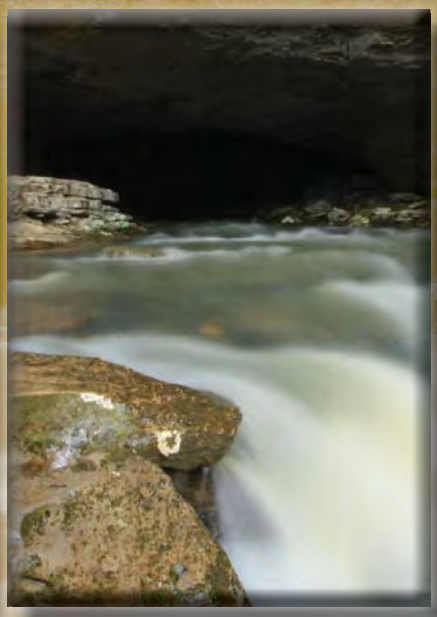
Proceedings of the Twenty-Second Tennessee Water Resources Symposium






April 11-13, 2012

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Proceedings from the

22nd Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 11-13, 2012

Sponsored by

Tennessee Section of the American Water Resources Association

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PREFACE

On behalf of a team of dedicated hardworking planning committee members, I welcome you to our 22nd Tennessee Water Resources Symposium sponsored by the Tennessee Section of the American Water Resources Association.

This year, 2012 (the Chinese Year of the Dragon), marks the 40th anniversary of the Federal Water Pollution Control Act Amendments of 1972 (known informally as the Federal Clean Water Act). Prior to the Federal CWA, Tennessee passed the Tennessee Water Quality Control Act (WQCA) in 1971. This legislation was the first where, as a matter of public policy, water was held as a public trust and that the people of Tennessee, as beneficiaries of that trust, have a right to unpolluted waters. The state has an obligation to take all prudent steps to secure, protect, and preserve that right.

The implementation of the Tennessee WQCA as well as the Federal CWA has helped to improve, maintain, and protect our waterways and associated aquatic ecosystems. Today, Tennessee is known not only as the home of the blues, country music and great barbeque, but also as a place with rich water resources and expertise to manage those resources.

The rapid advancement in communication and information technologies has brought the world closer together. News and information are communicated instantly in real time through cyber space. Collaborations and exchanges can now be conducted through the internet via blogs, web-based meetings, Facebook and Twitter. The information technology has and will provide numerous innovative methods to us for future global outreach and knowledge exchanges. In recognition of this, the Tennessee Section of AWRA is going “global.”

In China, the fast paced growth and economic development for the past two decades have increasingly brought forward many issues and challenges to its water resources similar to those the US experienced during the 60s and 70s. Since water resource issues are fundamentally global issues, we have invited a group of academics from Xi’an University of Technology (Xi’an is the City where Terracotta soldiers were buried in 219 - 209 BC) to share information and findings from their research projects, to hear about Tennessee’s experiences, and to initiate future collaborations with Tennessee. Please join me in welcoming our distinguished guests from China.

Finally, I want to express my special thanks to Lori Weir for her perpetual leadership of managing this annual event, to Scott Gain for his superb organizational skill of categorizing topics and assigning papers, to Amy Knox for producing our proceedings and to our loyal sponsors and exhibitors.

Sherry Wang, President, Tennessee Section AWRA, 2012 Conference Chair

前言

我代表一组劳苦功高的规划小组委员会委员们，欢迎各位来參加第22屆田纳西州美国水资源协会主办的研讨会。

今年，2012年，是中国的龙年，也标志着1972 年美国联邦清洁水法(Federal CWA)執行的四十周年。在那年之前的1971年，我们田纳西州就通过了水质控制法 (TNWQCA)
。这项法令，第一次制定了田纳西州的一项公共政策，声明田纳西州的水是公众信託的財產，受益者是人民，人民应有享受清洁水的权利。田纳西州政府有义务采取所有审慎的步骤，确保人民用水安全，保护和保留这个民众的权利。

四十多年来，由于田纳西州水质控制法以及美国联邦清洁水法的落实执行，帮助了提高、维护和保护田纳西州水质及相关的水生生态系统。今天，田纳西州不仅只闻名于乡村音乐、布鲁斯和烧烤，同时，也是一个有优良的水质，又有丰富的水资源和也有很多水资源管理专业知识人士的地方。

通信和信息技术的快速进步拉近了世界的距离，新闻和信息可立即通过网络空间实时传达。我们也可以通过博客和互联网、用基于微博平台的会议方式、和利用脸书与Twitter进行交流。今后，这些创新的技术和方法，将会提供给我们更多的机会来推广全球知识交流。所以，美国田纳西水资源协会现在开始"全球化了"。

中国，在过去二十多年的快速经济发展下，水资源管理的问题和挑战越来越多，完全类似美国在六十年代和七十年代期间的经历。由于水资源问题根本上是全球问题，我们这一次邀请了一团中国西安理工大学学者 （西安市是公元前 219-209 年兵马俑陪葬处），来分享他们的研究项目，来听取田纳西州的经验，并希望来启动与田纳西州未来的合作。各位同行、同事和朋友们，请与我一起来欢迎我们来自中国的贵宾。

最后，我特别要先感谢 Lori Weir的经营和管理這个每年一度的研讨会，再要感谢Scott Gain高超的组织能力，对每篇论文主题的适当分类和分配，也要感谢Amy Knox每年为我们的研讨会刊印论文，更要感谢对我们始终忠诚的每位研讨会参展商和赞助单位。

王晓蕾，会长，田纳西州美国水资源协会， 2012年研讨会主席

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PLANNING COMMITTEE FOR THE 22nd TENNESSEE WATER RESOURCES SYMPOSIUM

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- Alfred Kalyanapu, Tennessee Technological University
- Amy Knox, Center for the Management, Utilization and Protection of Water Resources-TTU
- Larry Lewis, Tennessee Association of Utility Districts
- Forbes Walker, University of Tennessee

12:00 – 1:30 p.m.
Wednesday, April 11
Keynote Address *by* Thomas J. Wilbanks, Oak Ridge National Laboratory

"RESPONDING TO CHALLENGES IN ASSURING RESILIENT WATER SYSTEMS FOR TENNESSEE"

12:00 – 1:30 p.m.
Thursday, April 12
Luncheon Presentation *by* Steve McDonald, Carollo Engineering

"INTEGRATED WATER RESOURCES PLANNING—SUSTAINABLE CONCEPTS AND STRATEGIES"

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Qiang He
TNAWRA Chinese Liaison
University of Tennessee

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Research on Dynamic Ecological Requirements and Its Application to the Main Reach of the Weihe River
Ni Wang, Jiancang Xie, Jungang Luo, and Jiwei Zhu……..……...……SS-17

Modeling Chloride Transport in an Aggregated Soils with Three Models
Zhou Beibei, Li Yun, Wang Quanjiu, Jiang Yanli, and Shao Ming'an……...……SS-18

Development and Application of X-WSR-Z System Methodology in Water Resources Management
Jiwei Zhu, Jiancang Xie, and Ni Wang…….……..…….SS-20

Interval Two-Stage Stochastic Integer Programming for Urban Water Resources Management Under Uncertainties
ShuHong Mo, HaiNi Duan, and Bing Shen…….……SS-22

Study on Comprehensive Development Model and Effects of Regional Water and Land Resources in Urbanization
Zhu Jiwei, Xie Jiancang, Zhao Yuewang, Wang Ni, and Huang Yinbing……..……SS-23

SESSION 1A

FLOOD I
1:30 p.m. – 3:00 p.m.

Probabilistic Flood Risk Management Using Monte Carlo Based Fast 2D Flood Model to Incorporate Uncertainty
A. Kalyanapu, F. Hossain, W.Y. Yigzaw, S. Shankar, and D.R. Judi

Technical Review of Drainage and Flooding Issues in the Lick Creek Drainage Basin, Memphis, Tennessee, 2011
Eric J. Byrne

Using Dynamic Stormwater Modeling to Plan and Design a Regional Stormwater Detention Basin in Collierville
Justin Avent

FLOOD II
3:30 p.m. – 5:00 p.m.

Nashville SAFE: A City-Wide Program for Flood Emergency Preparedness
Jennifer Higgs

Operation of the Cumberland River System Projects During the Historic Ohio and Mississippi River Floods of 2011
Randall Z. Kerr and Robert B. Sneed

Using Geographic Information System Techniques to Map and Predict Flood Inundation in Tennessee
David E. Ladd

PROBABILISTIC FLOOD RISK MANAGEMENT USING MONTE CARLO BASED FAST 2D FLOOD MODEL TO INCORPORATE UNCERTAINTY

A. Kalyanapu[1], F. Hossain[1], W.Y. Yigzaw[1], S. Shankar[2], and D.R. Judi[3]

With more than 2.8 billion of world's population living within 9 miles of rivers, flood risk is a major challenge facing planning and development agencies. Recent examples are the May 2010 Tennessee floods, which resulted in 31 casualties along with more than $1.5 billion in damages and 2011 Mississippi River flood which resulted in evacuation of thousands of homes and deliberate flooding of 2900 sq. mi. of rural Louisiana and losses up to $4 billion (majority of damages occurred in urban areas). Understanding and estimating the spatio-temporal distribution of floods at its intersection with urban environments is critical for floodplain management. The success of these essential floodplain management actions is based on accurate and rapid prediction of flood inundation, which is achieved by flood models. Computer simulations of floods have been applied over the past five decades to understand the effects of flood disasters. They are typically modeled as free surface flows, using one-dimensional dynamic wave simulations, also known as Saint Venant equations. Even though this approximation is sufficient for channel dominant flows, flows in floodplain are complex and multi-directional thus breaking down the 1D approximation. A higher order topographic representation and lateral flow in floodplains are better represented through two-dimensional models. Two limiting factors for two-dimensional models are computational intensity and model uncertainty. A major limiting factor for applying 2D numerical flood models is their computational intensity (Kalyanapu et al., 2011). Despite the advances in computer hardware and technology, it can still take a long time to run 2D models. For example, a dam break event simulation for a 62 sq. km area (624 x 1136 cells at 9.36 m spatial resolution), on a 2.33 GHz Intel™ Core2Duo® desktop with 2 GB RAM and Windows XP Professional Operating System, took 10 hrs to simulate approximately 15 minutes of flow. This limits the number of scenarios, spatial extent and/or level of detail that is expected for a particular flood problem especially in the development of Monte Carlo based risk assessment methods for flood modeling (NRC, 2009; Buijs et al. 2003; Sayers et al. 2000; Lamb et al. 2009). The advances in integrated circuit technology and computer hardware, in the past decade, brought about an evolution of graphics hardware, commonly called as graphics cards in the video game industry (Sony Play Station3, Personal Computer games etc.). The graphics cards, also called as Graphics Processing Unit (GPU) possessed microcomputer-like programmability, similar to a Central Processing Unit (CPU), which is considered the heart of a computer machine. To address this computational intensity issue, to simulate 2D flood flows, a GPU based 2D flood model named Flood2D-GPU has been developed (Kalyanapu et al., 2011). This study demonstrates Flood2D-GPU model application to simulate flood inundation downstream of Folsom Dam, on the American River, in California, under probable maximum flood (PMF) conditions.

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Another important need in numerical flood modeling (of any dimension) is reducing the uncertainty introduced during modeling. Numerical models are but the conceptualizations of reality and hence reduce physical complexity through simplifications through systems of equations (Wagener and Gupta, 2005). Flood model uncertainty is of critical concern especially when modeling results are used to set policy, decision making and emergency planning. This study demonstrates applicability of Flood2D-GPU, in a Monte Carlo based flood risk framework. The approach is demonstrated by computing and analyzing the relative benefits of implementing flood proofing in the Swannanoa River floodplain in Buncombe County, North Carolina, USA for a continuous flow distribution and selected discrete recurrence interval events. Using a Monte Carlo framework, 1000 samples from the flood frequency curve were selected and used to drive a new graphics processing unit based 2D flood model. The computed flood depths and extents are used to estimate flood damage and then flood damage frequency and annualized risk curves are created. The results indicate the typical flood control analysis approach of determining Estimated Annual Damage (EAD) using discrete return periods, underestimated damage compared to EAD calculated using continuous flood damage frequency curve for the Swannanoa basin. The hypothesis that designing flood proofing for a higher probability and lower magnitude event results in a greater relative level of damage reduction for a lower implementation cost compared to the traditional use of the 1% annual exceedance flood event will be tested and presented.

TECHNICAL REVIEW OF DRAINAGE AND FLOODING ISSUES IN THE LICK CREEK DRAINAGE BASIN, MEMPHIS, TENNESSSEE, 2011

Eric J. Byrne

INTRODUCTION

In recent years, the City of Memphis has performed several studies to help determine the best way to address drainage and flooding problems in the Lick Creek Drainage Basin. Despite these studies and ongoing efforts by the city to help alleviate flooding, there are many areas that continue to flood during heavy rain events. In response, Tetra Tech was requested by the Memphis City Council to perform an independent technical review of the drainage and flooding issues, to provide an independent report, and to coordinate and host a public meeting to obtain input and ideas from residents to help inform the technical review. The primary goals of the technical review were to provide a comprehensive assessment of the City's current plan and projects, existing flood models, and to consider public input while recommending measures to reduce or alleviate flooding.

APPROACH

Tetra Tech performed a review of existing models and planning studies, and then coordinated a public meeting to promote an exchange of ideas and concepts. After the public meeting, Tetra Tech implemented a volume approach to help quantify the level of flood protection required. Lastly, a follow up public meeting was held to communicate the results of the study with the public.

RESULTS AND DISCUSSION

Tetra Tech used a combination of existing reports, public comments, GIS, and the volume approach to identify future project opportunities to reduce or alleviate flooding.

USING DYNAMIC STORMWATER MODELING TO PLAN AND DESIGN A REGIONAL STORMWATER DETENTION BASIN IN COLLIERVILLE

Justin Avent[1*]

INTRODUCTION

There are several drainage laterals that run through the Town of Collierville and drain into the Wolf River. There tends to be some recurring flooding along one of these laterals, Lateral J, during the more intense rainfall events. In fact, in the last few years several homes in the area have flooded on multiple occasions. Collierville hired SSR to build a dynamic stormwater model of the related 1,600-acre drainage basin, investigate why the problems are occurring and develop alternative solutions. In the end, four alternative solutions were developed and the results of these improvements were compared to the existing conditions model. GIS was used to created color coded flooded area maps to aid in the comparisons and evaluations.

APPROACH

The specific tasks performed for this project include the following:

1. Collecting and incorporating all pertinent data required for the development of the hydrologic and hydraulic models. Data sources used for the drainage study include storm sewer maps from the Town's records, 2-foot contours provided by Shelby County, aerial photography, and zoning maps. Survey information was collected, as needed, to supplement the available information.
2. Conducting field investigations at known flooding sites and along the study reaches. Field investigations were performed to supplement the information available in the Town's storm sewer maps.
3. Developing basin-wide integrated hydrologic and hydraulic (H&H) model to estimate the extent of the flooding problems occurring throughout the study area.
4. Modeling alternative improvements to the drainage network intended to reduce the severity and extent to flooding problems in the study area.
5. Meeting with City officials at regular intervals to discuss progress, review the model selection process, review modeled scenarios, and to review the final report.
6. Prepare a report that provides a narrative, flooded area maps, and water surface elevation estimates.

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RESULTS AND DISCUSSION

After completing the study and report, Collierville decided to follow through with the recommended solution which involved purchasing some property and using it to construct a five-acre regional detention facility that will also double as greenspace along the Town's existing greenline. The detention facility design is complete and the project is scheduled to begin construction this spring. The intent of the design is to use the detention area as a common open space for citizens during dry weather conditions. There are low flow channels that will be used to carry smaller storm events. All low flow channels will be lined with a turf reinforcement mat. All pipes that discharge into the pond will have ScourStop at the outlets to help dissipate the energy. An asphalt trail follows the top banks of the pond and there is ADA accessible ramp that leads to the bottom of the pond. Trees will be planted along the low flow channels to landscape the pond.

The town also using the pond construction as an opportunity to solve a bank stabilization issue. There are several homes along Rillbrook Drive that back up to the main channel of the lateral. The channel in this area has eroded and property owners along Rillbrook have lost portions of their back yards. During construction of the pond, this eroded bank will be repaired and sodded. The result of this project will be reduced flooding, a stable bank along the channel, and a common open space that can be used for public enjoyment.

NASHVILLE SAFE: A CITY-WIDE PROGRAM FOR FLOOD EMERGENCY PREPAREDNESS

Jennifer Higgs[1]

The widespread flooding that occurred across the Nashville Metropolitan area following unprecedented amounts of rainfall on May 1-2, 2010 prompted thorough assessments of the services provided during flood emergencies by federal, state, and local agencies. These assessments identified a need for more coordination between agencies, a need for more and better data for analysis and interpretation, as well as a need for more personnel who could make qualified decisions and recommendations during a flood emergency. From this need, the Nashville Situational Awareness for Flood Events (SAFE) program was born.

The Nashville SAFE program is a partnership between Metro Water Services (MWS), Metro Office of Emergency Management (OEM), Metro Planning Department (Planning), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the National Weather Service (NWS), and AMEC Environment & Infrastructure, the purpose of which is to provide Metro emergency management personnel with a myriad of internal tools to assist in decision making during a flood event.

One of the three fundamental components of the program is the Nashville SAFE tool. The Nashville SAFE tool is an internal mapping program developed by Metro Planning which can retrieve real-time NWS, Metro, and USGS precipitation and river stage data and display a resulting flooded area and impacts associated with current and predicted flooding based on modeling provided by the USACE. The MWS Watershed Advisors are a team of trained engineers whose purpose is to analyze current and predicted stream conditions and make recommendations to the Situation Management Team at the Emergency Operations Center during a flood event that will minimize potential human loss or injury and property damage from flooding. Watershed Advisor interprets data shown on the Nashville SAFE Tool and provides scientifically-based impact assessments and decision recommendations to the Situation Management Team during a flooding event.

This presentation will describe the Nashville SAFE program, with emphasis on the Nashville SAFE tool, from its infancy to today, and promote it as a means of cooperation and communication between federal, state, and local agencies meant to protect the citizens of Nashville during the next flood emergency.

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Jennifer Higgs has been the manager of the GIS Section at the Nashville Planning Department for almost 14 years. Jennifer has B.S. in Geology and an M.S. in Geography, both from Murray State University. Jennifer has been featured in a Planetizen publication "Insider's Guide to Careers in Urban Planning" and served as a board member for the Tennessee Geographic Information Council.

OPERATION OF THE CUMBERLAND RIVER SYSTEM PROJECTS DURING THE HISTORIC OHIO AND MISSISSIPPI RIVER FLOODS OF 2011

Randall Z. Kerr and/or Robert B. Sneed[1]

The Mississippi and Ohio River floods in April and May 2011 were among the largest and most damaging recorded along these waterways in the past century, comparable in extent to the major floods of 1927, 1937 and 1993. In April 2011, two major storm systems deposited record levels of rainfall on the Mississippi River watershed. When runoff from the heavy rainfall was combined with an abundant amount of springtime snowmelt, the rivers and many of their tributaries swelled to record levels by the beginning of May.

On May 2, the Birdspoint-New Madrid floodway was operated for only the second time since its construction was complete in 1932, with the last operation of the floodway in 1937. The use of the floodway significantly reduced water levels upstream, essentially saving the town of Cairo, Illinois. Also, for the first time in 37 years, the Morganza Spillway was opened on May 14, deliberately flooding 4,600 square miles of rural Louisiana to save most of Baton Rouge and New Orleans.

The Cumberland River and the Tennessee River enter the Ohio River a short distance upstream of Cairo, Illinois. This presentation will focus on the operation of the Cumberland River projects during the major flood event on the lower Ohio and Mississippi Rivers. For non-flood events, the United States Army Corps of Engineers (USACE), Nashville District and the Tennessee Valley Authority (TVA) coordinate the releases from Barkley (the last project on the Cumberland River) and Kentucky (the last project on the Tennessee River) to optimize multi-purpose benefits of the projects. This coordination is necessary due to the projects being linked by an unregulated navigation canal. The releases must be coordinated to keep the pool elevations within a reasonable range to keep from damaging the canal with high water velocities. However, when the stage at Cairo is above 35 feet and forecast to go above its flood stage of 40 feet, the Lakes and River Division (LRD) of the USACE assumes control of the releases from Barkley and Kentucky. LRD remains in control of the projects until the stage at Cairo falls below flood stage. In 2011, LRD initiated a flood control event on February 25 and did not relinquish control until June 7.

The Cumberland River system consists of 10 multi-purpose reservoir projects over a 17,913 square mile area. Upstream of Barkley reservoir, the Cumberland River system has 4 major tributary flood control projects – J Percy Priest, Center Hill, Dale Hollow and Wolf Creek. Two of these projects, Center Hill and Wolf Creek, are experiencing foundation seepage issues that have led the USACE to implement a number of risk reduction measures, including pool restrictions. They also happen to be the two largest tributary flood storage projects within the Cumberland River Basin.

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January and February on the Cumberland River drainage area had been relatively dry, with January recording less than half of normal rainfall and February about 0.5 inch below the normal amount of 4.2 inches. Thus the project inflows were below normal and the inflows into Barkley reservoir had averaged less than 10,000 day-second-feet (dsf) for the week prior to the initiation of the flood control event. On February 24, 2011 the pool level at Center Hill was over 4 feet below the pool restriction level, while the other three major tributary storage projects were essentially within a foot of either the pool restriction level or the project's flood guide elevation. On February 22, Barkley pool level was also within a foot of the flood guide.

Following more heavy rainfall for the Ohio River basin in early March, the stage at Cairo crested at 54.0 feet on March 18, 14 feet above flood stage. Barkley pool level would crest at elevation 363.05 following the crest date and later return to a pool level of 355.80 on April 5. The four major tributary storage projects were used primarily during this period to help reduce the flood stage at Nashville. Peak elevations for this storm event were as follows;

PROJECT	PEAK ELEV (FT)	DATE
WOLF CREEK	711.4	3/14/2011
DALE HOLLOW	652.9	3/15/2011
CENTER HILL	645.6	3/12/2011
J PERCY PRIEST	488.4	3/10/2011
BARKLEY	363.05	3/20/2011

The crest of 54 feet at Cairo was one foot above major flood stage. Modeling results show without reservoir operations on the Ohio River reservoir system the water level at Cairo would have crested 3.28 feet higher. Total damages averted at Cairo during the March event, for the Ohio River reservoir system, were $113,256,000, with $41,417,240 attributed to the TVA system and $28,588,893 to the Cumberland River system.

Following the March event, significant efforts were made to recover flood storage space. As previously mentioned, Barkley was returned to within a foot of flood guide while the tributary projects were lowered to the following;

PROJECT	ELEV (FT)	DATE
WOLF CREEK	699.7	4/4/2011
DALE HOLLOW	650.1	3/29/2011
CENTER HILL	633.1	4/3/2011
J PERCY PRIEST	484.1	3/25/2011

From April 14–16, the storm system responsible for one of the largest outbreaks of tornadoes in US history also produced large amounts of rainfall across the southern and midwestern United States. Two more storm systems, each with heavy rain and tornadoes, hit in the third week of April. In the fourth week of April, from April 25–28, another, even more extensive and deadly storm system passed through the Mississippi Valley dumping more rainfall resulting in deadly flash floods. This latter storm produced over 250 tornadoes, the deadliest tornado outbreak since 1925. The unprecedented extensive rainfall from these four storms, combined with springtime

snowmelt from the Upper Midwest, created the perfect situation for major flooding along the lower Ohio and Mississippi Rivers.

