	0	0	1	3
Post-Doc.	0	0	0	0	0
Total	9	0	0	2	11

Notable Awards and Achievements

None for FY 2012

Publications from Prior Years

1. 2008TN53B ("A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables") - Articles in Refereed Scientific Journals - Schwartz, J.S., K.J. Neff, and F.J. Dworak, 2013, Modeling three-dimensional hydraulics in an incised channel with woody bank vegetation: implications for stream rehabilitation River Research and Applications, "in preparation".
2. 2008TN53B ("A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables") - Articles in Refereed Scientific Journals - Keaney, F.B., J.S. Schwartz, Q. He, and K.J. Neff, 2013, Stream Channel Stability and Channel Evolution in a Rapidly Urbanizing Ridge-and-Valley Watershed Beaver Creek, Knox County, Tennessee. Physical Geography, "in Preparation".
3. 2008TN53B ("A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables") - Conference Proceedings - Schwartz, J.S., K.J. Neff. 2011. Use of River2D hydrodynamic model for stream restoration assessment and design. ASCE/EWRI World Water & Environment Resources Congress; Palm Springs, CA.
4. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Conference Proceedings - Neff, K.J., J.S., Schwartz, A.B., Dodson, and M.S., Hamrick, 2010, Restoring Pool-Riffle Habitat in Beaver Creek, Knox County, Tennessee: Lessons Learned in a Platform-Constrained Urban Stream, Stream Restoration in the Southeast: Connecting Communities with Ecosystems; Raleigh, NC; November 2010.
5. 2005TN17B ("Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use") - Conference Proceedings - Neff, K.J., J.S., Schwartz, A.B., Dodson, and M.S., Hamrick, 2010, A Modeling Approach to Restoring Pool-Riffle Structure in an Incised Straightened Channel of an Urban Stream. Session in the Hydraulics and Waterways Section; World Water and Environmental Resources Congress of the American Society of Civil Engineers and Environmental and Water Resources Institute; Providence, RI; May 2010.
6. 2010TN71B ("Development of GIS Data Management System for Water Resources and Climate Research in Tennessee") - Articles in Refereed Scientific Journals - Koirala S.R., R.W. Gentry, P.J. Mulholland, E. Perfect, J.S. Schwartz, and G.S. Sayler, 2011, Persistence of Hydrologic Variables and Reactive Stream Solute Concentrations in an East Tennessee Watershed, Journal of Hydrology 401:221-230.
7. 2010TN71B ("Development of GIS Data Management System for Water Resources and Climate Research in Tennessee") - Articles in Refereed Scientific Journals - Koirala, S.R., R.W. Gentry, E. Perfect, P. Mullholland, and J.S. Schwartz, 2011. Hurst Analysis of Hydrologic and Water Quality Time Series. ASCE Journal of Hydrologic Engineering, 16(9): 717-724. DOI 10.1061/(ASCE)HE.1943-5584.0000357.
8. 2009TN61B ("Drought Variability in Reconstructed Streamflow") - Dissertations - Moser, Cody. 2011. Use of Remote Sensing Climate Reconstruction and Forecasting for Improved Water Resources Planning and Management, PhD Dissertation, Department of Civil & Environmental Engineering, College of Engineering, University of Tennessee, Knoxville, TN., pp. 194.
9. 2009TN61B ("Drought Variability in Reconstructed Streamflow") - Dissertations - Aziz, Oubeid, 2011. Use of Oceanic-Atmospheric Variability in Hydrologic Forecasting, PhD Dissertation, Department of Civil & Environmental Engineering, College of Engineering, University of Tennessee, Knoxville, TN., pp. 238.