Just following the detonation of the Birdspoint-New Madrid Floodway, the stage at Cairo crested at 61.72 feet, over 2.2 feet above the previous stage of record set in 1937. Without flood control operations above Cairo the water level would have crested at 65.50 feet and without the breach of the floodway the crest would have been at 66.73 feet.

The Cumberland River system was called on to store flood waters like never before. Barkley pool level crested at a record elevation of 372.50 on May 5, almost 2.5 feet higher than the previous pool of record. Wolf Creek headwater crested just under elevation 726, almost 45 feet above the February 24 pool level. Dale Hollow crested at elevation 660.2, Center Hill at elevation 658.2 and J Percy Priest at 501.6. Over 3.3 million acre-feet of water had been stored in the four flood storage projects since late February.

Without reservoir operations on the Ohio River reservoir system the water level at Cairo would have crested 3.78 feet higher. Total damages averted at Cairo during the record setting flood event, for the Ohio River reservoir system, were $95,328,000. This total is separate from the earlier March event. The amount attributed to TVA operations was $20,121,130 with $51,457,329 to the Cumberland River system. The Cumberland system amount was significantly higher than the TVA amount for the May event due to the operation of the tributary storage projects.

Although a generally wet spring for the Cumberland system, with March rainfall totals one inch above normal and April approximately 2.5 times normal, at no point did the stage at Nashville exceed 30 feet. However, natural river conditions would have exceeded the flood stage of 40 feet on three separate occasions.

Following the flood event, recovering flood storage space in the reservoirs was a long and tedious process. J Percy Priest was back to summer pool level on May 20, Barkley pool levels were returned to normal levels before the end of May, the drawdown at Center Hill was slowed down at elevation 633 at the first of June, Dale Hollow was still almost 1 foot above summer pool on June 15 and Wolf Creek was still at elevation 686.1 at the end of June.

USING GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES TO MAP AND PREDICT FLOOD INUNDATION IN TENNESSEE

David E. Ladd[1]

The May 2010 and 2011 floods in Tennessee revealed a critical need to provide the public with accurate and timely information that might help prevent loss of life and property. During or before a flood, maps and Geographic Information System (GIS) products depicting flood elevation, depth, and aerial extent can provide emergency responders and property owners with critical information to aid in rescue efforts, determine escape routes, and assess damage. An analysis of recent and historical flood data can improve our understanding of what flood profiles and inundated areas might look like during future floods. GIS methods and flood-profile data can be used to produce flood-inundation surfaces depicting current and future flood events. The U.S. Geological Survey (USGS) is developing a system for extrapolating flood depth and extent, based on current or projected flood stage, and for publishing maps of inundation surfaces in a format that is readily accessible to community planners, emergency responders, and the general public.

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SESSION 1B

RESTORATION I
1:30 p.m. – 3:00 p.m.

The Effects of the May 2010 Floods on TSMP Stream Restoration Projects
Adam L. Spiller and Joey Woodard

Rehabilitating Oostanaula Creek: Use of Stream Enhancement and Agricultural BMPs, CFD Modeling, and University Students
Keil J. Neff, Andrea Ludwig, John Schwartz, Brett Connell, and Forbes Walker

Oostanaula Creek Watershed Restoration Project: Rural and Town Projects to Date
Lena Beth Carmichael Reynolds and Forbes Walker

RESTORATION II
3:30 p.m. – 5:00 p.m.

Transportation Mitigation
Nathan Ober

Stream Restoration and Stormwater Treatment Approaches in an Urban Watershed
William K. Barry, Charles R. Oligee, and Judd Langham

Water Quality Best Management Practices at the Little River Animal and Environmental Unit
Andrea Ludwig, Shawn Hawkins, Jaehoon Lee, Larry McKay, Forbes Walker, and Bob Hunter

THE EFFECTS OF THE MAY 2010 FLOODS ON TSMP STREAM RESTORATION PROJECTS

Adam L. Spiller and Joey Woodard

Nearly two years have passed since the historic floods in May 2010. These floods were of particular concern for the Tennessee Stream Mitigation Program (TSMP), which had 21 completed stream restoration and enhancement projects statewide at the time. In the months after the floods, the TSMP conducted site visits and evaluations at every project and began figuring out how to deal with the damage. The initial evaluation found that eight projects were found to be completely unaffected, another eight had only minor or localized damage, and five projects sustained damage that would require detailed assessments, repair design, and a significant construction effort. Immediately after these evaluations, the TSMP began focusing on these repairs. Within a year and a half of the floods, most of these sites had been repaired, and the 2011 monitoring found them to be stable functioning systems. This presentation offers a look at how the TSMP responded to this historical event in an efficient and cost effective way and some perspective at how and why some projects were impacted and others were not.

REHABILITATING OOSTANAULA CREEK: USE OF STREAM ENHANCEMENT AND AGRICULTURAL BMPS, CFD MODELING, AND UNIVERSITY STUDENTS

Keil J. Neff*[1], Andrea Ludwig[2], John Schwartz[3], Brett Connell[4], and Forbes Walker[5]

A reach of Oostanaula Creek (McMinn County) impacted directly by cattle was selected for stream rehabilitation to integrate into curriculum of EV595 (Stream Restoration Design, UTK). Impacts in this reach included impaired water quality (sediment and bacteria), degraded instream habitat, channel widening, non-ecologically functioning riparian corridor, and stream bank failure. Students completed an assessment and preliminary restoration design while learning principles in fluvial geomorphology, stream ecology, ecohydrology/ecohydraulics, biomonitoring/bioassessment, aquatic habitat modeling, and agricultural best management practices (BMPs). The hydraulic flow patterns were modeled in River2D to assess bed and bank sheer stresses, and instream velocities, to facilitate stable restoration design by identifying placement of structures and sizing substrate. Approximately 300 feet of stream was rehabilitated through the addition of instream habitat, bank stabilization best management practices, and riparian vegetation enhancement. Fencing was installed to restrict cattle access to Oostanaula Creek, excluding them from the restored stream segment and limiting them to a constructed narrow crossing. Features included coconut coir geolifts, toe rock structures, and cedar tree revetments to stabilize failing banks; use of boulders to modify hydraulics and resultant geomorphology; substrate addition for enhancement of macroinvertebrate habitat; and native riparian plantings to enhance bank stability and canopy cover. By enhancing habitat and reducing cattle impacts to this stream reach, we hope to multiply and diversify the aquatic and riparian species. As part of a 319(h) grant, this project also serves as an example to other landowners by demonstrating practices to enhance and protect the waters in Oostanaula Watershed.

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OOSTANAULA CREEK WATERSHED RESTORATION PROJECT: RURAL AND TOWN PROJECTS TO DATE

Lena Beth Carmichael Reynolds* and Forbes Walker

Oostanaula Creek Watershed contains rural and farm land in McMinn County, plus the City of Athens. A multitude of problem sites have been determined in the watershed, with multiple agencies involved in the process of improving water quality. Several farm improvements related to water quality have been implemented through UT Extension, while the City of Athens improvements have been headed by the Public Works Department. Photos of problem sites will be shown, with descriptions agency cooperation and sources of funding. Improvement of the sites will be shown, with photos of the sites after the work is complete. Innovative strategies for successful cooperation and funding will be presented. Examples of farm projects include cattle traffic lanes, stream crossing, controlled access cattle watering sites, alternate watering facilities, and stream bank restoration. Sites within the City of Athens will include a green parking lot, pervious sidewalks and parking lot, rooftop to storm sewer disconnect with rain garden, rain gardens on private property, and the wetlands and park created by the library.

TRANSPORTATION MITIGATION

Nathan Ober[1]

The balance of ecology and public transportation can be achieved on-site with stream and wetland mitigation. Through integrated planning during roadway designs transportation departments (DOTs) in various states have incorporated natural channel designs to complement roadway corridors. Traditional design methods for roadway project-related stream relocations produce oversized streams resulting in improper channel morphology and disequilibrium. Success of on-site mitigation designs is a product of proper assessments, site selection, planning, and project delivery which require collaboration throughout the roadway development process. Challenges associated with limited corridors and roadway structures can be overcome through a strategic restoration and culvert enhancements design approach. Although off-site mitigation can provide substantial benefits to the ecosystem, on-site mitigation provides benefit to local communities within the impacted watershed. Over 190 million people in the United States have driver licenses and travel past rivers and wetlands every day on public roads. A high percentage of drivers do not adventure off the road to visit these resources and they base their impressions of natural resources from the window of the vehicle. Through examples of on-site ecosystem restoration in the Southeast, this presentation will focus on: 1) the design approach for confined corridors, 2) enhancement of culverts to promote bankful dimensions, 3) challenges integrating restoration into roadway designs, and 4) benefits and disadvantages to on-site transportation mitigation.

[1] Nathan S. Ober, Geomorphologist, Stantec Consulting Services Inc, 601 Grassmere Park Road, Suite 22, Nashville TN 37211

STREAM RESTORATION AND STORMWATER TREATMENT APPROACHES IN AN URBAN WATERSHED

William K. Barry, PE, D. WRE[1]*; Charles R. Oligee, PE[2]; and
Judd Langham, ASLA, LEED AP[3]

ABSTRACT

Stream restoration and stormwater treatment in urban areas are difficult due to many constraints including roads, buildings, utility infrastructure and multiple landowners. Efforts are underway to perform stream restoration and stormwater treatment within the Genetta Ditch watershed in Montgomery, Alabama. The watershed is comprised of moderate to high density residential areas, commercial areas, parks, and some wooded areas in its downstream portions. Genetta Ditch is culverted for the upper half of its approximately four mile length. Downstream of this is an approximately 3,000 foot trapezodial concrete channel that is parallel to Interstate 65, with the balance of its length being an earthen channel that was straightened soon after World War II. The project is projected to ultimately consist of at least two stromwater treatment wetlands, restoration of the earthern portion of the channel, and naturalization of the trapezodial concrete lined portion of the channel. Park and greenway elements will also be incorporated. Currently in the design stage, design options evaluation will be discussed along with specific goals and challenges of the project.

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WATER QUALITY BEST MANAGEMENT PRACTICES AT THE LITTLE RIVER ANIMAL & ENVIRONMENTAL UNIT

Andrea Ludwig[1], Shawn Hawkins[1], Jaehoon Lee[1], Larry McKay[2], Forbes Walker[1], and Bob Hunter[2]

Protecting water quality is not only an operational goal at the new dairy research and education center at the University of Tennessee, but it is also a primary focus for research and demonstration. The objectives of this work are to 1) demonstrate to the dairy community the implementation of effective practices for protecting water quality, 2) collect data on their effectiveness at preventing nonpoint source pollutants from making into surrounding streams, and 3) identify optimal use and maintenance of practices for maximum pollutant attenuation. Baseline water quality data have been collected at the farm for nearly five years and has provided a record of seasonal variation in chemical and physical properties of the drainage (including nutrients, sediment, and pathogens). This year, storm sampling has begun to characterize the event-driven transport of potential pollutants carried in stormwater. Water quality best management practices have been selected and partially installed around the facility to mitigate the impacts of the operation on the surrounding waters of the State. These include native warm season grass field borders, riparian buffers, and shallow water treatment zones (or created wetlands). The borders and buffers were planted in September 2012 and were installed to meet two criteria: 1) to buffer the field operations for the perimeter of the property (borders) and wet weather conveyances (buffers), and 2) be created with a native grass that could be bailed as hay. The shallow water treatment zone locations were located in areas that made since with the given topography of the farm. Two existing wetlands were delineated and will be maintained as shallow water treatment zones. An additional two areas have been identified for the installation of created wetlands to intercept stormwater flow and filter nutrients and pathogens before stormwater reaches waters of the State.

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[2] Department of Earth and Planetary Sciences, University of Tennessee

SESSION 1C

GROUNDWATER
1:30 p.m. – 3:00 p.m.

Occurrence of Nitrate and Pesticides in the Memphis-Sparta Aquifer in West Tennessee and Northwest Mississippi
James A. Kingsbury

Geochemistry of Deep Aquifers in Tennessee and Implications for Carbon Sequestration
Michael W. Bradley and Thomas Parris

Hydrologic and Geologic Controls on Carbon Tetrachloride Transport and Biodegradation at the Valsicol Dump, Hardeman County, Tennessee
Tom Byl, Michael Bradley, Randy Thomas, and Brandon Cobb

KARST
3:30 p.m. – 5:00 p.m.

Tennessee Underwater Caves: Enabling Watershed Management Through Direct Observation, Mapping, and Visualization of High Flow Water Conduits
Christina Richards and Jason Richards

Deciphering Microbial Controls on Carbon Cycling in Karst Aquifers
Terri Brown, Kathleen M. Brannen, and Annette S. Engel

Quantitative Dye Tracing—Development of a New Interpretative Method
Irucka Embry, Victor Roland, Roger Painter, Rick Toomey, and Lonnie Sharpe

OCCURRENCE OF NITRATE AND PESTICIDES IN THE MEMPHIS-SPARTA AQUIFER IN WEST TENNESSEE AND NORTHWEST MISSISSIPPI

James A. Kingsbury[1]

Sixty-one wells completed in the Memphis-Sparta aquifer have been sampled in west Tennessee and northwest Mississippi as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. A 30 well network consisting of primarily domestic and public supply wells was sampled in 2007. A second network of 31 monitoring wells located near agricultural fields to characterize the quality of shallow groundwater was sampled in 2011. Samples were analyzed for major and trace inorganic constituents, nutrients, and pesticides as well as for chemical tracers used to estimate groundwater ages. Nitrate concentrations were less than the maximum contaminant level in all samples from the existing network of supply wells with a median concentration of 0.07 mg/L NO_3 as N. In contrast, three samples of shallow groundwater in agricultural areas had concentrations greater than 10 mg/L, and the median concentration was about 2.4 mg/L for the network. Low dissolved-oxygen concentrations and longer groundwater residence times in parts of the aquifer sampled by the supply well network are factors that result in low nitrate concentrations. Pesticides were detected relatively frequently in both well networks. At least one pesticide was detected in 20 percent of samples from the domestic and public supply network and in almost 75 percent of the samples of shallow monitoring wells. Concentrations of pesticides in both networks were low with the maximum concentration measured of about 1.2 micrograms per liter. Concentrations of pesticides generally were an order of magnitude lower in the domestic and public supply wells than in the shallow monitoring wells. The herbicides atrazine, simazine, and metolachlor and degradates of atrazine were the most frequently detected pesticides which is consistent with results for other groundwater networks sampled by NAWQA across the country.

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GEOCHEMISTRY OF DEEP AQUIFERS IN TENNESSEE AND IMPLICATIONS FOR CARBON SEQUESTRATION

Michael W. Bradley[1] and Thomas (Marty) Parris[2]

Geochemical data from deep formations in the Appalachian and Illinois Basins in Kentucky are being used to evaluate the evolution of the water, the degree of confinement, and the potential suitability of the deep aquifers for carbon sequestration. Geochemical data available for groundwater in Tennessee can also provide similar information for the deep aquifers in Tennessee. Geologic units being tested for carbon sequestration in the Appalachian and Illinois basins include formations equivalent to the Mascot Dolomite of the upper Knox Group, the Chepultepec Dolomite of the middle Knox Group, and the Copper Ridge Dolomite of the lower Knox Group. Water-quality data from about 900 samples from Precambrian to Pennsylvanian aquifers in Kentucky and about 600 samples from Cambrian to Pennsylvanian aquifers in Tennessee indicates that groundwater from the Mascot Dolomite of the Cambrian-Ordovician Knox Group has lower dissolved solids concentration than would be predicted by trends in other aquifers. Selected water quality and geochemical data, including total dissolved solids, chloride/bromide ratios, and stable isotope ratios (del-D and del-18O) are evaluated for the aquifers in the Knox Group in Tennessee.

Water quality and geochemical data from recently sampled Knox wells along the western side of the Cincinnati Arch in Tennessee and Kentucky indicate a mixing of formation and meteoric water. Groundwater from two wells west of the Cincinnati Arch in Kentucky have very high dissolved solids and dissolved chloride concentrations and are indicative of evaporative marine water in the formation. Groundwater from two wells in Middle Tennessee, west of the Cincinnati Arch, have relatively low dissolved solids and chloride concentrations and indicate the influence of younger meteoric water in the formation. The stable isotope data for oxygen and hydrogen for the wells are close to the meteoric water line, suggesting the influence of meteoric water. (Hancock County, Kentucky del-18O= -5.1 to -5.5 per mil, del-D= -40 to -41.5 per mil; Hickman County, Tennessee del-18O= -6.35 per mil, del-D= -38.3 per mil; Wayne County, Tennessee del-18O = -5.26, del-D = -28.2) Chlorine-36 isotope analysis for water from the two wells also suggests the influence of modern waters for Knox wells in Middle Tennessee. The chlorine-36 analysis for Hickman County, Tennessee well indicated significantly younger water with results for the Kentucky well indicating a much older water (>1.5 million years).

The occurrences of lower dissolved solids in water at depth in the Knox Group in Middle Tennessee are indicative of a permeable unit that has some connection with meteoric water. The indicated mixing of formation and meteoric water and the potential interconnection with groundwater from shallower aquifers has implications on possible carbon sequestration in these formations. Potential recharge and movement of younger, relatively fresh water into and through the Mascot Dolomite indicates the potential for carbon dioxide leakage updip or possible leakage through fractures in the overlying formations.

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HYDROLOGIC AND GEOLOGIC CONTROLS ON CARBON TETRACHLORIDE TRANSPORT AND BIODEGRADATION AT THE VELSICOL DUMP, HARDEMAN COUNTY, TENNESSEE

Tom Byl[1], Michael Bradley[1], Randy Thomas[2], and Brandon Cobb[1]

An unlined landfill in Hardeman County, Tennessee was used by the Velsicol Chemical Corporation from 1964 to 1973 to dispose of 100,000 to 300,000 barrels of industrial waste. An investigation of groundwater contamination at the landfill was conducted to identify contaminant sources and the modes of contaminant transport, quantify contaminant concentrations and loads in the tributaries draining to Clover Creek, and evaluate the potential for in situ biodegradation. A seepage investigation and water-quality results identify two modes of contaminant transport to the tributaries. A ground-water plume transports carbon tetrachloride (CCl_4) and other contaminants to the streams through diffuse discharge, resulting in typical CCl_4 concentrations of 2 mg/L or less and consistent concentrations and loads in the tributaries. High permeability zones, probably related to gravel in the terrace deposits, and concentrated flow zones near sand/clay contacts have produced seeps and springs along the banks of the tributaries and at the edge of the adjacent wetland with notably higher carbon tetrachloride concentrations (2 to 28 mg/L). Geochemical and microbial evaluations from multiple groundwater samples indicate that conditions are favorable for natural or enhanced attenuation of the contaminants in the Clover Creek valley, but not in the uplands. Groundwater discharge along the tributaries and into the wetlands was iron or sulfur reducing. Lab microcosms constructed with upland aquifer materials had carbon tetrachloride half-lives of 90 days when no supplements were added; half lives dropped to 2 days when supplemented with lactate and molasses. Similar lab microcosms constructed using aquifer soils collected in the valley had a CCl_4 half-life of 16 days when no supplements were added. Addition of lactate and molasses to the valley-microcosms reduced the half-life to 2 days. In general, contamination from the landfill continues to migrate from the landfill to a creek to the east, north to the Clover Creek wetlands, and to tributaries west of the site. A large contaminant mass remains in the subsurface, and dissolved phase VOCs are discharging along the higher elevation tributaries that drain to Clover Creek and at seeps along the southern edge of the Clover Creek wetland. The ratio of parent product to breakdown by-product is greater than 6 to 1 in the upland wells, indicating less biodegradation is occurring there. That ratio of parent product to breakdown by-product shifts to less than 2 to 1 in the low lands. The microcosm results indicate that the electron donors driving the biological reductive dechlorination process is lacking in the upland aquifer, but is more prevalent in the subsurface near the valley tributaries and Clover Creek.

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TENNESSEE UNDERWATER CAVES: ENABLING WATERSHED MANAGEMENT THROUGH DIRECT OBSERVATION, MAPPING, AND VISUALIZATION OF HIGH FLOW WATER CONDUITS

Christina Richards and Jason Richards

ABSTRACT

Tennessee's rich karst environs are home to nearly 10,000 caves, many of which act as high speed phreatic conduits to move extensive amounts of water. Often considered to be isolated sinkhole springs, many of these consist of miles of underground passageways, potentially posing hazards to people and the environment far from the spring opening. Because these systems cannot be accurately modeled using typical fractured media or karst terrain hydrologic models, exploring and mapping by trained cave divers provides the only reliable method to establish point source pollution and evaluate effects on downstream water resources. For the past six years, cave divers have explored and mapped some of these systems throughout Tennessee. Two examples to demonstrate the work and its importance are caves that have been mapped in Marion and Ruther ford counties. State regulatory agencies are using results gained from the exploration of Jasper Blue Spring in Marion County, to refine watershed estimation and planning. Divers surveyed 2,632 feet of main passage and identified three troglobitic species previously unknown in the spring. Cow Crap Cave, previously believed to be an isolated karst feature, moves millions of gallons of water, animal wastes and surface debris into a subsurface tunnel believed to connect to a major karst drainage system in Rutherford County. Currently surveyed to 6,811 feet, the cave is threatened by encroaching development from nearby Murfreesboro. These caves are excellent examples of how knowledge of subsurface conduit transport provided by divers is essential to land managers attempting to protect aquifer resources.

DECIPHERING MICROBIAL CONTROLS ON CARBON CYCLING IN KARST AQUIFERS

Terri Brown[1], Kathleen M. Brannen[1], and Annette S. Engel[1]

Dissolved organic matter (DOM) is the predominant form of organic carbon in freshwater ecosystems, and is important in processes such as metal complexation, mobilization of radionuclides and anthropogenic pollutants, and nutrient cycling. Aquifers have not been considered in the development of carbon budgets or climate change models, but may be significant due to microbially-induced transformation and recycling of organic material. Caves and aquifers offer model systems for carbon cycle studies under aphotic, oligotrophic conditions, and enable the measurement of DOM properties as sensitive tracers of organic matter inputs from terrigenous (allochthonous, plant-based) and internal (autochthonous, microbial) sources. Most karst aquifers are interconnected with surface water systems - receiving allochthonous inputs via sinking streams and other forms of recharge, and returning microbially-transformed recalcitrant DOM at spring resurgences and hyporheic inflows.

Fluorescence spectroscopic characterization of bulk water samples can be used to differentiate between sources and timing of groundwater recharge, and to indicate potential pollution. More detailed information can be gleaned from DOM through the use of a new configuration of solid phase extraction to rapidly isolate DOM *in situ* into major macromolecular groups. ATR-FTIR analyses of the isolates allow the identification of microbial metabolites (lipids, polysaccharides, and proteinaceous materials) that vary with depth and distance along the flow paths of cave streams and aquifers. These biomarkers can be isotopically labeled and measured to elucidate biotic and abiotic processes, enable the estimation of carbon fluxes through carbonate aquifers, and to develop metrics for monitoring the long-term biogeochemical status of groundwater ecosystems.

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QUANTITATIVE DYE TRACING - DEVELOPMENT OF A NEW INTERPRETATIVE METHOD

Irucka Embry[1], Victor Roland[1], Roger Painter[1], Rick Toomey[2], and Lonnie Sharpe[3]

Special acknowledgment to Tom D. Byl[1,4], USGS, for assistance in this study and manuscript review

Due to the complexity of possible flow paths in karst aquifers, it is difficult to create a mathematical framework to model the flow of contaminants and other particles through the aquifer. The objective of this project was to apply both traditional methods of tracer interpretations and a new interpretative method to tracer data from a quantitative field tracer study at Mammoth Cave National Park. Generally, a tracer study is performed to qualitatively or quantitatively approximate the flow conditions. The quantitative results of the tracer experiment are displayed in the tracer breakthrough curve which represents the effluent tracer concentration over time. The breakthrough curve can be used to determine the residence time distribution (RTD) function. The RTD function numerically describes the time that particles have spent reacting in a system. This project focuses on the continued development and application of a new dye tracer interpretative method as compared to the traditional advection dispersion equation (ADE) method. The interpretive method is based on the gamma probability density function (PDF) where the tracer travel distance and linear velocity are assumed to be randomly distributed variables with gamma distributions. The gamma RTD function is derived from the individual distributions of tracer travel distance and linear velocity based on their relationship with time. The normalized forms of the gamma RTD and the advection dispersion equation RTD were compared with the normalized tracer RTD. The normalized gamma RTD function had a better fit than the advection dispersion equation RTD function with the tracer RTD function. This conclusion is based on the sum of the squares of the differences (SOSOD) between the normalized form of the gamma and the tracer RTD function versus the SOSOD between the normalized form of the advection dispersion equation and the tracer RTD function.

Keywords: Karst conduits, Tracer breakthrough curves, Residence time distribution, Advection dispersion equation, Gamma distribution, Normal distribution, Travel distance, Linear velocity, Travel times, Probability density function

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INTRODUCTION

A descriptive, probabilistic mathematical model was developed to model karst aquifers which is based on the gamma distribution. The gamma distribution is a function of random variables that are exponentially distributed and is frequently used as a probability model for waiting times studies. In hydrological karst studies, the gamma distribution can create an appropriate RTD as it is a two parameter model and allows for the flexibility to account for nonlinearities. It is unclear which physical interpretation can be ascribed to the gamma distributions' two parameters (α, β). To address this, a gamma distribution for the residence time was derived by assuming that the velocity and travel distance of the karst system were gamma distributed random variables.

This gamma distribution RTD function was tested on a natural karst system at Mammoth Cave National Park. The results of that function were compared to the results from the traditional advection dispersion equation (ADE) RTD function (see Field, Fogler, and Metcalf & Eddy for a discussion of the ADE RTD model). A quantitative rhodamine dye study was run to determine the travel time from the outlet of the Post Office filter to two receiving areas in the cave system, *Shaler's Brook* and *Devil's Cooling Tub*, which are indicated in Figure 1. The elevations and horizontal distances pertinent to better understanding Figure 1 and the dye study are included in Table 1. The test was set up on the afternoon of December 20, 2011, because it was scheduled to rain, but the rain came much later (around 3 A.M. on December 21). A tipping delivery system was triggered by the rain event and released both salt & rhodamine dye. (This set up is described more in the Materials and Methods section.)

At the outlet of the stormwater treatment system, which services the Post Office parking lot, a stream forms which empties into the cave downstream. The stream flow path and the approximate flow paths in the cave system are shown in Figure 1. Inside the cave, the stream has been shown to empty into an area known as *Annetta's Dome* (now *Annette's Dome*) and portions are also entering into another area called *Devil's Cooling Tub*, both located approximately 200 feet beneath the surface. *Devil's Cooling Tub* and *Annette's Dome* were part of the cave tours during the early 1900's and tourists routinely drank from these flowing waters as part of their tour. Figure 2 provides approximate locations for *Devil's Cooling Tub*, *Annette's Dome*, and other important features in the cave system.

Annette's Dome creates another feature known as *Shaler's Brook*, located approximately 60 feet beneath the ceiling. *Shaler's Brook* receives direct discharge from *Annette's Dome*, therefore it is used as an endpoint in the dye study along with *Devil's Cooling Tub*. These subsurface areas were selected because previous tracer studies indicated relatively rapid rates of surface recharge at *Devil's Cooling Tub* and *Shaler's Brook*. At *Devil's Cooling Tub* discharge rates ranged from 0.5 L/min to 51.95 L/min. Discharge measurements for *Shaler's Brook* were taken at the formation known as *Lee's Cistern*, which receives direct discharge from *Shaler's Brook* approximately 50 yards downstream. *Lee's Cistern* discharge measurements ranged from 6.57 L/min to 176 L/min.

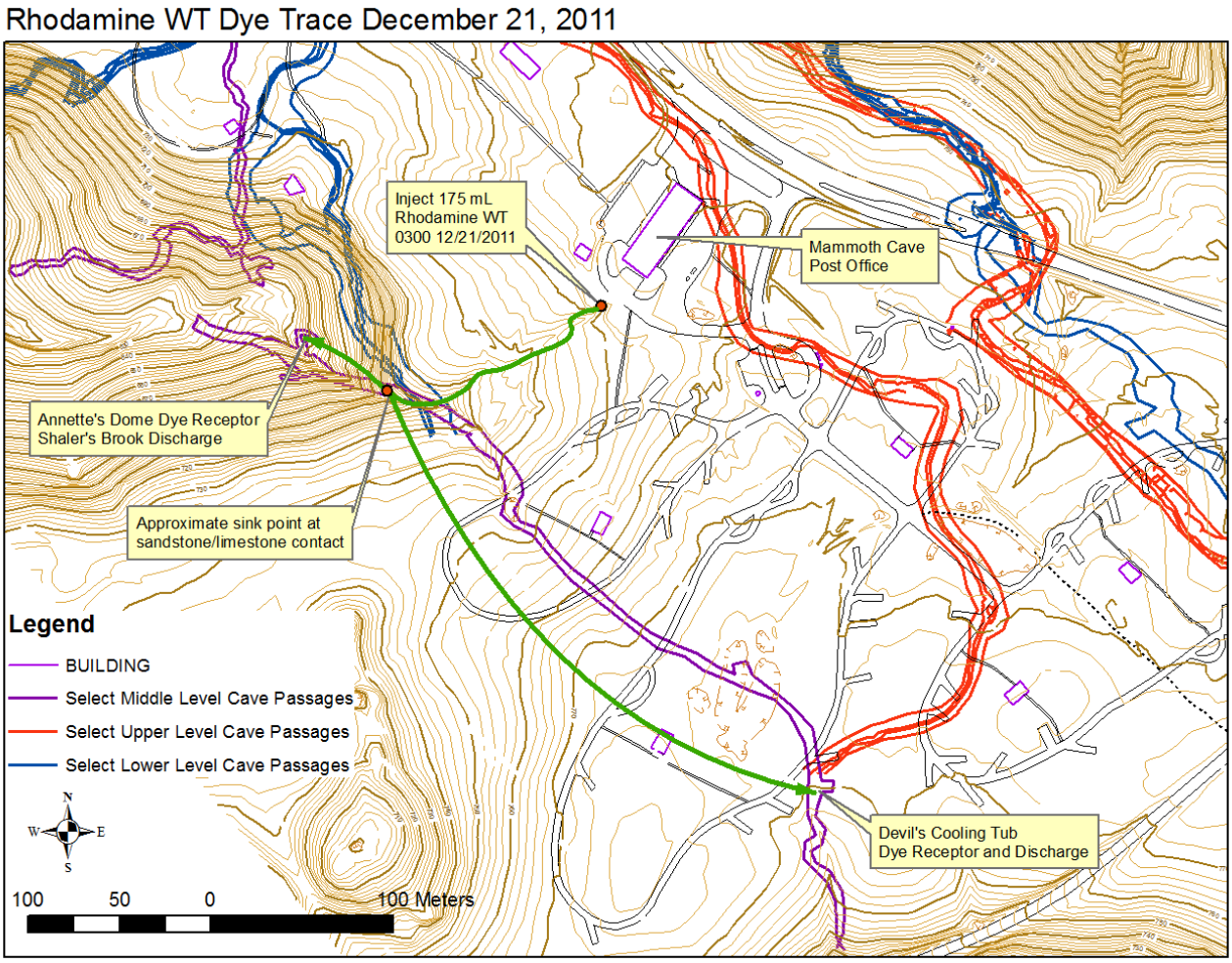

Figure 1: Topographical map of cave features with surface overlay. The green line represents the surface stream and an approximate flow path to both Shaler's Brook and Devil's Cooling Tub.

Table 1: Elevation and Distance Estimates for the Site Area	US Units	SI Units
Dye input site elevation	751 ft	229 m
Shaler's Brook elevation	~538 ft	~164 m
Devil's Cooling Tub elevation	~558 ft	~170 m
Dye site to Shaler's Brook straightline horizontal distance	541 ft	165 m
Dye site to Shaler's Brook horizontal distance along surface stream	640 ft	~195 m
Dye site to Devil's Cooling Tub straightline horizontal distance	968 ft	~295 m

Note: all elevations are amsl – above mean sea level

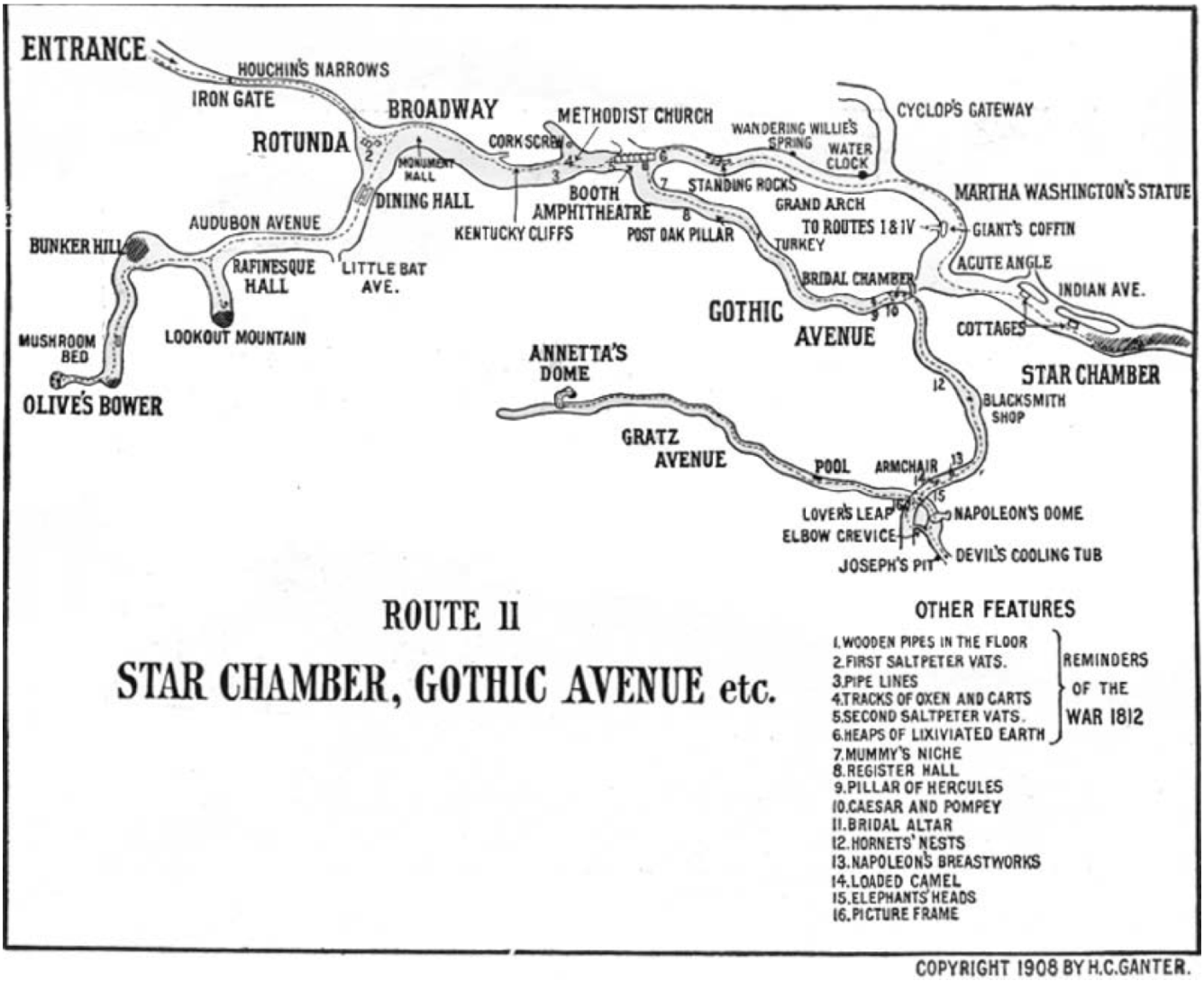

Figure 2: 1908 Tour Map showing the 200 ft level of the cave showing cave features by their colloquial names, which are used to this day. Annette's Dome (Annetta's Dome on the map) and Devil's Cooling Tub were referred to in this study.

MATERIALS AND METHODS

Discharge measurements were collected at *Lee's Cistern* and *Devil's Cooling Tub* at various dates preceding the quantitative dye tracer study. These discharge measurements were used to determine the amount of dye needed to avoid poor results from excessive dilution, but also remain within a safe range to preserve the karst ecosystem. At *Lee's Cistern,* discharge was measured using a plastic tarp to concentrate the stream, and then recording the amount of time needed to fill a container of known volume. This was done in triplicate. At *Devil's Cooling Tub,* a similar procedure was followed to measure discharge.

The quantitative dye study was conducted on December 20, 2011, beginning on the surface at the outlet of a stormwater filter, which services parking lots adjacent to the post office on the park grounds. Inside the cave, fluorometers with rhodamine sensors and 1st flush samplers were placed in two areas of the cave where they measured the amount of time taken by the dye to move through the karst system. The locations within the cave, *Shaler's Brook* and *Devil's Cooling Tub*, were selected because they were suspected to interact with the surface relatively rapidly and provide surface recharge for two major karst springs in the formation, Echo River and River Styx. Dye selected for the study was Rhodamine WT-20. Concurrently, a salt tracer study was also conducted to gain additional hydrologic data. The tracers were placed on a release mechanism, see Figure 3 for the setup. The release mechanism consisted of a Styrofoam tray with approximately ¼ lb of table salt (114 g NaCl) laying flat on the tray & 175 mL of Rhodamine WT-20 in a plastic bottle standing upright on the tray. This mechanism was placed in the outlet of the storm filter system. Below, we placed a 1st flush sampler (white plastic container with the red lid) and a YSI datasonde (to measure the salt concentration) set to read every 5 minutes.

Additional 1st flush samplers and YSI datasondes with rhodamine sensors set to read at 20 minute intervals were placed in the cave. See Figure 4 to see the location of the datasondes and the 1st flush sampler in *Shaler's Brook*. As the storm waters exited the filter, they reached a high enough velocity to flush the tray out & spill it. The tray was elevated approximately 0.5 inches in the discharge pipe to keep it from dumping on the very first trickle; rather, it needed enough flow to lift it & destabilize it. Based on the readings measured by the instruments, we concluded that the tracers were released at approximately 3:00 A.M. on December 21, 2011 due to the rain event.

Figure 3: Photograph showing the dye and salt release mechanism. Also shown in the picture are the 1st flush sampler and the YSI datasonde.

Figure 4: Photograph showing the pool at the bottom of Annette's Dome and the beginning of Shaler's Brook. Also pictured is the YSI datasonde with the 1st flush sampler.

RESULTS

The results of the Rhodamine WT-20 quantitative dye study at Mammoth Cave are shown in the following graphs and tables. The results have been analyzed for *Shaler's Brook* only.

The results from numerical integration of the concentration versus time (tracer breakthrough curve) data for the tracer study conducted are shown in Table 2. Table 3 displays the numerical integration of the normalized gamma RTD versus the normalized time.

Figure 5 shows the tracer breakthrough curve.

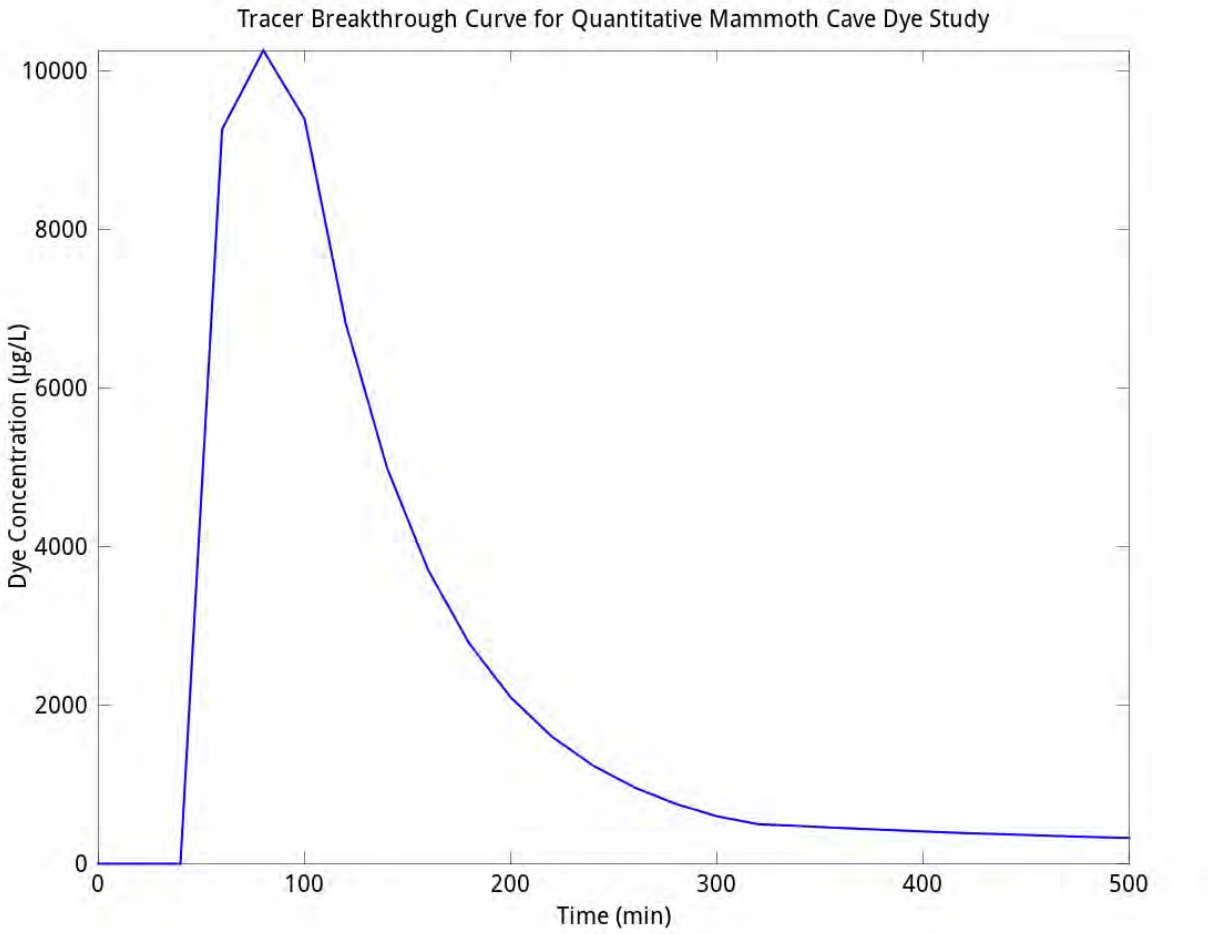

Figure 5: Dye concentration in Shaler's Brook versus time data for the conservative tracer test. This data was used to determine the mean, variance, and Peclet number for the karst system.

The results of the dye study were then used to develop the residence time distribution (RTD) function. The RTD function [E(t)] for contaminant molecules in a single karst conduit or a complex system of conduits is a probability density function (PDF) which can be interpreted to define the probability that contaminant molecules present at the influent at time equals zero will arrive at the effluent after a particular amount of time. The RTD is depicted as a plot of E(t) versus time as time goes from zero to infinity (or a reasonably long time where the RTD approaches zero).

E(t) was determined by injecting a pulse of a conservative tracer (Rhodamine WT-20) into the cave system by the mechanism shown in Figure 3 at time (t) = 0 and then measuring the tracer concentration in the effluent as a function of time.

Note: The mean residence time (t_m) is the 1st moment of the RTD function E(t). The variance (σ^2) is the 2nd moment taken about the mean. The magnitude of the variance is the "spread" of the distribution.

Table 2: Experimental Results for Tracer Study	
σ^2 (min^2)	7951
t_m (min)	140
Space Time (min)	111
Peclet Number (dimensionless)	7.56
Mass in (g)	208
Mass out (g)	50
Recovery (%)	25

Note: The mean residence time (t_m) is the 1st moment of the RTD function E(t). The variance (σ^2) is the 2nd moment taken about the mean. The magnitude of the variance is the "spread" of the distribution.

Table 3: Normalized Gamma RTD Results	
σ^2 (dimensionless)	0.60
t_m (dimensionless)	1.56
mean velocity (dimensionless)	136.5

The tracer normalized (dimensionless) RTD model from the numerical integration of the tracer data is shown along with the normalized advection dispersion equation (ADE) RTD model and the normalized gamma distribution RTD model in Figure 6.

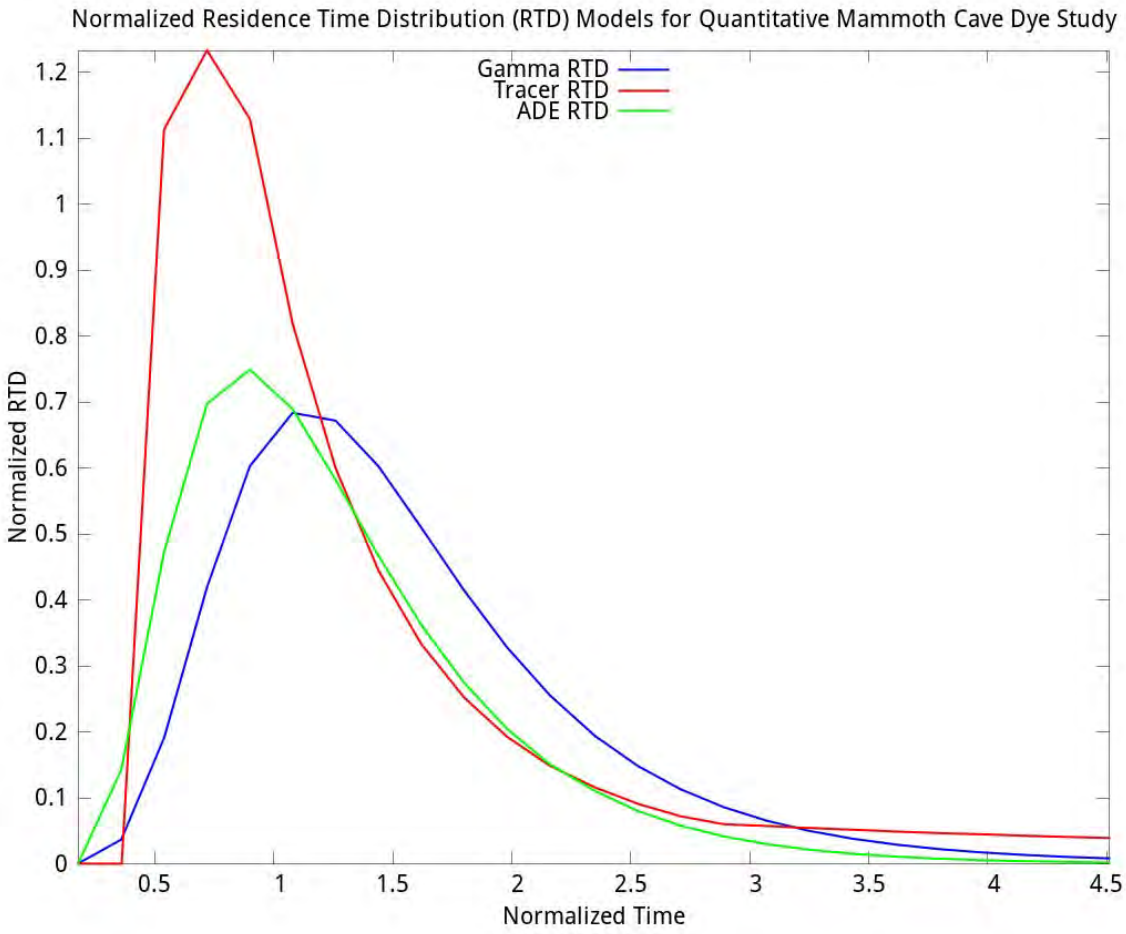

Figure 6: Comparing the normalized (dimensionless) tracer RTD, the normalized advection dispersion equation RTD, and the normalized gamma distribution RTD models for the tracer study conducted at Mammoth Cave (Shaler's Brook).

DISCUSSION AND CONCLUSIONS

The normalized gamma RTD function had a better fit with the tracer RTD function than the advection dispersion equation RTD function. The sum of the squares of the differences (SOSOD) between the normalized form of the gamma RTD and the tracer RTD was approximately 63; however, the SOSOD between the normalized form of the advection dispersion equation (ADE) RTD and the tracer RTD was approximately 751. See Table 4 for the numerical comparison of the normalized RTD models graphically compared in Figure 6. With the normalized gamma RTD function it is possible to calculate the mean velocity and the mean distance traveled from the α and β parameters obtained from the best fit of the normalized gamma RTD to the normalized tracer RTD. This correlation is not possible with the normalized ADE RTD function. For those reasons, we conclude that the descriptive, probabilistic, gamma distribution RTD function better models this particular karst site at Mammoth Cave, Kentucky.

Note: The SOSOD for the normalized gamma RTD was approximately 63; however, the SOSOD for the normalized ADE RTD was approximately 751.

Table 4. Comparison of the Normalized ADE and Gamma RTD versus the Normalized Tracer RTD

Normalized ADE RTD Values	Normalized Gamma RTD Values	Normalized Tracer RTD Values
0.0015	0.00070	0
0.1420	0.03667	0
0.4728	0.19076	1.113
0.6972	0.41906	1.233
0.7488	0.60269	1.129
0.6892	0.68362	0.819
0.5823	0.67176	0.600
0.4670	0.60274	0.445
0.3622	0.50967	0.333
0.2745	0.41436	0.252
0.2047	0.32818	0.193
0.1509	0.25548	0.149
0.1102	0.19382	0.116
0.0800	0.14819	0.091
0.0578	0.11291	0.072
0.0416	0.08592	0.060
0.0298	0.06541	0.057
0.0213	0.04987	0.054
0.0152	0.03811	0.052
0.0108	0.02921	0.049
0.0077	0.02246	0.047
0.0055	0.01734	0.045
0.0039	0.01344	0.043
0.0028	0.01046	0.041
0.0020	0.00817	0.039

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ACKNOWLEDGEMENTS FOR THE MAPS

Mammoth Cave International Center for Science and Learning

Hovey, H.C. 1909. Mammoth Cave Kentucky Hovey's Practical Guide to the Regulation Routes. Louisville, KY: John P. Morton & Company, Inc.

SOFTWARE ACKNOWLEDGMENTS

LibreOffice Writer/Calc 3.3.4
http://www.libreoffice.org/

GNU Octave 3.2.4
http://www.gnu.org/software/octave/

Gnuplot 4.4
http://www.gnuplot.info/

SESSION 2A

HEALTH
8:30 a.m. – 10:00 a.m.

Results of a Data Evaluation to Establish Priority Remediation Areas for Dry Weather Fecal Contamination in a Karst Influenced Watershed
Steve Evans, Stefanie Farrell, and Demetria R. Kimball

Survey of Pharmaceutical and Personal Care Products in Untreated Drinking Water in Tennessee
Alice Layton, Fu-Min Menn, Melanie Eldridge, Gary Sayler, Scotty Sorrells, and Tom Moss

Review of a Municipality's Use of a qPCR Technique for Fecal Source Tracking in Impaired Streams
Megan Stallard

HEALTH II
10:30 a.m. – 12:00 p.m.

Assessing Microbiological Integrity of Water Supply with High-Throughput Sequencing
Qiang He and Yan Zhang

Detection of Pentobarbital in Leachate from an Organic Burial Pit Containing Euthanized Large Animals
Shawn Hawkins, Fu-Min Menn, and Forbes Walker

Major Ion Toxicity: Technical Issues, Regulatory Status, and Options in Water Quality Management
Lauren Minella and Scott Hall

PLANNING I
1:30 p.m. – 3:00 p.m.

The City of Franklin's Integrated Plan to Address Water Resource Challenges
David Mason and Zach Daniel

Dissolved Oxygen, What 10 Years of Data Tells Us About Water Quality in the Harpeth River
Dorene Bolze and Michael Cain

Working with Non-industrial Private Forest Landowners to Ensure a Clean, Abundant Public Water Supply
David Arnold, Kerry Livengood, and Tim Phelps

PLANNING II
3:30 p.m. – 5:00 p.m.

Climate Adaptation for Water Resources in Tennessee
Gwen Griffith

Past, Current, and Future Water-Use Studies in Tennessee
John A. Robinson

Understanding Flood Events in the Greater Nashville Metropolitan Area 1970-2010: Correlating Urban Growth with Analysis of Storm Water Discharge in the Cumberland River Watershed
C. Schaney and A. Kalyanapu

RESULTS OF A DATA EVALUATION TO ESTABLISH PRIORITY REMEDIATION AREAS FOR DRY WEATHER FECAL CONTAMINATION IN A KARST INFLUENCED WATERSHED

Steve Evans[1], Stefanie Farrell[1], and Demetria R. Kimball[2]

Synopsis – This study will demonstrate how to utilize E. *coli* concentration with flow data to comparatively analyze pollution sources to direct the investigation of hot spots and/or sewer line maintenance in a variety of watershed applications but specifically focused on the challenges associated with karst drainage systems.

ABSTRACT

The goal of this study was to utilize a simple, cost effective means of identifying the land areas with the highest rate of sanitary sewer exfiltration to prioritize sanitary sewer investigations and point repairs. While wet weather problems including sanitary sewer overflows (SSOs) are generally well characterized by wastewater managers, sources of dry weather exfiltration are more difficult to identify, particularly in karst systems. This study was conducted in the Wolf Run watershed in Lexington, KY and analyzed stream flow and *E. coli* concentration data in conjunction with prior microbial source tracking assessments collected under low flow conditions in order to identify catchments with the highest incremental fecal load yields.

Two data sources were utilized in this analysis, each governed by an approved quality assurance project plan. A microbial source tracking study conducted in 2010 by the University of Kentucky Environmental Research and Training Laboratory (Brion et al 2011) was utilized to indicate the fecal load source. To calculate the fecal loading, dry weather *E. coli* sampling and stream flow measurements conducted under an EPA 319(h) grant for development of a Wolf Run watershed plan were utilized. *E. coli* samples were collected by Friends of Wolf Run and analyzed by the LFUCG Town Branch Laboratory and flow was measured by Third Rock Consultants.

The total loading and incremental loading were calculated in twelve catchment areas by utilizing the geometric mean of loading results from dry weather events and a simple spreadsheet model. In order to determine incremental yields, drainage areas were adjusted to account for karst flow.

As a result of this analysis, several areas within the Wolf Run watershed have emerged as priority areas to focus sanitary sewer remediation efforts. In order of priority, these areas include: 1) Wolf Run between Faircrest Drive and Lafayette Drive (W09), 2) Big Elm Tributary upstream of Harrodsburg Road (W11), and 3) Vaughn's Branch upstream of Tazwell Drive (W07).

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Correspondence between the microbial source tracking results and the highest loading sources indicates that human sewage is also the primary source of fecal pollution in the watershed.

As a result of this analysis, the LFUCG Division of Water Quality is conducting follow-up investigations, in addition to the remedial measures plan, to determine locations for point repair and remediation.

SURVEY OF PHARMACEUTICAL AND PERSONAL CARE PRODUCTS IN UNTREATED DRINKING WATER IN TENNESSEE

Alice Layton[1]*, Fu-Min Menn[2], Melanie Eldridge[3], Gary Sayler[4] Scotty Sorrells[5], and Tom Moss[6]

WATER QUALITY MONITORING AND ASSESSMENTS

Over the past decade, water quality surveys indicate that numerous areas of the United States, including Tennessee, have pharmaceuticals and steroid hormones in their waterways. Additional studies have linked the exposure of fish and amphibians to natural and synthetic steroids to reproductive and endocrine disruption (estrogen and/or androgen). Within the State of Tennessee, little is known about the potential for pharmaceutical compounds and/or endocrine disrupting compounds to contaminate drinking water supplies. However, it is reasonable to assume that protection of surface waters from contamination is an important step in protecting drinking water sources. In this project, 348 untreated drinking water samples (surface water and ground water) were tested for the presence of both pharmaceutical compounds and endocrine disrupting compounds. Fifteen chemicals were analyzed using GC/MS analytical methods and endocrine disrupting compounds were analyzed using estrogenic and androgenic detecting bioluminescent-based yeast (*Saccharomyces cerevisiae)* reporters. In general, concentrations for chemicals detected were less than 1 ppb. The most frequently detected class of chemicals was plasticizers, followed by fecal indicators, pesticides and detergents. The least frequently detected compounds were the pharmaceutical compounds. As may be expected, the frequency of detection of the chemical contaminants was higher in surface water than in groundwater. Overall, these results suggest that untreated drinking water sources in Tennessee have similar levels of trace organic contaminants with respect to both concentration and frequency of occurrence to water found in other parts of the United States.

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REVIEW OF A MUNICIPALITY'S USE OF A qPCR TECHNIQUE FOR FECAL SOURCE TRACKING IN IMPAIRED STREAMS

Megan Stallard[1]

Metro Water Services (MWS) in Nashville, Tennessee established a molecular laboratory in January 2010 to assist in identifying fecal sources in impaired 303d streams. A real-time quantitative polymerase chain reaction (qPCR) assay using the fecal bacteria, *Bacteroides* spp, was adopted from a protocol developed by Dr. Alice Layton, University of Tennessee (Knoxville). Traditional pathogen indicator (*E. coli/Enterococcus*) methodologies are limited to only presence/absence of fecal contamination without identifying the source. The genetic fingerprint of *Bacteroides* spp. is highly host-specific making it a promising tool for associating fecal contamination with the correct source. MWS is proactively collecting and analyzing seasonal data under both dry and wet weather conditions in Davidson County's impaired watersheds on a 5-year rotational basis. Through use of the PCR analysis, it is MWS' goal to determine the source inputs (animal or human) of fecal bacteria so that targeted pollution prevention programs can be implemented on a watershed basis. This laboratory will serve all MWS departments in prioritizing sewer and stormwater infrastructure projects, as well as creating a more focused public education program. This presentation will provide a brief overview of the technique, start-up considerations, achievements, limitations, and future direction for MWS and qPCR.

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ASSESSING MICROBIOLOGICAL INTEGRITY OF WATER SUPPLY WITH HIGH-THROUGHPUT SEQUENCING

Qiang He and Yan Zhang
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Controlling microbial contamination of drinking water is critical to public health. However, understanding of the microbial ecology of drinking water remains incomplete. Representing the first application of high-throughput sequencing in drinking water microbiology, pyrosequencing was used to characterize the bacterial diversity in drinking water. Pyrosequencing of 16S rRNA gene amplicons significantly improved the coverage of bacterial communities in drinking water, particularly rare populations that could not be readily identified by other techniques. The bacterial community composition was dominated by Alphaproteobacteria and Betaproteobacteria; however, rare populations accounted for the majority of bacterial diversity. The bacterial community in drinking water also experienced significant seasonal changes, with Oxalobacteraceae succeeding Methylobacteriaceae as the predominant bacteria family from winter to summer. These results were consistent with those from a 16S rRNA gene clone library analysis conducted in parallel with pyrosequencing. Phylogenetic analysis of the 16S rRNA gene sequences further revealed that bacterial populations with high relative abundance in drinking water were closely related to metabolically versatile bacterial species broadly distributed in natural environments, suggesting a potential link between environmental distribution, metabolic trait, and presence in drinking water.

DETECTION OF PENTOBARBITAL IN LEACHATE FROM AN ORGANIC BURIAL PIT CONTAINING EUTHANIZED LARGE ANIMALS

Shawn Hawkins[1,2], Fu-Min Menn[2], and Forbes Walker[1]

The disposal of animal mortalities creates surface and ground water pollution concerns. In the case of euthanized animals, there is particular concern for drugs residuals that may be mobilized in leachate as carcasses decompose. In this study, we describe an experimental organic burial pit containing mature dairy cattle euthanized after participation in a clinical vaccination trial. The animals were buried in wood chips to promote composting and rapid decomposition of the carcasses. The pit included a plastic liner that allowed rainfall derived leachate to be collected from the pit. New GC/MS detection methods were developed to analyze the leachate for the two barbiturates used to euthanize the animals, namely xylazine and pentobarbital. Our findings indicate that the xylazine degrades quickly, but that the pentobarbital was persistent over a period of several weeks and easily detectable in the leachate. We describe the burial experiment, the new GC/MS detection techniques for xylazine and pentobarbital, and leachate concentrations of xylazine, pentobarbital, *E. coli*, and oxygen demand.

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MAJOR ION TOXICITY: TECHNICAL ISSUES, REGULATORY STATUS, AND OPTIONS IN WATER QUALITY MANAGEMENT

Lauren Minella and Scott Hall
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Chloride is currently the only “major ion” for which EPA has published water quality criteria. Some states have developed chloride and sulfate standards, both of which are a function of water hardness. Recent research has indicated that the toxicity of many major ions, those typically present in natural waters and effluents at relatively high mg/L concentrations, is a function of water quality, especially the presence of other major ions. Additionally, much is now known about the relative sensitivity of different aquatic taxa to various major ions, the relative toxicity of individual ions, and the emerging knowledge that freshwater mussels may be especially sensitive to major ions. This presentation summarizes the recent knowledge on major ion toxicity, the relative toxicity of the ions, and emerging knowledge on water matrix effects on ion toxicity that is being incorporated into water quality management.

THE CITY OF FRANKLIN'S INTEGRATED PLAN TO ADDRESS WATER RESOURCE CHALLENGES

David Mason, PE, D.WRE, and Zach Daniel, PE
CDM Smith

The City of Franklin experienced rapid growth in the 90's and 00's. With this growth came increased pressure on City services and infrastructure, such as water, wastewater and stormwater. Historically, as in most communities, planning for these separate utilities in Franklin had been conducted independently. However, the City realized that there are certain advantages to performing integrated planning of water resources, such as 1) comprehensive understanding of the impacts of decisions over all aspects of water management; 2) cost savings to the City and ratepayers; and 3) common means—in this case, the Harpeth River—to measure progress and, ultimately, success. In order to develop this plan, the City organized a broad public stakeholder effort that included local citizens, elected officials, regulators and environmental interests. The plan included recommendations for water supply and treatment, wastewater treatment and disposal, water reuse, and stormwater management. The overarching goal of the Intergrated Plan was to provide a means for continued economic growth in the City while also meeting environmental regulations, such as local TMDLs on the Harpeth River. In the fall of 2011, the stakeholders agreed on a plan to present to the City's Board of Mayor and Aldermen for consideration. This presentation will focus on the process for developing the plan, the criteria for evaluating the plan, and the results of the plan.

DISSOLVED OXYGEN, WHAT 10 YEARS OF DATA TELLS US ABOUT WATER QUALITY IN THE HARPETH RIVER

Dorene Bolze[1] and Michael Cain[1]

For ten years the Harpeth River Watershed Association has collected DO data along nearly 70 miles of the Harpeth River. The headwaters of the Harpeth are in rural Rutherford County, an area that is highly agricultural, then the river flows through Williamson County that runs from rural to suburban to urban to suburban and back to rural before entering Davidson County, which is predominately suburban/urban, and then into Cheatham County that is mostly rural. There is one large point source discharger – the Franklin STP – and several smaller dischargers on the main stem of the river from Eagleville in Rutherford to Cheatham County and on several tributaries in Williamson, Cheatham and Dickson Counties.

The Franklin STP, the largest discharger by far in the Harpeth River watershed, has the capacity to treat 12 MGD. Currently the facility's annual average daily rate is 7.5 MGD, but with current reuse of effluent for irrigation, discharges just over 6 MGD into the river. In comparison, the river's daily mean flow is 3.2 MGD (5 cfs) or below over 45% of the time in September based on USGS gage data two miles upstream of the discharge point. The Dissolved Oxygen data indicate that the river does not meet the TN state water quality standard for dissolved oxygen of 5 mg/L upstream of the Franklin discharge, and that low DO below the state standard consistently occurs downstream for over fifty river miles. During the river's summer low flow season, the percentage of flow that is effluent in the river can range from 25% to over 90%, and this is at the current discharge of about only half the capacity of the Franklin STP. Over 50 miles of the Harpeth River is effluent dominated about four months of each year.

The DO data indicates the need for better management of this resource through better management of non-point source pollution especially in the upper reaches, but that the most significant effect on the river's DO concentrations during the low flow summer session is the discharge of treated effluent from the sum total of the 3 sewage treatment facilities on the Harpeth in Williamson County. The best chance for improving the water quality, lies in the management of these point sources along the river, especially the overwhelming volume of the Franklin STP. This problem is only due to get worse as Franklin continues to grow and increase its discharge up to the limits of its current NPDES permit.

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WORKING WITH NON-INDUSTRIAL PRIVATE FOREST LANDOWNERS TO ENSURE A CLEAN, ABUNDANT PUBLIC WATER SUPPLY

David Arnold, Kerry Livengood, and Tim Phelps[1]*

INTRODUCTION

Tennessee has a diverse and extensive forest resource. The state is over half forested (52%), is overwhelmingly a hardwood state (89%), with most forestland in non-industrial private ownership (85%) (Paugh and others, 2010; Oswalt and others, 2009). Tennessee's forests also supply the raw materials needed to support a $21 billion dollar economic engine providing over 101,000 jobs across the state (Menard and others, 2011). The state's forests provide other "non-traditional" benefits, including water quality and quantity protection, habitat for wildlife, habitat for rare and endangered plants and animals, opportunities for recreation, aesthetics, carbon sequestration, and open spaces.

The 2008 Farm Bill directed all states to develop a statewide Forest Action Plan (FAP) that characterized the state's forest resources, identified threats impacting those resources, and developed strategies to address these threats. Tennessee's FAP emphasizes the role forested watersheds play in protecting, maintaining and enhancing public use water supplies. The highest priority watersheds in the FAP are greater than 50% forested, face significant threat to development and provide most of the public water supply for at least one water intake. Therefore, these watersheds depend on healthy forests and riparian buffers for quality water yield. Strategies are underway within these priority watersheds to encourage forest landowners to keep their forests as forests, plant forested riparian buffers, and utilize forestry best management practices when harvesting timber. These efforts are designed to ensure watersheds continue to produce clean, abundant water for public use.

APPROACH

The goal of this project is to protect, maintain and enhance priority public use water supplies by improving and maintaining forest cover. Active forest management planning and implementation of sound forestry practices on private lands will maintain, enhance and protect water quality. Following is a description of how priority watersheds and landowners were identified to allow focusing of limited technical and financial resources that lead to active forest management planning and practice implementation.

Priority watersheds were identified at the 12 hydrological unit code (HUC) level. The resolution offered by 12 HUC watersheds (25,000 to 50,000 acres) helps clarify planning, mapping, communicating, and implementing project priorities and activities. Characteristics of priority watersheds include 1) greater than 50% forested, 2) face significant threat to development, and 3) provide most of the public water supply for at least one water intake.

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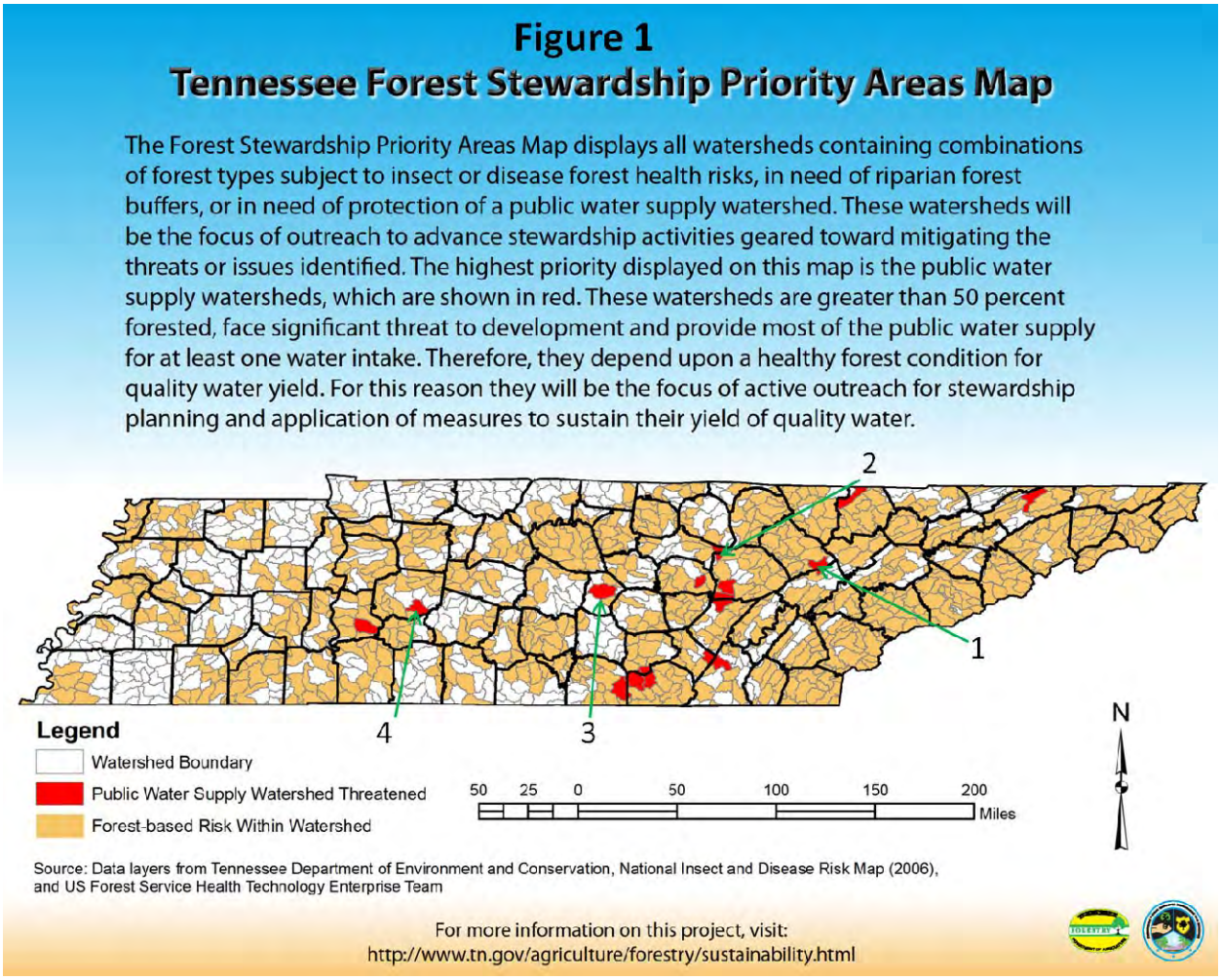
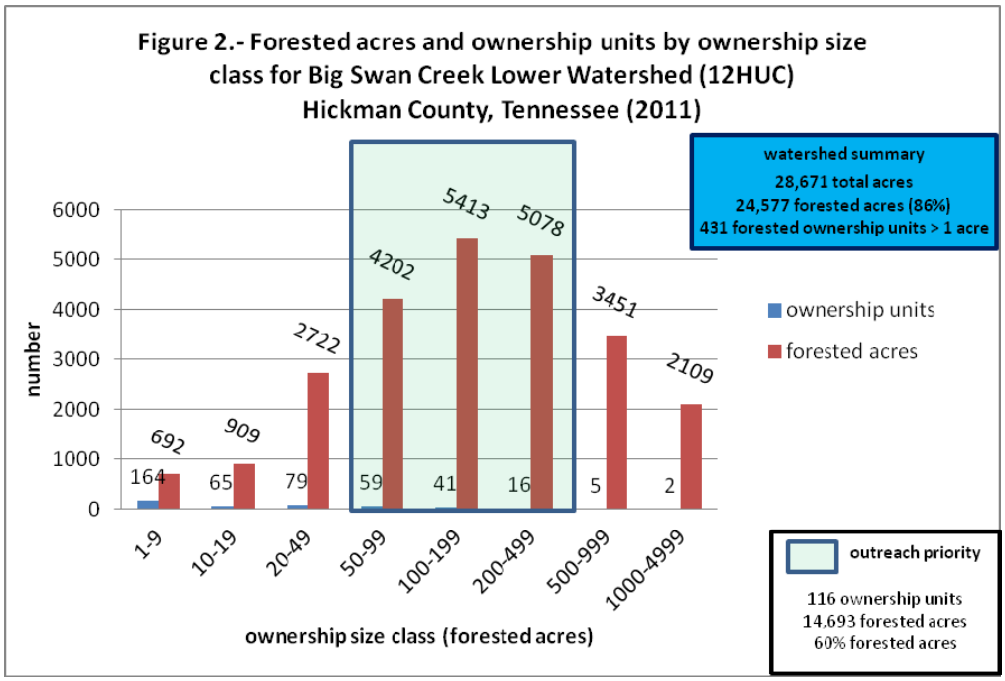
Information on forest cover, threat to development, and location of public water supply intakes was summarized using geographic information system (GIS) technology. The resulting analysis identified 14 public water supply priority watersheds (red watersheds) within the state (figure 1).

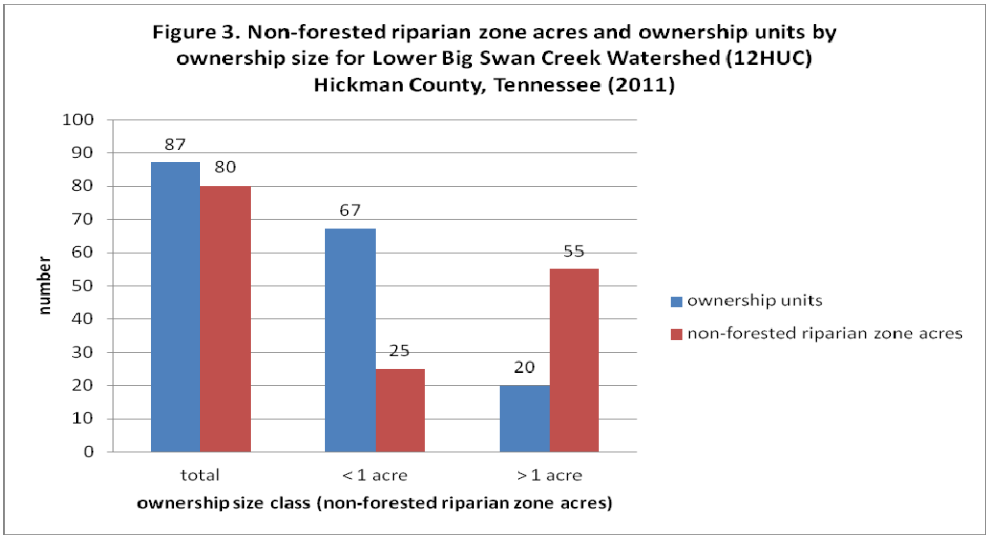


Four of the public water supply priority watersheds were then selected to develop protocols for the project. These initial watersheds included: 1) Little Emory River, 2) East Fork Obey River, 3) East Fork Stones River-Hollis Creek and 4) Big Swan Creek Lower (figure 1). Priority landowners were then identified in each watershed based on forestland ownership size and amount of stream bank without forested riparian buffer.

Forest cover and county tax assessor parcel GIS layers were used to characterize forestland ownership demographics within each watershed. Methodology as used by Butler (2008) provided a means to summarize forestland ownership and potential program participants. Prioritization was based on identifying a demographic "slot" that balanced the number of landowners by forested acres size classes. The goal was to work with a manageable number of landowners who owned a significant portion of the forestland in the watershed (figure 2).



Forest cover, county tax assessor parcel, and stream GIS layers were used to characterize forested riparian buffer ownership within each watershed. The stream layer was buffered by applicable distances based on stream size then analyzed for the presence or absence of riparian forest buffer. The county tax assessor parcel layer was then used to identify riparian area ownership. Parcels were ranked by acres of stream segments without forested riparian buffers. Landowners having one acre or greater of riparian area without forest cover were identified as potential program participants. Similar to the forestland priority, the goal was to work with a manageable number of landowners who owned a significant portion of the riparian area needing improvement in the watershed (figure 3).



NEXT STEPS

Direct mailings, individual personal communications, participant/partner meetings, and other strategies will be used to encourage priority landowners to participate in activities that maintain forests in priority watersheds. These landowners will be made aware of the role their forestland plays in protecting local water supply. They will also receive information on the services/programs available through natural resource management agencies/organizations that would help them "keep forests as forests, plant trees along creeks, and implement forestry best management practices when harvesting timber". We hope these efforts result in landowners becoming more engaged in maintaining and establishing forest cover, resulting in the maintenance, enhancement and protection of the public use water supply.

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CLIMATE ADAPTATION FOR WATER RESOURCES IN TENNESSEE

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INTRODUCTION

The safeguarding of our water resources is critical to the capacity of communities and wildlife to adapt to a rapidly-changing climate. The impacts of climate change are becoming more evident every year with recording breaking heat waves, drought, extreme storms, floods, seasonal shifts, and forest fires. The already burdened surface and ground water systems are being further degraded by these climate impacts. Tennessee is no stranger to these effects. The state has seen record high temperatures, severe drought in 2007, catastrophic flooding in 2010, and unprecedented deadly tornados in 2011. While no single event can be tied to climate change, this trend is very consistent with the climate model predictions. The southeast region can expect to continue to see more intense floods, droughts and storms with shifting seasonal precipitation patterns, more water quality degradation, and seasonal local supply issues.

Despite the fact that two-thirds of the U.S. water supply sources from rural forested watersheds, the critical role of U.S. forests and watersheds is often overlooked in efforts to bring climate resilience to local communities through planning and land use practices**. *Climate Solutions University: Forest and Water Strategies (CSU)*** is a program designed to address this gap by empowering rural communities to become climate resilient through adaptive strategies that protect forest, water and economic assets. CSU is an initiative of the Model Forest Policy Program (MFPP) developed in collaboration with the Cumberland River Compact. MFPP is a national organization that advocates for forest policies and practices that restore and sustain healthy productive forests, clean and abundant water supplies, and economically thriving climate-resilient communities. The Cumberland River Compact is a regional nonprofit dedicated to protecting the health, enjoyment and use of the water resources of the Cumberland River Basin through education and cooperation. Together MFPP and the Compact have created a program that helps rural communities design and implement climate adaptation plans that develop specific local watershed stewardship, land use policy and management practices at a variety of scales.

APPROACH

The CSU program is an outgrowth of two successful community planning processes that MFPP conducted in Tennessee and Idaho from 2007 to 2009. Both resulted in increased public engagement and customized policy changes to address climate planning and protect local watersheds and forests. MFPP subsequently partnered with the Cumberland River Compact to replicate the model in six communities in 2010 and six communities in 2011 stretching across the states of ME, NY, MI, TN, CO, UT, NM, CA, ID and WA. Four more communities from NC, CA and MI are beginning the program in 2012.

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The CSU program is provides in the first year a 10-month webinar-based curriculum and coaching program that guides communities through a process to assess their climate risks and opportunities and implement policies and practices that protect forests and watersheds from climate impacts. These communities in turn serve as a model for future locally-led forest and water climate adaptation planning. Through analysis of the lessons learned from local natural resource climate planning efforts, CSU aims to inform climate adaptation planning on regional, state, and federal policy levels.

To date, 3 Tennessee communities have been engaged in the CSU program – City of Cookeville, Sumner County, and Greene County. These community leaders have used the distance-learning CSU program as a guide to conduct an assessment of climate risks and create a strategy to address those risks through education, policy and on-the-ground conservation. The process and outcomes of the CSU climate adaptation program in Tennessee communities is the subject of this presentation.

The communities are chosen through a competitive application process. They are selected for rural forest and water resources in need of protection, leadership capacity, need for assistance, geographic distribution and funder priorities. They are provided a $10,000 stipend to support the work of the local project leader. The leaders may represent local government, watershed associations, educational institutions or other local civic organizations. Each participating community leads a project team through a four-step multi-year process: 1) build a climate team that incorporates strong and diverse stakeholder engagement; 2) conduct in-depth assessments of the local risks and opportunities related to climate, forest, water and economic conditions; 3) analyze the assessment findings and develop a specific and actionable climate adaptation plan that protects forest and water resources; and 4) implement the action plan with measurable results and adaptive management as needed. The work is facilitated through monthly webinars, coaching conference calls, weekly one-on-one community check-ins and additional customized coaching and consultation as needed to meet local team needs. Throughout the process, CSU encourages communities to engage scientific expertise and resources from local academic institutions and state and federal agency offices. MFPP continues to partner with communities for up to five years beyond the planning process as each works to implement the identified policies and projects.

RESULTS AND DISCUSSION

Three Tennessee communities have engaged with the CSU climate adaptation process so far:

- In 2009-10, the City of Cookeville Planning Department was engaged as the original southeast pilot community.
- In 2010, Sumner County Planning led the community through the CSU process in the first full year of the CSU adaptation curriculum.
- In 2011, the Middle Nolichucky Watershed Alliance led a team in Greene County during the CSU second year of curriculum delivery.

Each community was led by a local project leader who formed a local stakeholder team to support the process. Each one discovered climate related impacts already occurring plus long range projections of greater impacts in future decades. The following briefly summarizes the findings and approaches to climate adaptation for each community.

City of Cookeville Planning, TN

The Cookeville project was conducted as a pilot community project to test a method of adaptation planning. A local project leader was hired by the Model Forest Policy Program to seek engagement with the City of Cookeville. Over a period of 18 months the project leader conducted a series of educational programs on climate science and policy with a select group of local leaders and researched the climate risks and opportunities with the community work group. The risk findings included evidence of direct climate related impacts such as record temperature increases and changes in precipitation patterns with more severe storms, floods and drought conditions. They also found non-climate related stressors that were exacerbating water quality and supply issues such as poorly planned development and increases in nonpoint source storm water pollution. However, the middle Tennessee region appeared to have relatively modest climate impacts compared to other parts of the region, especially the coastal regions where storms and sea level rise threatens to force migration inland. One conclusion from the analysis was that growth and development from climate migration inland may be a significant threat to the forest and water resources of the Cookeville / Putnam County region in coming decades. As result of these findings, the Cookeville Planning Department was motivated to consider how to better manage growth in the face of climate change and the need for more sustainable development patterns. This was a timely process as the city was also in the process of updating their comprehensive plan in the same year. In 2009 the new Cookeville Comprehensive Plan became the first in Tennessee to integrate climate considerations into their long range planning guidelines. The city is still in the process of translating those guidelines into updated codes and ordinances, with a focus on managing growth and promoting low impact development.

Sumner County Planning, TN

In 2010, the Sumner County Planning Department led the CSU project along with a diverse team of local stakeholders. Again, the CSU process dovetailed nicely with the county's comprehensive planning process. The local CSU team served as the natural resource subcommittee for the planning process and the forest and water assessments informed the content of the county's newly adopted 25 year comprehensive plan.

Climate change impacts were identified in several key areas involving temperature, water, extreme weather, wildlife habitats, and public health. Temperatures are expected to continue increasing by 6 degrees Fahrenheit causing longer heat waves and more unpleasantly hot days over 100 degrees. Heat related illnesses and deaths will be more common. Water fluctuations, both too much and too little, are more likely. Flooding will be most likely in middle Tennessee, and droughts will impact water supply disrupting navigation, recreation, and electricity. Sumner County has experienced two recent examples—both with the flooding of May 2010 and the drought in 2007. Some wildlife habitats will win and some will lose. Biggest losers will be those in the coldest headwaters and birds in wetlands. Health will be impacted with poor air quality, increasing instances of asthma, and increase likelihood of diseases that cannot survive cold winters. High rates of waterborne diseases and vector borne diseases are also anticipated.

The climate adaptation plan complements the comprehensive plan, which was the second in Tennessee to integrate climate considerations into long range planning. The primary recommendations of the Sumner County adaptation plan focused on managing development, especially the need to protect headwater streams and forest resources by better managing steep slope development and increasing county-wide tree canopy coverage overall. In 2011, with a new county planner, the county has begun to implement specific elements of the CSU plan, with a focus on enhanced ordinances that support both adaptation goals and the county efforts to meet the new EPA Water Quality Scorecard requirements for stormwater management. Progress was made toward establishing a new 60 foot riparian buffer zone ordinance for the county, which is expected to be approved in 2012. This will support the headwater stream protection objective as well as overall low impact development. The next steps will be to pursue new subdivision regulations regarding tree canopy requirements and a steep slope ordinance to manage development on the forested "Ridge" area covering the central 1/3 of the county.

Middle Nolichucky Watershed Alliance – Greene County, TN

The Middle Nolichucky Watershed stretches across the TN and NC border covering over 1100 square miles with 2800 stream miles flowing through five wildlife management areas and the Cherokee National Forest. Though rural in nature the watershed has significant challenges with over 50% tested streams on the state's impaired waters list, mainly due to agricultural impairments.

The small nonprofit watershed organization, the Middle Nolichucky Watershed Alliance, led the CSU process and did an excellent job of stakeholder outreach to local leaders, agencies, and businesses. Their risk assessments findings revealed climate impacts already occurring related to forest health, water quality and quantity, and economic drivers of agriculture, tourism and timber harvesting. Of particular concern were: rising air and water temperatures; drier soils; extreme weather including drought, floods and tornados; invasive and pest species impacting the forest health; water pollution from sediment related to flash floods and farm runoff; and growing development pressures. To address this list of concerns, the adaptation strategies revolve around three main goals to protect forest cover and health with better growth planning and low impact development; protect water quality and supply with riparian zone enhancements and policy to reduce flood plain development; and support local economies with a focus on sustainability for farming, tourism and forestry.

Each of these rural communities has served an outstanding leadership role. They are individually improving the climate resilience of their community and collectively they are improving the climate adaptation capacity of our region.

Since the CSU program began in 2008, more agency attention has begun to turn to this issue. At the federal level, public agencies have begun to recognize the need to incorporate climate change into research, planning, and land management. The U.S. Forest Service (USFS) has advocated for watershed health and climate adaptation strategies by issuing a mandate to its districts to build partnerships to 'reduce the vulnerability of resources and places to climate change'. In 2011, the USFS unveiled its *Climate Change Performance Scorecard* to help offices comply with the new mandate (http://www.fs.fed.us/climatechange/advisor/scorecard.html). In 2012 the CSU program is forging a stronger relationship with the Forest Service to work in synergy with these federal initiatives and help provide the local community opportunities for climate adaptation collaborative efforts.

Moving forward in 2012, MFPP and the Cumberland River Compact will continue to support the implementation efforts of these communities while adding to them with at least four new communities this year and four to six more in 2013. In coming years ongoing monitoring of the long range effectiveness of this approach to climate adaptation for rural communities will be important to guide future programs and contribute to the body of knowledge in this pioneering field of climate adaptation.

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PAST, CURRENT, AND FUTURE WATER-USE STUDIES IN TENNESSEE

John A. Robinson[1]

As the population increases, land use changes, and climate varies, water-resource managers and policy makers are challenged with difficult decisions concerning the effects of increasing and competing demands on water resources in Tennessee. Collecting, integrating, quantifying, forecasting, and delivering water-use information and understanding the effects of water use on the ecosystems, water resources, and natural hydrologic systems in areas of Tennessee where water may be abundant or limited are important to the public and to policy makers. To assist policy makers and water-resource managers, the U.S. Geological Survey (USGS) has published national compilations with estimates of water use for the United States at 5-year intervals and also has conducted various studies documenting water use and water-use demands since 1950.

Beginning in 2009, a Tennessee Regional Water-Supply Planning Technical Working Group, including Federal, State, and local agencies as well as non-governmental agencies, has been working to establish a general framework of methods and information to support collaborative water-supply planning among interdependent systems at a regional scale. As part of this effort, the USGS Tennessee Water Science Center has worked cooperatively with the State of Tennessee and other agencies to evaluate current water-use information and to produce estimates of future water use for two pilot study areas in Tennessee in which one or more utility systems experienced some supply limitation during the drought of 2007. Beginning in 2012, the USGS Tennessee Water Science Center will begin a cooperative effort with other Federal, State, and local agencies to document estimates of water use --groundwater and surface-water withdrawals-- by county in Tennessee for several water-use categories for the 2010 national compilation. As an integral part of this effort, the USGS Tennessee Water Science Center also is working towards developing factors for estimating per capita water use and thermoelectric-power water use in Tennessee.

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UNDERSTANDING FLOOD EVENTS IN THE GREATER NASHVILLE METROPOLITAN AREA 1970 - 2010: CORRELATING URBAN GROWTH WITH ANALYSIS OF STORM WATER DISCHARGE IN THE CUMBERLAND RIVER WATERSHED

C. Schaney[1] and A. Kalyanapu[2]

ABSTRACT

Growth of impervious surface in areas of rapid urban growth has serious implications with regard to increased incidence of flash flooding. Although numerous examples address impervious surface to water quality, this research is designed to uncover the relationship between flooding and increased impervious surface within the Cumberland River Watershed. This proposed research will encompass assessing water volume in two phases and two scales. The first will examine land cover changes within the Cumberland River Watershed using Landsat imagery to quantify percent change of impervious surface. The data will then be used to quantify changes in water flow during the time period 1970 - 2010. Changes in impervious surface will then be modeled using HEC-HMS model in order to estimate changes in surface runoff. Secondly, aerial photography will be used in conjunction with geographic information systems to identify and model impervious surface growth in the Nashville-Davidson, Tennessee Urbanized Area. Additionally inputs from water management facilities, changes in pool level (Nashville District United States Army Corps of Engineers), and information collected from stream gages over the time period 1970 – 2010 will be used to quantify and model changes in stream flow. Meteorological data will also be incorporated to determine minimum rainfall events that illicit responses from water management facilities. The goal of this research is to provide a better understanding of the relationship the built environment has on incidences of flooding in the Nashville area, and give storm water managers another tool in offsetting future flooding events.

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SESSION 2B

WATER SUPPLY/AVAILABILITY
8:30 a.m. – 10:00 a.m.

Estimating Water Use at Thermoelectric Power Plants
Melissa A. Harris

The Federal Role in Providing Water Supply in the Cumberland River Basin
Benjamin L. Rohrbach

A Comparison of 7Q10 Low Flow for Rural and Urbanized Watersheds in the East, East Central and Northeast of USA
Saeed Zabet and John S. Schwartz

MONITORING AND WATER QUALITY
10:30 a.m. – 12:00 p.m.

Tennessee Volunteer Watershed Monitoring
David Pelren and John McFadden

The TVA Kingston Ash Spill: Three Years Later
Neil E. Carriker

Investigation and Status of Continuous Turbidity Monitoring at TMI Sites in East Tennessee Streams
John Schwartz, Carol Harden, Robert Woockman, Jeremy Mefford, and Hunter Terrell

STORMWATER
1:30 p.m. – 3:00 p.m.

Incorporating Effective Maintenance Strategies into a Stormwater Management Program
Mark B. Miller and Marc Lelong

What, Where, and How Much Will It Cost? Watershed-Scale Stormwater BMP Planning and Optimization
Dustin Bambic

High Turbidity at Three Tennessee Highway-Construction Outfalls
Tim Diehl

ENGINEERING APPLICATIONS
3:30 p.m. – 5:00 p.m.

Evaluation of a Bioreactor to Reduce Contaminant Load at Hardeman County Landfill, Tennessee
Brandon D. Cobb, Michael W. Bradey, Tom D. Byl, and Randy Thomas

Innovative Solutions to Complex Environmental and Wastewater Issues
Danny Adams

SPR High Turbidity Wastewater Purifier and Technology: The SPR Technology Changes Municipal Sewage of City Into Secund Water Resources of City
Taiquan Liao, Lihua Tang, and Chunjiang Liao

ESTIMATING WATER USE AT THERMOELECTRIC POWER PLANTS

Melissa A. Harris[1]*

The U.S. Geological Survey (USGS) compiles and publishes national water-withdrawal estimates for various uses on a five-year cycle. Thermoelectric power plants have accounted for the largest water withdrawals since 1965. In the past, thermoelectric water use has been compiled and estimated from self-reported information provided to state and federal agencies by facility operators. Often this information has contained inconsistencies and gaps, and in some cases reported values for consumptive use have been thermodynamically unrealistic. Given the unknown quality and uncertainty in this information, estimates of consumptive water use by thermoelectric power plants were not included in recent USGS summaries.

As a result of recent concern by the U.S. Congress over increasing demand for water and energy the General Accounting Office reviewed the federal reporting of water-use data and recommended that steps be taken to resume the reporting of thermoelectric water consumption (forced evaporation) in future USGS water-use compilations. To address this issue, the USGS has identified a number of approaches to improve and quality assure this information. Among these is a means to reality check numbers by estimating forced evaporation based on energy budgets that are constrained by power-plant technologies and environmental variables.

As a case study, this approach was applied to forced evaporation within the Apalachicola-Chattahoochee-Flint (ACF) River basin under three scenarios: annual average electrical generation (2003-2009) and environmental conditions (20-30 year averages); specific generation and environmental conditions for a drought year (2007); and a hypothetical climate- change condition representing a two-degree Celsius temperature increase. This energy-budget approach produced an estimate of forced evaporation in the ACF of about two percent of streamflow for a period of peak anticipated stress (August 2007) and indicated that plants with cooling towers consume more water than plants with once-through-cooling. This method and other improvements in data-collection guidelines should provide a more comprehensive and accurate estimate of water use by thermoelectric power plants for the 2010 USGS national water-use compilation.

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THE FEDERAL ROLE IN PROVIDING WATER SUPPLY IN THE CUMBERLAND RIVER BASIN

Benjamin L. Rohrbach[1]

INTRODUCTION

U.S. Army Corps of Engineers national policy regarding water supply states that the primary responsibility for water supply rests with states and local entities. Primary legislation governing the use of U.S. Army Corps of Engineers (USACE) reservoir projects for water supply is the Water Supply Act of 1958 (Public Law 85-500). The Water Supply Act of 1958 provides the authority for the Corps to reallocate existing storage space in federal reservoirs to municipal and industrial (M&I) water supply provided that any reallocations that would significantly affect the purposes for which the project was authorized are made only upon approval of Congress. The law was enacted by Congress when significant public interest developed in using Corps' reservoirs for water supply. The Water Supply Act requires that users who wish to purchase storage in a Corps' reservoir pay a one-time fee for the reallocated storage space. In addition to this one-time fee, water supply users are required to pay their pro-rata share of additional costs required to operate and maintain the project. These costs consist of: annual operation and maintenance expenses; and any repair, replacement, rehabilitation, and reconstruction costs. Storage reallocated for a specific water supply user, and the costs for purchase of that storage, are documented in a water storage agreement between the user and the United States government.

HISTORY

The Cumberland River system of dams is comprised of a series of multi-purpose 'lock and dam' and 'dam and reservoir' projects operated and maintained by the Nashville District U.S. Army Corps of Engineers (Nashville District). The projects were largely conceived and designed in the 1930's and 1940's to meet existing and projected demands for navigation, hydropower, flood control, and recreation. Water supply was not included by Congress as a project purpose at any project in the Cumberland River basin because there was little demand at the time. The lock and dam projects, also known as main-stem or run-of-river projects, include Cordell Hull, Old Hickory, Cheatham, and Barkley. These projects were authorized, and are operated, primarily for hydropower generation and to provide adequate river depth for commercial navigation. With the exception of Barkley (which contains storage used to reduce flood impacts on the lower Ohio and Mississippi Rivers), these projects are not designed, or operated, to store water for long periods of time. The dam and reservoir projects, also known as tributary or storage projects include Martins Fork, Laurel, Wolf Creek, Dale Hollow, Center Hill, and J. Percy Priest. These projects were authorized, and are operated, primarily to provide flood control benefits for populations along the Cumberland River, for hydropower generation, and to provide recreation opportunities for the region. In order to meet these objectives, dam and reservoir projects store water for long periods of time and release this water from storage in a controlled manner. Historically, municipal and industrial (M&I) water supply users were originally granted permits and easements to place water supply intakes within dam and reservoir, and lock and dam, projects in the Cumberland River basin without a reallocation of storage for a water supply

purpose, and without being charged for use of that storage. The Nashville District received guidance from USACE Headquarters (HQUSACE) in the late 1990's to evaluate the existing use of Cumberland River projects for water supply, and to execute water supply storage agreements for all municipal and industrial water supply users at dam and reservoir projects in the basin.

POLICY

Subsequently, the Nashville District has reallocated storage for water supply, under the authority of the 1958 Water Supply Act, from storage originally designated for hydropower production, at the following dam and reservoir projects: J. Percy Priest Lake, Center Hill Lake, Dale Hollow, and Laurel River Lake. These storage reallocations were recommended and approved only after specific studies were performed for each reservoir to evaluate the effect of the proposed reallocations on other project purposes, as well as the environment, consistent with provisions of the National Environmental Policy Act. Upon approval of the studies, and subsequent water storage agreements, water supply became an authorized purpose of the project. Table 1 provides details of the current water storage agreements in the Cumberland River basin.

In addition, the District has adopted a policy, based on HQUSACE guidance, to not charge for water supply usage at the lock and dam projects: Cordell Hull, Old Hickory, Cheatham, and Barkley, as long as there are no impacts to navigation, or other authorized project purposes, due to those water supply withdrawals. If there are impacts to project purposes due to water supply withdrawals then storage from upstream dam and reservoir projects may need to be reallocated to mitigate those impacts. If that is the case, then storage agreements and the applicable charges are required.

Project	M&I User	Storage (acre-feet)	Cost
J. Percy Priest	City of LaVergne, TN	2,733	$ 1,818,550
(TN-5&6)	City of Murfreesboro, TN	5,084	$ 3,051,429
	Town of Smyrna, TN	5,002	$ 2,350,000
	YMCA, TN	22	$ 16,638
	Consolidated Utility District, TN	4,374	$ 2,624,886
	Cedar Crest Golf Course, TN	96	$ 75,951
Center Hill	City of Cookeville, TN	6,680	$ 2,915,045
(TN-4&6)	City of Smithville, TN	401	$ 54,536
	DeKalb Utility District, TN	668	$ 783,585
	Riverwatch Resort, LLC., TN	131	$ 103,381
Dale Hollow	City of Byrdstown, TN	1,841	$ 372,716
(TN-4&6; KY-1)	Trooper Island Camp, KY	2	$ 916
	Dale Hollow St. Park, KY	368	$ 176,532
Laurel	City of Barbourville, KY	586	$ 1,903,609
(KY-5)	Laurel County WD #2, KY	519	$ 166,847

Table 1. Current Water Storage Agreements in the Cumberland River Basin

RESPONSE TO REGIONAL CHANGES

Major regional changes have occurred in the last 80 years which are putting pressure on the current river system. The ten multi-purpose projects within the Cumberland River Basin are a part of the Nation's aging infrastructure. Major rehabilitation efforts are already underway to fix seepage issues at the two largest dam and reservoir projects in the system, Wolf Creek and Center Hill. Significant pool draw downs, decreasing the risk of dam failure at these projects, have drastically reduced the amount of water available for release. During dry seasons, the majority of water flowing in the Cumberland River is released by these projects. Weather patterns are also changing causing both more severe floods and more severe droughts than ever before seen in the period of record. Between 1950 and 2010, the population of the Nashville metropolitan statistical area has grown by 187%, approximately double the national average. The rate of growth in recent years, 2000-2010, is still on the rise; consistently more than double the national average. The increased population has created environmental pressures: reducing water quality and dramatically increasing the demand for water supply.

During the drought of 2006-2009, and with pool restrictions at Wolf Creek and Center Hill, Nashville District was often unable to operate the Cumberland River to fulfill all authorized purposes at the lock and dam projects. Specifically, Old Hickory could not routinely meet minimum hydropower generation requirements nor reliably support commercial navigation. Water quality was also severely impacted.

There are numerous municipal and industrial water supply intakes on Old Hickory withdrawing over one billion gallons per day from the lake, making it the most intensively used project for water supply in the Cumberland River basin. A previous study of water supply withdrawals from Old Hickory, conducted in 1999, concluded that water supply usage as then projected to the year 2009 could have an impact upon the ability of the project to reliably provide navigation. Based upon observations during the recent drought, and to prevent further potential impacts, a temporary moratorium was enacted in January 2010 on Corps of Engineers' approval of applications for increasing existing water supply withdrawals or constructing new water supply intakes at Old Hickory Lake.

Due to the major changes in the Cumberland River Basin, Nashville District is currently conducting a holistic system-wide reconnaissance study using funds made available by Congress after the May 2010 flood. The reconnaissance will document any and all water resources issues within the basin including flood risk management, ecosystem restoration, navigation, hydropower, and water supply and recommend areas for future study. Nashville District may recommend studying the possibilities of utilizing new technologies and modeling to retool the system for more modern purposes, and to improve the value Corps projects provide to the region. Any proposed significant operational changes or other modifications would require Congressional authorization.

SUMMARY

Water supply was not an originally authorized purpose of any of the reservoirs in the Cumberland River basin. Reallocation of storage in the early 2000's resulted in authorizing water supply as a project purpose at Laurel, Dale Hollow, Center Hill, and J. Percy Priest reservoirs. However, while providing the benefits our projects were authorized for, the Cumberland River system of reservoirs does benefit water supply users at our lock and dam projects. Primarily, this is by ensuring a continuous flow of fresh water during periods of drought, providing cooling water for power generation, reducing pumping costs by providing a steady pool, and improving water quality and treatability by diluting wastewater discharges.

The Cumberland River dams form a system operated in coordination to provide the greatest benefits for the entire region. Environmental and social changes, including increasing demand for water supply, which affect the operation of one project, affect the entire system. Current Corps national policy states that water supply is a state and local concern. However, we recognize the role our reservoirs play in providing for water supply. The Nashville District is committed to finding solutions to allow continued support of existing and future water supply needs while ensuring the purposes for which the system was originally intended.

A COMPARISON OF 7Q10 LOW FLOW FOR RURAL AND URBANIZED WATERSHEDS IN THE EAST, EAST CENTRAL AND NORTHEAST OF USA

Saeed Zabet[1] and John S. Schwartz[1]

INTRODUCTION

Increased runoff peak and volumes from urbanizing watersheds have been well documented where watershed hydrology becomes modified after 10 to 25% of land area is developed. Lowering of baseflow has also been reported to be modified from urbanization, however hydrology thresholds related to percentage of land area developed is not well quantified and other environmental factors may influence these thresholds. Lowering of base flow may cause increased water pollution effects on aquatic and human life. There are lots of anthropogenic factors like urbanization which directly or indirectly affect low flow (Smakhtin, 2001). Water budget equation may employ to display the anthropogenic effects of urbanization on base flow:
Precipitation = Run off+ Infiltration+ Evaporation directly-Change in moisture storage
Based on this equation as impervious cover increases infiltration decreases and consequently it results in decreasing of base flow because the infiltration to the ground water table is the source of baseflow streams (Kauffman, 2009). Several studies are conducted on understanding the impacts of urbanization development on both base flow and low flow. Leopold (1968) displayed that the increasing of Impervious cover surface result in declining low flow. Later Hammer (1973) confirmed that the result of study done by Leopold for Imperviousness ratio less than 40-50%.

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Hollis (1976), Klein (1979), Simmons (1982), Ferguson (1990) in individual researches achieved the same results. Spinello and Simmons (1992), and Scorca (1997) on a study conducted for the same region, Long Island NY, found that base flow decreased due to urbanization development.

Kauffman et al. (2009) investigated the effects of urbanization on 19 watersheds in Newark, Del. Watersheds have experienced an impervious surface cover growth ranging from 3 to 44%. The results showed that there is a correlation between increased impervious surface cover and decreased base flow. Albeit lots of studies have done yet to understand the trends of base flow due to urbanization, the final results are inconsistent. Most of studies suffer from lack of data since the numbers of watersheds are small. Furthermore some researchers have used population density, introduced by Stankowski in 1972, as the indicator of urbanization. This method doesn't seem as much accurate as GIS based methods for computing the exact percentage of urbanization.

Since it is vital to understand the exact threshold values and percentages that result in changes of low flow, it's essential to use the results of satellite based images in these types of studies.

The objective of this research is to achieve a sound result and explore the real impacts of urbanization on low flow. Also to determine the exact interaction thresholds of urbanization and low flow.

APPROACH

100 watersheds in north and east central USA were chosen to investigate potential effects of urbanization on low flows, and identify whether a degradation threshold range can be quantified as a function of drainage area size. The low flow metric chosen for this analysis is the 7Q10. Historical flow records were obtained from the USGS gauges for computing the 7Q10, in which a minimum of 10 years of data were used corresponding with USGS Seamless land cover images for years 1992 and 2001. Using ArcGIS, land cover data for these two years were used to estimate percentage of urbanization by summing the land cover areas for industry, commercial, and high-density residential and dividing by the total watershed area above the USGS gauging station.

RESULTS AND DISCUSSION

Differences in 7Q10 values between the two periods were statistically analyzed using the Wilcoxon signed rank test. Results show a significant decrease in low flow due to increased urbanization percentage from 0 to 11%. Low flow increase sporadically as urbanization percentage increase from 11 to 23% and for urbanization percentage more than 23% the increasing of low flow is more constant. The hypothesis of this research is given below:

Null hypothesis: H0: $\mu 2-\mu 1=0$ no change in mean of low flow
Research hypothesis Ha: $\mu 2-\mu 1\neq 0$ change in mean of low flow
The "α" were used in this study is 0.05 which seems quit reasonable.

Difference: LF2001 - LF1992

DF	t Value	Pr > |t|
99	-2.17	0.0327

By comparing the p-value=0.0327 and α=0.05 it can be concluded that the null hypothesis is rejected. So by 95% confidence it can be said that the low flow changes due to urbanization development.

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TENNESSEE VOLUNTEER WATERSHED MONITORING

David Pelren (Tennessee Scenic Rivers Association, Adopt-a-River Program) and
John McFadden (Tennessee Environmental Council)

ABSTRACT

During 2010 and 2011, the Tennessee Environmental Council (Council) and Tennessee Scenic Rivers Association (TSRA) initiated a coordinated effort to educate volunteer watershed monitors in methods to assess stream integrity. The purpose of this effort is to identify opportunities for watershed improvements and to document ongoing stream health. Surveys include invertebrate sampling, physical habitat descriptions, and physiochemical sampling. Water quality ratings, as determined through invertebrate surveys, were good to excellent for the streams surveyed in 2011. Habitat and chemical sampling reflected these findings in general, but some degraded habitat conditions were documented. Coordinators of this effort and watershed monitors hope to build this program to focus more on streams that exhibit potential for improvement.

INTRODUCTION

The primary purpose of the Council / TSRA stream survey effort is to identify streams that would benefit from actions to pursue improvement of water quality and habitat. The surveys also provide an educational benefit and as a means to document the integrity of stream segments that are functioning well.

This effort is being initiated in middle Tennessee because TSRA and the Council are based in the region, and population centers there are expected to maximize the potential for attaining goals. Surveys in other parts of the state are also being pursued as opportunities arise. At this point, sampling is being conducted on streams that are most readily accessed by volunteer monitors. As watershed monitors gain experience in conducting stream surveys, we hope streams that are most likely to function at a low level of integrity will receive more focused attention.

METHODS

Volunteer stream monitors are trained in survey methodologies discussed on the TSRA Adopt-a-River program web site at “www.paddletsra.org/adoptariver.html.” Benthic macroinvertebrate sampling and stream/riparian physical habitat description are emphasized, and physiochemical sampling is also addressed when possible. Land uses and possible watershed challenges are noted.

Izaak Walton League methods were used as a basis for invertebrate sampling. Then multipliers were used to weight rare, common, and abundant taxa within each of pollution sensitive, intermediate, and pollution tolerant invertebrate groups to calculate water quality scores. Scores less than 17 are indicative of poor stream sites. Fair sites have scores between 17 and 25.9, scores of good sites are between 26 and 39, and scores of excellent sites are greater than 39. The

data form used for all reporting is found on TSRA's Duck River Opportunities Project web site at "www.paddletsra.org/duckriver. html".

Physical habitat descriptions of streams and riparian (streamside) areas included streambank vegetation, channel substrate types, and riparian forestation. Photographic documentation of physical habitat is also collected and included with reports in an effort to validate visual data. Finally, physiochemical sampling included dissolved oxygen (DO), pH, temperature, nitrate, and phosphate.

The data collection/processing methods and the use of volunteers present specific limitations to data use. For example, macroinvertebrates are processed to the order level and thus pollution tolerance variance is greater among families within orders as opposed to species within families. Order level macroinvertebrate data are however well suited for discerning grossly polluted aquatic systems from fair to excellent systems.

RESULTS

Survey data are presented in the appendix to this report. For the five stream surveys that involved invertebrate samples, the number of taxa types for pollution sensitive organisms ranged from four to seven. The range for intermediate organism types was one to five, and the range for pollution tolerant organism types was two to five. Resulting invertebrate scores ranged from 26.8 to 56.3. Three of the water quality ratings were good, and two were excellent.

Water chemistry reflected the good to excellent invertebrate water quality ratings. Habitat and chemical sampling reflected these findings, but some degraded physical habitat was documented.

CONCLUSION

Some degradation of streams surveyed during this effort may be attributable to the land uses reported. Sediment deposition related to erosion and stormwater runoff appears to be a common problem in some of the watersheds surveyed. Within these watersheds, additional observation of land uses in conjunction with continued stream surveys will continue in an effort to further identify potential actions for watershed improvements. Stream surveyors will also seek opportunities to survey streams that may have or that are known to have ongoing challenges. One or more training sessions will be conducted to support this level of effort.

Appendix: Stream survey data.

Investigator	**J. Beckett**	**J. Beckett**	**G. Garrett**	**G. Garrett**	**D. Pelren**
Stream name	Station Camp Creek	Station Camp Creek	Abby's Creek	Straight Creek	Blackburn Fork
County	Sumner	Sumner	Claiborne	Claiborne	Jackson
Survey date	5-30-11	9-10-11	5-25-11	5-25-11	10-14-11
Location	Lower Sta. Camp Cr. Rd.	Near Sta. Camp High Sch.	Clairfield area	Falls at Clairfield	20' upstream of Dry Fk. Mouth
Land uses	Residential, quarry, nursery	Residential construction	Logging, road, mining, ATV's	Logging, road, mining, ATV's	Residential, forested
% bank veg. – left descending	50-75	---	>75	>75	>75
% bank veg. – left descending	25-50	---	>75	>75	>75
Forested riparian zone width (ft.) - left	---	---	30-40+	30-40+	<10
Forested riparian zone width (ft.) - rt.	---	---	30-40+	30-40+	30-40+
Streambed composition – most to least abundant	Some sediment deposits	---	Sand, silt, cobble, gravel, boulder	Boulder, sand, silt, gravel, cobble	Cobble, boulder, gravel, sand
Special problems	Discharge pipe & stormwater runoff	---	5+ feet sediment deposits	High turbidity levels, iron seeps	Recent flooding & logjam
DO (ppm)	---	---	10.0	12.0	---
pH (SU)	---	---	7.5	7.5	---
Temperature (degrees C)	---	---	14.0	12.0	---
Nitrate (ppm)	---	---	---	---	---
Phosphate (ppm)	---	---	---	---	---
Invertebrate Habitats sampled	Riffle, pool, logs	---	---	---	Riffle
Invert. score	33.5	---	---	---	26.8
Invert. water quality rating	Good	---	---	---	Good
Notes	---	Moderately unstable banks with erosion.	Conductivity 1080. Sediment photos available.	Conductivity 1020 – rising in recent years.	9 sq. ft. sampled for inverts. 36.27251 lat. 85.56373 long.

Investigator	**D. Pelren**	**D. Pelren**	**D. Pelren and J. McFadden**	**J. Young**	**J. Young**
Stream name	Clear Cr.	Mansker Cr.	Mansker Cr.	McCrory Cr.	Stoner Cr.
County	Anderson	Sumner	Sumner	Davidson	Davidson
Survey date	9-10-11	5-14-11	10-8-11	7-6-11	5-31-11
Location	36.21296 lat. 84.07296 long.	Moss-Wright Park	Moss-Wright Park	Greenway Bridge	0.4 mi. downstream of Central Pike
Land uses	Grist mill, road	Residential, commercial	Residential, commercial	Parkland	Landfill
% bank veg. – left descending	>75	50-75	>75	0-25	>75
% bank veg. – left descending	>75	50-75	>75	25-50	50-75
Forested riparian zone width (ft.) - left	30-40+	---	30-40+	---	---
Forested riparian zone width (ft.) - rt.	road	---	30-40+	---	---
Streambed composition – most to least abundant	Gravel, cobble, boulder, sand	Cobble, gravel, silt, boulder, bedrock	Silt, bedrock, gravel, sand	Silt, cobble, boulder	Bedrock, silt, gravel, cobble, sand, boulder
Special problems	---	---	---	---	---
DO (ppm)	8.0	---	7.0	8.0	8.0
pH (SU)	8.0	---	7.7	8.0	7.0
Temperature (degrees C)	17.0	---	19.0	22.0	20.0
Nitrate (ppm)	0-1	---	---	---	---
Phosphate (ppm)	2.0	---	---	---	---
Invertebrate Habitats sampled	Riffle	Riffle, run	Riffle, run, pool, boulder, leaf packs	---	---
Invertebrate score	56.3	37.5	46.0	---	---
Invertebrate water quality rating	Excellent	Good	Excellent	---	---
Miscellaneous notes	Chemical site below invert. sample site.	---	---	Poor invertebrate habitat	Primarily bedrock substrate

THE TVA KINGSTON ASH SPILL: THREE YEARS LATER

Neil E. Carriker[1]

Visitors to the area adjacent to the Kingston ash spill witnessed a stark landscape in the first few weeks and months following the December 22, 2008 release of 5.4 million cubic yards of fly ash into the Emory River and Swan Pond Creek. Shortly after the spill, TVA made a commitment to the Kingston and Harriman communities to "make things right."

Continuous and rapid progress towards that goal has been evident during the three-plus years of ash recovery. The landscape has changed, and continues to change at a remarkable pace, with completion of ash recovery expected to occur around mid-year, 2012. Over three million cubic yards of ash was recovered from the Emory River in less than two years, and another million cubic yards was removed from the upper end of the Swan Pond embayment over the course of the next year.

This presentation discusses these and other milestones that have been achieved, presents a photographic record of the progress, and reviews the plans for completing recovery of the spilled ash and closure of the ash storage landfill. It briefly reviews the ecological monitoring and research supporting the recovery, and concludes by presenting plans already underway to convert about 900 acres of property adjacent to the site to recreational uses that will benefit the community.

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INVESTIGATION AND STATUS OF CONTINUOUS TURBIDITY MONITORING AT TMI SITES IN EAST TENNESSEE STREAMS

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Excessive suspended sediment in rivers and streams beyond some natural condition, referred to as siltation is a major cause of water quality impairment in the United States (USEPA 2003, 2006). These impaired river and stream segments are listed in accordance with §303(d) of the Clean Water Act, and total maximum daily loads (TMDLs) for sediment must be generated to meet state water quality criteria (USEPA 1999). Although 32 states have developed numeric criteria for turbidity or suspended sediment concentrations (SSC), or both according to the USEPA (2006), criteria are typically written as a percent exceedance above background and what constitutes background is not well defined. Defining a background level is problematic considering SSC and related turbidity levels change with flow stage and season, and limited scientific data exist on relationships between sediment exposure and biotic response. Tennessee, like most U.S. states has no sediment standard that defines the levels which may cause impairment. Turbidity, a measure of the penetration of light through a water column, is a well-established surrogate measure of SSC. It can be measured and logged continuously by a sonde, thereby providing a data time series. Protocols for quantifying measured turbidity or SSC over a range of flows into concentration-frequency and concentration-duration relationships have been published. Sediment exposure measures quantified into concentration, frequency, and duration relationships are essential to correlate with biotic response measures because elevated SSC are episodic in nature, and lotic ecosystems to some degree are resilient to episodic disturbances. In the case for fish, biotic responses to elevated SSC appear to be dose dependent, where dose represents concentration times duration. This study investigates the use of turbidity sondes to characterize concentration-duration-frequency relationships at eight Tennessee Macroinvertebrate Index (TMI) sites. These sites were located in East Tennessee near Knoxville in the Ridge and Valley EcoRegion Providence. Site monitoring is in progress and will continue through June 2012. This presentation provides a status of the project and summarizes common technical issues associated with collecting this field data using sondes.

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INCORPORATING EFFECTIVE MAINTENANCE STRATEGIES INTO A STORMWATER MANAGEMENT PROGRAM

Mark B. Miller[1] and Marc Lelong[2]

Implementing and sustaining a comprehensive stormwater management program requires considerable planning between multiple stakeholders including regulatory agencies, the private sector and business community. Factors to consider for program development can include (a) program structure, (b) BMP performance monitoring, functionality and maintenance, (c) BMP implementation and maintenance costs, and (d) measures of success. The inclusion of low-impact development (LID) design concepts into stormwater programs has dramatically expanded in recent years; and, LID practices can be enhanced or complemented through the utilization of manufactured treatment devices (MTDs) or materials. This presentation explores how BMP maintenance programs for both LID practices and MTDs should be considered as an integral and proactive component of a stormwater management program. It is fundamentally recognized that BMPs utilized for LID designs and MTDs require maintenance. A proactive approach to BMP maintenance not only serves to meet water quality goals, but also allows for sound fiscal administration of the program. The maintenance cycle and cost for any BMP should be considered during the BMP selection process. In contrast, a stormwater program that addresses maintenance issues on a reactive basis allows for the perpetuation of a BMP selection process that does not adequately consider annual and long term functionality and maintenance costs. For example, while a given BMP may be perceived as a lower cost approach, the long term effectiveness of that BMP may be diminished when it is later determined that maintenance activities cannot be effectively sustained.

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WHAT, WHERE, AND HOW MUCH WILL IT COST? WATERSHED-SCALE STORMWATER BMP PLANNING AND OPTIMIZATION

Dustin Bambic[1]

Stormwater is the leading cause of water quality impairments in urbanized areas of the United States. Under the Clean Water Act, municipalities are increasingly under pressure to control the volume and quality of stormwater discharges in order to attain water quality standards. Management of municipal stormwater is often challenging due to large and highly variable flows; the large number of discharge points; wide array of pollutants-of-concern; and co-mingling among municipal jurisdictions. In addition, there are a large number of potential scenarios by which stormwater best management practices (BMPs) can be implemented in watersheds. That is, there are multiple types of BMPs available, large numbers of potential sites to locate the BMPs, and each BMP can be constructed with varying designs (footprint area, depth, media, etc.).

This presentation describes the state of the practice for developing watershed-scale implementation plans to address water quality impairments by stormwater. Examples from across the U.S. will be described where hydrologic, water quality, and BMP models have been coupled to quantitatively evaluate stormwater BMP scenarios and optimize pollutant load reduction versus cost. Watershed models to simulate hydrology and pollutant loading include LSPC (Loading Simulation Program – C++) and BMPs have been simulated using a process-based model called SUSTAIN (System for Stormwater Treatment and Analysis Integration). In addition, customized models have been developed to optimize BMPs at subwatershed (large) scales. Applications have simulated a wide array of BMPs including structural (infiltration and treatment), distributed (e.g., rain barrels), and institutional (e.g., street sweeping, ordinances, etc.) controls. Functions used to estimate BMP costs account for construction, operation, and maintenance. The results of the cost optimization have shown different BMP strategies to have large cost differences, up to billions of dollars. The model results highlight which BMPs are "preferred" based on topography, urban setting, and other factors. The cost and load reduction of "green" scenarios that focus on Low Impact Development (LID) can be compared to those based on traditional structural BMPs such as regional detention.

The implementation plans developed to date have been used for TMDL compliance strategies, to prioritize available funding for capital improvements, and to engage stakeholders and regulators regarding regulatory issues such as maximum extent practicable (MEP). This presentation should be of interest to a wide array of stakeholders including municipal, state, federal, and non-governmental agencies.

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HIGH TURBIDITY AT THREE TENNESSEE HIGHWAY-CONSTRUCTION OUTFALLS

Tim Diehl

The U.S. Geological Survey (USGS) and Civil and Environmental Consultants (CEC), in cooperation with the Tennessee Department of Transportation, monitored six active highway-construction outfalls in Middle and West Tennessee to determine characteristic outfall turbidity. The USGS monitored discharge and turbidity at points where wet-weather tributaries to Sycamore Creek and South Garrison Branch left the construction right-of-way (ROW) of State Route (SR) 840. At these sites, stringent erosion-protection measures and sediment controls (EPSCs) were applied during construction, and turbidity remained below 1,000 formazin nephelometric units (FNU) during most storms. On the Sycamore Creek tributary, the period of extensive exposure of disturbed ground was short and did not coincide with heavy rain. Light runoff during construction was associated with turbidities that remained mostly above 100 FNU for two days. The maximum daily-average turbidity during construction, defined as the unweighted average of all measured turbidities from the beginning of flow until midnight or the cessation of flow, was 393 FNU. A moderate storm in the month after construction produced a peak turbidity of 560 FNU. Turbidity then decreased smoothly from the peak as flow receded, following the same pattern observed before construction. On the South Garrison Branch tributary, the maximum daily average turbidity was 332 FNU, and only one pumped sample exceeded 1,000 nephelometric turbidity ratio units (NTRU).

The USGS and CEC jointly monitored four other highway-construction outfalls; these sites were located along SR 101 near Crossville, along SR 16 near Tullahoma, and at two sites along SR 99 near Hohenwald and Darden. USGS monitored stream depth and turbidity (using a YSI 6136 turbidity sensor), and used a pumping sampler to collect samples that were analyzed for turbidity and suspended-sediment concentration. CEC monitored depth and turbidity (using an In Situ Troll 9500 water quality monitor).

At these sites, the frequency of fouling and the occurrence of turbidities above the maximum detection limits of both turbidimeters limited the usefulness of the turbidity measurements. We observed few periods in which both instruments were in valid reporting ranges (1 to 1,000 FNU for the YSI 6136 and 1 to 2700 FNU for the Troll 9000), and in fact maximum detection limits for both instruments were exceeded in most storms at these four sites. For periods when measurements were within range, the measured turbidity appeared uncorrelated between the two instruments except at the Hohenwald site.

Measured NTRU from pumped samples was more reliable. The average NTRU was about 11,000 at Tullahoma, 9,000 at Crossville, 3,000 at Hohenwald, and 6,000 at Darden during periods when turbidity exceeded 1,000 FNU based on the YSI 6136.

At these four sites, EPSCs appeared less stringent than at SR840. Based on this small set of samples, less stringent EPSCs appear to be associated with much higher maximum and daily-average turbidities, which may exceed the capabilities of typical field monitoring instrumentation.

EVALUATION OF A BIOREACTOR TO REDUCE CONTAMINANT LOAD AT HARDEMAN COUNTY LANDFILL, TENNESSEE

Brandon D. Cobb, Michael W. Bradley, Tom D. Byl, and Randy Thomas

The Hardeman County landfill, located near Boliver, Tennessee, is a 244-acre site used by the Velsicol Chemical Corporation to dispose of manufacturing waste from 1964 to 1973. During this time period, approximately 130,000 drums of waste containing heptachlor, heptachlor epoxide, dieldrin, endrin, carbon tetrachloride, and chloroform were disposed of in trenches. Contamination from the site, primarily carbon tetrachloride and chloroform, migrated laterally from the disposal site to Pugh Creek to the east and Clover Creek to the north, affecting local, private wells. Contamination in the private wells was confirmed in 1978 and municipal water was provided to local residents in 1979. The site was added to the National Priorities List in 1983. A pump-and-treat system was installed in 1996 and operated until it was removed from service in 2003. Contamination from the Hardeman County landfill continues to migrate from the landfill to Pugh Creek and to the Clover Creek wetlands. In addition to active mitigation, natural attenuation processes may be affecting and degrading the contaminants moving from the landfill.

Laboratory microcosm experiments using sand and wetland sediment from the site identified that natural attenuation of carbon tetrachloride was feasible at the site. After 14 days, carbon tetrachloride concentrations had decreased by about 29% in the sand microcosm and about 50% in the wetland sediment microcosm. A contaminated spring discharging to Pugh Creek was selected for a field test of a reactive cell to attenuate carbon tetrachloride in the spring discharge. Samples collected from this spring in 2010 indicated carbon tetrachloride concentrations of 18,000 to 26,000 micrograms per liter (µg/L) and contaminant loads of 400 to 900 grams of carbon tetrachloride per day.

On April 21, 2011, the spring run was lined with plastic and a low (approx. 2.5 ft.) plywood dam was installed about 16 feet downstream from the spring. The area between the dam and the spring was backfilled with a mixture of about 40 cubic feet of hardwood mulch and about 5 cubic feet of limestone gravel. The mixture provided an organic base for the natural attenuation of carbon tetrachloride through adsorption and reductive dechlorination. Investigations at similar sites have used fill including, mulch, mulch with supplements, and organic material shredded on-site.

The system was allowed to equilibrate for approximately one month. On May 20, 2011, the bioreactor was inspected and water-quality samples were collected from the inlet spring, the overflow outlet at the dam, and from an internal point located at the base of the fill. The carbon tetrachloride concentration at the inlet spring was 28,000µg/L. The concentration at the outlet was 24,000µg/L, a decrease of 4,000µg/L (14 %). The maximum decrease in concentration was observed in June 2011. The concentration of carbon tetrachloride was about 33,000µg/L at the inlet spring and about 21,000µg/L at the outlet; a 36% decrease in carbon tetrachloride concentration. By November 2011, adsorption onto the reactor matrix had reached equilibrium and inlet and outlet concentrations were relatively equal.

INNOVATIVE SOLUTIONS TO COMPLEX ENVIRONMENTAL AND WASTEWATER ISSUES

Danny Adams
EnSafe, Inc.

Innovative solutions to complex environmental issues can provide positive benefits to natural and human environments, demonstrate corporate responsibility to sustainability and conservation, provide a location for enhanced public education on environmental/conservation systems and processes, and demonstrate a commitment to fostering regulatory, community and stakeholder involvement. These solutions also foster the EPA's initiative of developing an Environmental Indicators Initiative that assembled, for the first time, the most reliable available indicators of national environmental and health conditions and trends that are important to the EPA mission.

Although innovative solutions can be developed for challenging environmental issues across all facets of the environment, the focus of this review only encompasses case studies involving complex water- or wastewater-related examples. The projects used in this review include wastewater management opportunities and solutions (including constructed wetlands) for passive treatment of stormwater and process wastewater and environmentally friendly closures (including constructed and enhanced natural wetlands) of process units and/or legacy industrial sites.

Based on the application of innovative solutions, the project results include: the demonstrated acceptance of these cost-effective technologies as an approach to solving complex environmental issues from the regulatory (both State and Federal level), local and stakeholder communities; development of sites with positive ecological response and increased ecological value versus more traditional control and closure technologies; and, demonstration of the leverage that corporate/public/private partnerships can assert to ensure sustainability of natural resources and ecological systems, improved water quality and increased recreational/educational potential.

SPR HIGH TURBIDITY WASTEWATER PURIFIER AND TECHNOLOGY: THE SPR TECHNOLOGY CHANGES MUNICIPAL SEWAGE OF CITY INTO SECUND WATER RESOURCES OF CITY

Taiquan Liao, Prof.[1], Lihua Tang[2], and Chunjiang Liao[3]

ABSTRACT

The conventional wastewater processing unites just can handle the wastewater with turbidity less than 500 mg/l. Moreover, the purified water only can reach the standard for discharging, and it is far from the requirement of reusing and recycling for city.

The SPR serial high speed wastewater purifier puts the process of coagulation, defecation, filtering and sludge concentration together in a tank delicately, according to the principles of chemical coagulation, inertia separation and hydraulics. (United States Patent: US 6,358,407) The total SPR processing time is only 30 minutes, and the suspension elimination rate is high up to 99.4% to 99.93%. The wastewater with high turbidity more than 500 mg/l—5000 mg/l, or with the organic pollutants (CODcr: 1000 mg/l), can be taken directly and continuously into the purifier for a long time of period. The effluent's turbidity can be less than 1 NTU (mg/l), and the organic pollutant (CODcr) can be less than 40mg/l~100 mg/l. Also the moisture of the concentrated sludge from the SPR System is as low as 92%, and it can be used to produce the floor tiles. The system can also remove the harmful impurities as the heavy metal from wastewater, such as Zinc, Lead, Iron, and Manganese.

The SPR System can be used as a system for reclamation and reusing of municipal effluents for small communities in city.

The total cost of chemicals for treating municipal sewage is $ 0.16/cum only. The sum of power consumption is 0.25kwh/cum only. The cost of investment can be less than $500/cum.day.

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BACKGROUND

The highly contaminated water is a byproduct of the industrialized societies. Whether it is the sewage created from mixing of human on other waste products in a sewage collection system from the home drains and toilets, or water contaminated from blood and carcasses at the slaughterhouses, or other water contaminated by some other manufacturing plants. Processing wastewater of high turbidity, such as water from the recycled papermaking mill, printing and dyeing mill, ceramic plants, marble mill, wet dust collector in foundries, wet precipitator on boiler with coal, coal pits and similar venues. The sewage and effluent so created is frequently so contaminated that it is harmful to the environment and to the health of just about any living thing encountering the high turbidity wastewater with turbidity over 500 mg/l and even up to 5000 mg/l.

How to treat this wastewater? Back to current purified form, was a constant and vexing problem for government and industry.

Ever increasing government standards for discharge water from sewer plants, factories, and manufacturing facilities, is increasing the strain on current device and technology for purification of high turbidity wastewater. This is especially true in the United States and other highly industrialized countries where environmental concerns have caused ever tightening standards for the cleansing of the high volumes of severely polluted wastewater generated in such economies. As developing nations mature, the problem will online increase.

Most such conventional wastewater purifiers can only handle wastewater with suspended solids with a turbidity of less than 500 mg/l. These conventional devices and processes work primarily with the principal of gravity sedimentation or the use of mechanical filters. When processing wastewater, these conventional purifiers have low purifying rates, which yield long processing time, and they consist of large and very expensive mechanical structures. As a general rule, water treated in this manner is still disposed of as it is considered non consumable by industry or living things, because the turbidity or suspended solids of treated water is higher than 3 mg/l. If the object of purification is providing a device which yields highly purified water for recycling and reuse, that is need to use fine filtering material, such as activated carbon or reverse osmosis membrane, and they consist of very expensive filtering structures and the high pressure pumping takes high toll of energy.

Such conventional methods of purification include the use of microbe in wastewater take to devour the organic contaminants. Unfortunately the wastewater that the microbes are subjected to that sometimes is even too contaminated for them causing their untimely demise. Further still, the propensity of the ponds for microbiological treatment to propagate offending odors, especially in the summer months. To the unfortunate neighbor downwind, such a method of handling organic wastewater can be an olfactory nightmare. The innovative wastewater treatment technology and purifier are needed for every country in the world.

The SPR purifier and SPR technology achieved a great deal in the domain of high turbidity wastewater reclamation, recycling and reuse.

The SPR technology is the **United States Patent: US 6,358,407.**

The SPR purifier and SPR technology for the filtration and purification of suspended solids from high turbidity wastewater using the slow circulating water flow inside a vessel of wastewater containing a mixture of coagulant and suspended solids. By determining and using a calculated velocity of the flow of the wastewater in the vessel, suspended solids are caused to separate from the wastewater in which they are suspended by natural actions of gravity and pressure differentials in the vessel ceasing the rise of the suspended solids. The suspended solids are filtered from the wastewater by a first filter layer of flocculent and suspended solids themselves which form a filter element for the wastewater at a determined level in the vessel where in suspended solids are separated and drain into the sludge storage cavity leaving cleaned water to rise through a secondary filtration layer of buoyant plastic balls floating at a higher lever in the vessel. Additional filtration of water and condensation of sludge is achieved using an optional second return conduit to leach additional water from solids drained into the sludge storage cavity from the first filter layer of flocculent and suspended solids.

The SPR purifier is capable of handling suspended solids in wastewater higher than 500 mg/l and as high as 5000 mg/l directly and continuously. The suspended solids of the purified water can be less than 3 mg/l, and the elimination rate of suspended solids is high up to 99.4% to 99.9% in the SPR purifier. The turbidity of the purified water can be less than 1 NTU too. (Such as Figure 1 shows the result of treatment for wastewater with suspended solids 3000 mg / l from ceramic manufacturing plant)

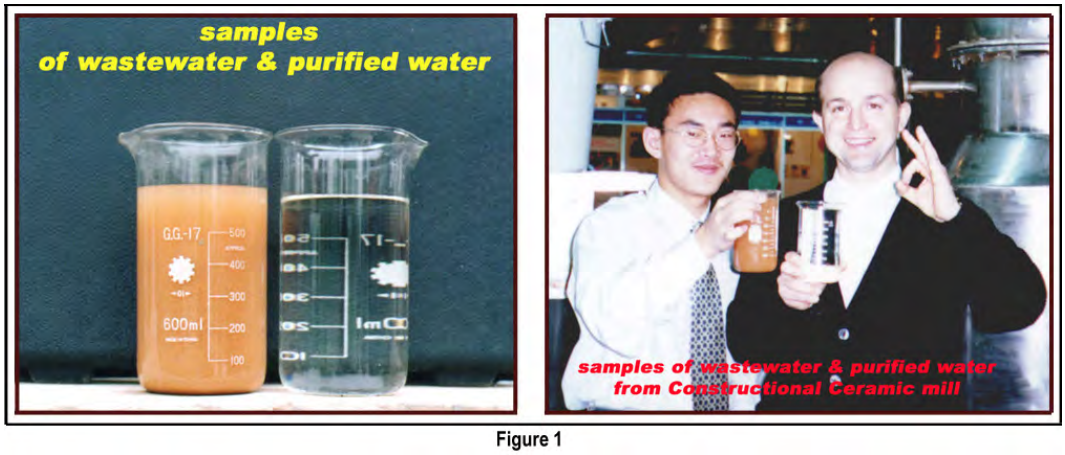


Figure 1

The SPR purifier system is also capable of handling organic pollutants in the wastewater that are higher than COD 1000mg/l, the elimination rate of organic pollutants are high up to 82% to 90%. The SPR purifier can also remove the heavy metal from the wastewater. The total processing time in the SPR purifier is only 30 minutes. The SPR system has small occupation spaces, small investment on civil works, low cost on operation, low power consumption and it is easy to handle.

The Design Principle of the SPR Purifier System
The flow diagram of SPR purifier system is showing in Figure 2 and Figure 3:

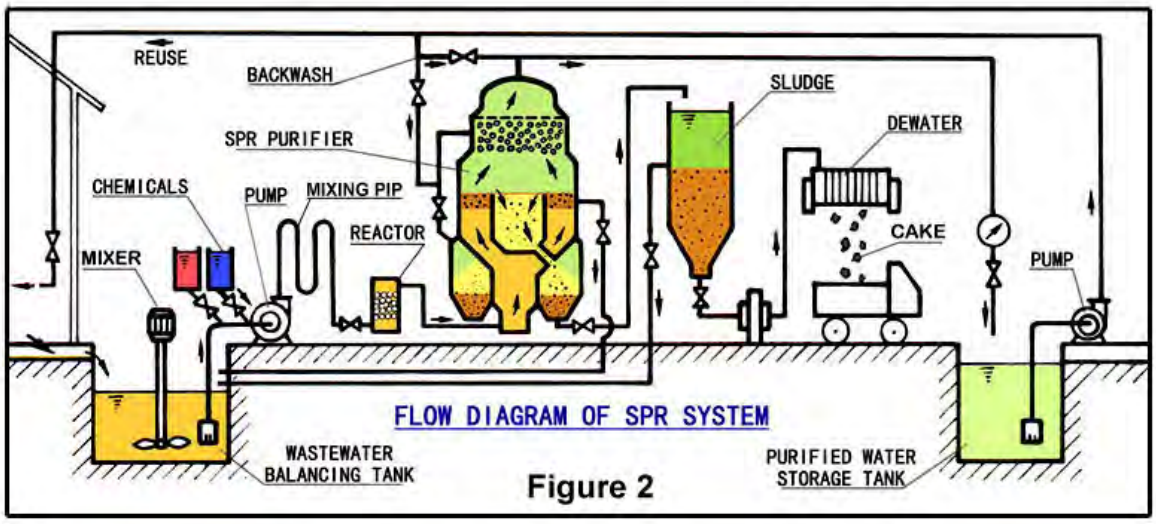


Figure 2

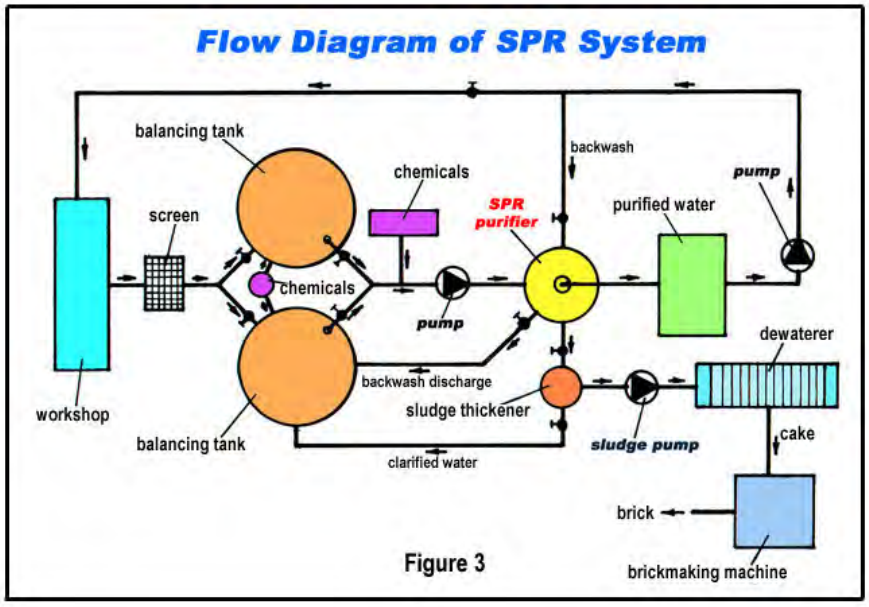


Figure 3

The coagulants are sucked into wastewater pipe quantitatively by the negative pressure, which is design at the sucking end of the water pump. The coagulants are mixed with wastewater, using a speedy rotating pump.

The coagulants are mixed with wastewater also using a mixing pipe, where in having a plurality of bends, which are substantially at angles of 180 degrees. The coagulants are mixed with wastewater again using a mixing container, which being substantially filled with porcelain balls yielding a reaction through the Kelvin skin affect of the water speed flow.

There is a valve at the input conduit, which being adjustable to thereby adjust the volume of mixed wastewater flowing there through into the SPR purifier. The means for regulation of flow of mixed wastewater stream from bottom portion toward the upper portion of vessel to yield a determined rise point of suspended solids in the interior vessel.

According to the coagulation mechanism and in consideration of the sort of the turbidity of the wastewater, pH value, temperature of the wastewater, the nature of the suspended solids and the pollutants in the wastewater, determining the optimum quantity of one or a combination of coagulants to be mixed with the wastewater to cause smaller particles of suspended solids to form into larger flocculent and to separate the impurity from the wastewater.
The Micrographs of the wastewater from foundries and the flocculent are showing Figure 4:

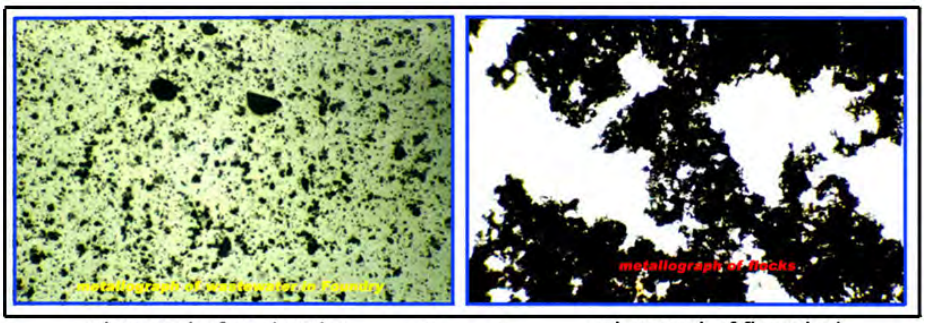


Figure 4

The certain chemicals have been taken to educe the solvable organic pollutants in wastewater into colloidal particles or small suspended particles with solid-phase interfaces, and than physical adsorption of the coagulants has been used to coagulate this colloidal particles and suspended particles into large flocculent.

(Such as Figure 5 is showing the result of treatment for the wastewater from recycled paper making mills, the chemical has been taken to educe the solvable lignin in wastewater into the unsolvable lignin acid, and to separate the lignin from the wastewater.)

Figure 5

The certain powdery absorbents which is very cheap have been used to absorb the organic pollutants in wastewater, and then physical adsorption of coagulants has been used to coagulate this powdery absorbents to absorbed the organic pollutants into larger flocculent.

(Such as the Figure 6 is showing the system of treatment for the wastewater from cashmere sweater mill, the absorbents have been used to absorb the organic pollutants in the wastewater and to remove the organic pollutants from wastewater.)

Figure 6. SPR System for wastewater reusing of cashmere sweater mill. (CHINA)

The certain decolorants have been used for decoloration from wastewater. (Such as Figure 7 is showing the result of treatment for the wastewater from the printing and dyeing mill.)

Figure 7. SPR to treat the wastewater from the printing and dyeing mill for reuse. (Hong Kong)

The certain chemicals have been taken to educe the heavy metal in the wastewater into colloidal particles or small suspended particles with solid-phase interfaces, and than physical adsorption of the coagulants has been used to coagulate this colloidal particles and suspended particles into large flocculent.

The certain disinfectants have been used for disinfect all of the Escherichia coli and other bacteria will be exterminated in the vessel of the SPR purifier, because the process for extermination is need 30 minutes, and the time of the wastewater flowing through the SPR purifier is 30 minutes too.

The certain chemicals have been taken to saturate acids or alkalizes before they are entered the vessel of the SPR purifier to change the pH value of the wastewater.

The optimum mix proportion of coagulants and chemicals is known how as a specific soft technology which is applicable to treat different industrial wastewater or municipal sewage. The construction of the SPR purifier is showing in Figure 8:

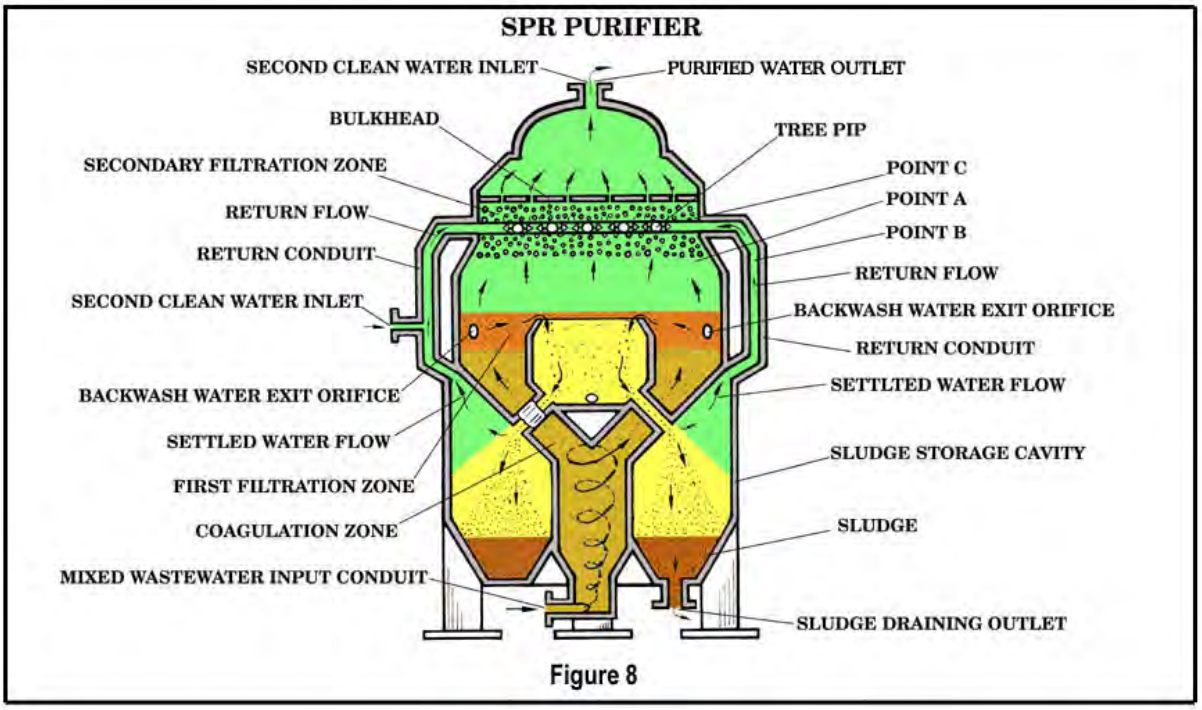


Figure 8

The mixed wastewater stream with pressure will be entering into the center cavity of bottom portion of the vessel. The input conduit is attached to the center cavity wall at a tangent to the center cavity. The mixed wastewater results in a circular flow of fluid around the canter axis of the circular, that to yield the best flow characteristic and lowest loss of energy.

A slow circulation and slow rise of mixed wastewater stream in the center cavity provides more time and chances for the suspended solids to interact with each other and to form larger flocculent. This is a coagulation zone.

The coagulation zone as defined additionally comprising the vessel being an inverted bell shape with being narrower at the bottom portion and wider than the bottom portion at the upper portion. The area available for fluid circulation is immediately increased due to the termination of the collector. The termination of the collector at the lip increases the area present for the path

of the upward circulation of the flocculent and suspended solids slowing the upward speed of both by natural action of increased area thereby forming a first filtration zone.

This first filtration zone formed of the flocculent and suspended solids forced up from below the first filtration zone by the upward circulation of the wastewater is also continually drawn into the collector due to the inability of the slower water circulation speed to the rise the flocculent and the suspended solids where the collector terminates. The thickness of layer formed of the flocculent and suspended solids at the first filtration zone is more than ten inches.

(The Figure 9 is showing the layer of slurry formed by flocculent and suspended solids at the first filtration zone.)

Figure 9.

Subsequent flocculent and the suspended solids in the wastewater stream reach this first filtration zone where they are intercepted by the layer of flocculent and suspended solids already formed at the first filtration zone. As a consequence the flocculent and the suspended solids are become the filter for their own removal therefrom.

As such, the pressure differences caused by the point eddy motion principal will draw substantially all of the flocculent and suspended solids toward the lower presser in the center of the vessel and into the collector. (See Figure 10, below)

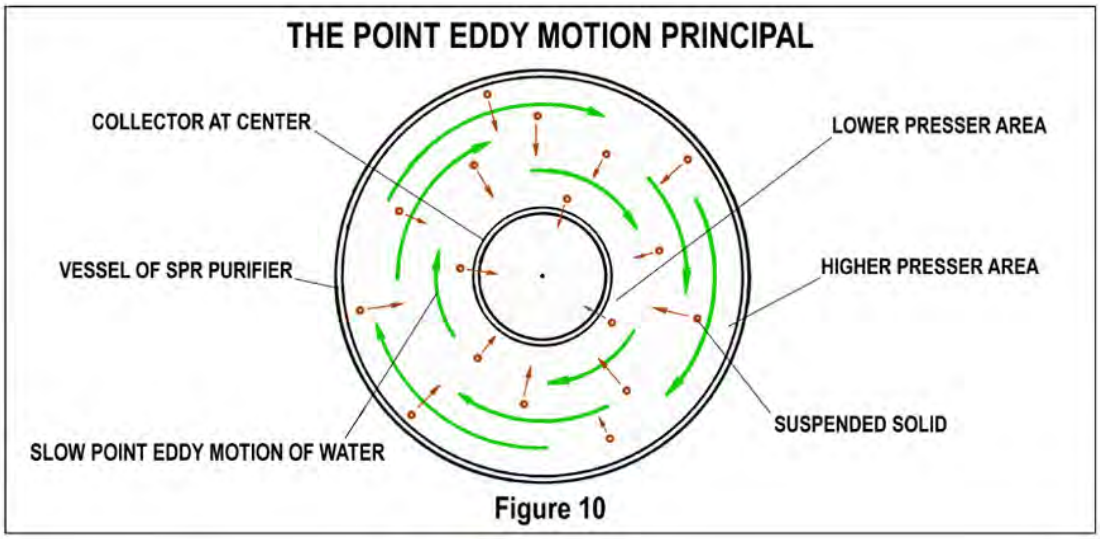


Figure 10

The result is being that only clean water that is substantially free of the first filtration layer consisting of flocculent and suspended solids to rise further past the lip of the collector and go up to a secondary filtration zone consisting of buoyant plastic balls.

The plastic balls of a specific gravity that is lighter than the water, works well for this layer as they naturally float to the high level in the vessel. This layer of buoyant plastic ball should have a small size in diameter-shaped components serves two purposes. First, the layer of plastic ball-shaped components, created a pressure differential between the water at the bottom of the secondary filtration zone layer and the water at the upper lever of the secondary filtration zone layer. This is because the water first encountering the bottom of the layer of the plastic ball-shaped components is at a higher pressure than the upper lever of the layer of the plastic ball-shaped components in accordance with the filter hydraulic principle. (See Figure 11)

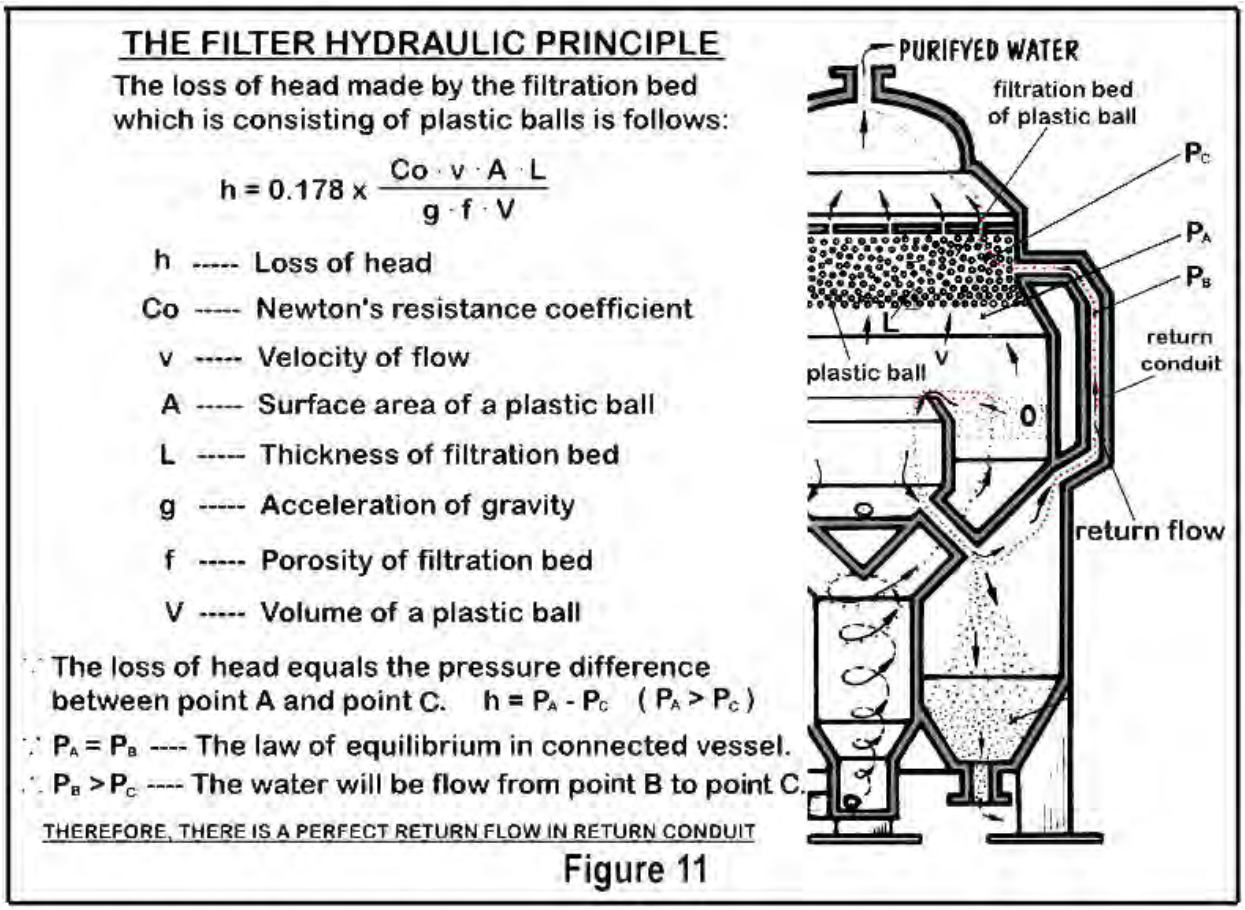


Figure 11

During the water flow through the secondary filtration zone layer, a pressure difference between point A and point C is created by the friction drag. Thus, the water pressure is higher at the bottom of the secondary filter zone (point A) than it is in the middle of the secondary filter zone (point C), ($P_a > P_c$).

The loss of the head equals the pressure difference between point A and point C, ($h=P_A-P_C$).

At the same time, the pressure at point A is equal with the pressure at point B in accordance with the law of equilibrium in connected vessels, ($P_A=P_B$).

So the pressure at point B is higher than the pressure at point C, ($P_B>P_C$).

The water will be flowing from point B to Point C. Therefore, a perfect return flow is made in the return conduit by this pressure difference. So the settled water in the sludge storage cavity will be up flow into the return conduit, which will exit into the middle of the secondary filtration zone from the top of the sludge storage cavity.

As a result, the flocculent and the suspended solids in the first filtration zone will be drawn into the collector and go into the sludge storage cavity with the perfect return flow very quickly.

Thus, the gravity and the pressure difference as well as the perfect return flow in the return conduit work in concert to remove the flocculent and suspended solids from the wastewater mix and deposit them into the collector very quickly.

The circulation of water through the vessel of SPR purifier can be additionally enhanced by the addition of the perfect return flow. As such, increased output is achieved of the purified water with the addition of the return conduit as is additional concentration of the sludge in the sludge storage cavity.

The discharging of the concentrated sludge in the sludge storage cavity would be done with the device not being run for water purifying, but using a flow of the clean water from the back wash pump through the second water inlet orifices into the vessel, and construct a twinkling water pressure in the vessel (such as 2 kgf/cm^2). After that, open the sludge draining ball valve, and the concentrated sludge in the sludge storage cavity is extruded through the valve. The moisture of the discharged sludge from the SPR System is as low as 92% (such as ceramic clay). The discharged sludge from the SPR System is easy to dry directly, and it can be used to produce the floor tiles. (Such as the Figure 12 is showing the floor tiles, which are made by sludge discharged from the printing and dyeing mill.)

products of floor tiles **Figure 12** floor tiles are made by dischaged sludge

Concurrently, this layer of buoyant plastic ball-shaped components serves as a secondary filtration zone which tends to remove any small remaining suspend solids that may have inadvertently made it past the layer composed of the flocculent and suspended solids at the first filtration zone.

After running for four hours, the backwashing of the layer of buoyant plastic balls in the second filtration zone would be done with the device not being run for water purifying, but using a flow of clean water from the back wash pump through the second water inlet orifices into the vessel, the flow of clean water will be backwashed from the top of the buoyant plastic balls to the bottom of the layer of the buoyant plastic balls. The backwashed water exits through the special exit orifice and goes back to wastewater tank for next purifying process, the backwashing intensity equivalent to 5 l/s.m^2, and about three minutes long, this operation is simple.

In the present, four patterns of the SPR purifier are available in the market, thus, their water put respectively are 50 cum / hr, 30 cum / hr, 15 cum / hr, 0.5 cum / hr. In accordance with the requirement of the volume of wastewater, several SPR purifiers can work together in parallel. (The Figure 13 is showing the purifier, which has water production of 50 cum / hr per set, below)

Figure 13. SPR to treat the wastewater from the printing and dyeing mill for reuse. (HongKong)

The SPR purifier system herein is disclosed, uses a slow circulation of the wastewater inside the vessel and requires minimal energy to operate. The sum of power consumption for SPR purifying system is only 0.25 kwh / cum. By using the pressure differences caused by the point eddy motion principal and the perfect return flow in the return conduit to separate coagulated solids from the wastewater very quickly, a high degree of filtration is achieved without the need for filtering screens or filter sand or activated carbon or reverse osmosis membrane which might clog decreasing maintenance requirements.

(Such as the Figure 14 is showing the purified water from exit of purifier in ceramic manufacturing plant)

Figure 14. SPR System for wastewater reusing of ceramic manufacturing plant. (CHINA)

Figure 15. SPR System for reusing of municipal effluents for communities in city. (Taiwan)

Figure 16. The SPR changes water of Mekong river into drinking water at Cambodia.

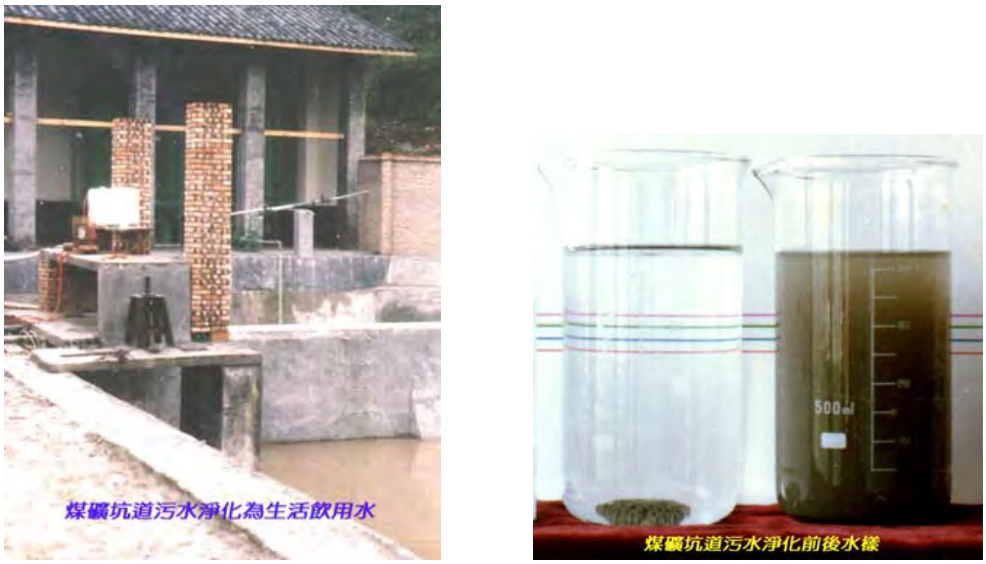
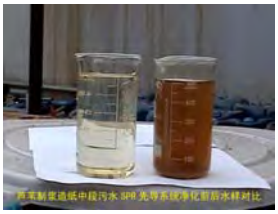


Figure 17. 300cum/d On Treating Wastewater from Coal Mine into Drinking Water. (China)

Figure 18. 600cum/d SPR-30 system (CHINA)



SPR to treat the wastewater of washing and bleaching effluent from Paper Pulping Line

The SPR purifier and SPR technology will be contribute significantly to solution for water scarcity problems in the world.

The ability would allow the SPR purifier system to process wastewater from recycled papermaking mills, printing and dying mills, ceramics plants, marble mills, wet precipitator on boiler with coal, coal pits, slaughterhouses, foundries, and municipal sewage. And the purified water can be reuse for industry or living things.

Figure 19. SPR System for 1200cum/day on textile industry (2005 & 2008 CHINA)

Figure 20. SPR System for 1200cum/day on plastics recycling industry. (2012.2 & 2012.3 CHINA)

Therefore, the SPR purifier system would not only be applicable to current municipal and industrial sewage plants, it would be ideal for use in countries where energy available is minimal and the technical personnel to complicated devices are not readily available. It could thus be immediately introduced into the stream of commerce to aid in purification of sewage and also of contaminated river water into potable or drinking water in third world countries as well as in water-deficient areas. When natural calamities are occurring such as the flood or earthquake, the smaller SPR purifier system setting up on trailer will be used to produce the drinking water for the victims. (The Figure 21 is showing the SPR purifier, which has water production of 0.5 cum / hr per set, below)

Figure 21. SPR system to treat Municipal Sewage into Recycled Water. (CA. USA)

Figure 22. President Zhang of US-China Guangdong Chamber of Commerce visit SPR in China.

Figure 23. Prof.Liao read paper of water reuse on Confernce of circular economy-China-US.

Figure 24. President of IDE Co. of Israel visit SPR system in China (2009—2011).

SESSION 2C

EDUCATION
8:30 a.m. – 10:00 a.m.

Building a Successful Rainwater Harvesting Outreach Program through Creative Partnerships
Jason R. Scott, Parci Gibson, and John Shubzda

The Potential of Rainwater Harvesting in Tennessee
Joanne Logan

The Creation of Nashville's Low Impact Development Manual
Rebecca Dohn

MODELING TOOLS
10:30 a.m. – 12:00 p.m.

Simulation of Time-Varying Land Use with LSPC
Jeremy Wyss, John Riverson, and Brian Watson

A New Tool for CE-QUAL-W2 Model Calibration
Gerald A. Burnette and Jeffrey S. Gregory

Water Reuse and Conservation Considerations in Drought Planning Using OASIS® Modeling
Benjamin Fennell, Dennis George, and Yvette Clark

ECOLOGY/BIOLOGY I
1:30 p.m. – 3:00 p.m.

What is Affecting the Mussel Populations on the Clinch River?
Greg C. Johnson

Chemical Analysis of Trout Otoliths as a Measure of the Biological Impact of Aqueous Aluminum in the Smokies
Michelle H. Connolly, Keil J. Neff, Matt A. Kulp, John S. Schwartz, Steve E. Moore, and Theodore B. Henry

A Network for Monitoring the Effects of Climate Change on Macroinvertebrate Populations in Southeastern Streams
Deborah H. Arnwine

ECOLOGY/BIOLOGY II
3:30 p.m. – 5:00 p.m.

Using Species Sensitivity Distributions in a Tennessee Watershed Assessment
Dana Brooke Coffey, Susan M. Cormier, and John Harwood

Fish Community Response to Altered Ecological Flow Regimes
Rodney R. Knight and Jennifer C. Murphy

Which Types of Hydrologic Models Best Address the Needs of Ecological Flow Research?
Jennifer C. Murphy, Rodney R. Knight, William J. Wolfe, and W. Scott Gain

BUILDING A SUCCESSFUL RAINWATER HARVESTING OUTREACH PROGRAM THROUGH CREATIVE PARTNERSHIPS

Jason R. Scott, C.S.M[1], Parci Gibson[2], and John Shubzda[3]

INTRODUCTION

Rain barrels and other water catchment devices such as cisterns offer a highly modular and customizable method of reusing rainwater on-site and eliminating runoff and pollutants associated with this runoff. With the issuance of the 2010 NPDES Municipal Stormwater Permit, rainwater harvesting has been identified as one of three ways that water should be managed on-site along with infiltration and evapotranspiration. This presentation's intent is to detail the process and framework of a successful rain barrel distribution / public information program that combines the visual arts, workshops and truck load sales with an emphasis on the importance of cross jurisdictional partnerships and the subsequent sharing of information to create like programs in the region, other parts of the US and abroad.

APPROACH

A combination of artistic rain barrel competitions, rain barrel sales and rain barrel making workshops were utilized between 2008-2012 to distribute over 2,250 rain barrels throughout Knox County and surrounding areas. This success can largely be attributed to a variety of dynamic partnerships between government, non-profit and private entities.

RESULTS AND DISCUSSION

The results of the Rainy Day Brush-Off Artistic Rain Barrel Competition include the distribution of over 2,250 rain barrels in the Knox County area while engaging local artists to create over 115 unique artistic rain barrels. It is anticipated that after the conclusion of the 5th and final Rainy Day Brush-Off in the summer of 2012 that well over 2,500 rain barrels will have been distributed as a direct result of the program. Stronger ties between diverse community interests are another result of the cooperation required to make this type of program successful.

REFERENCES

Tennessee Department of Environment and Conservation, 2010, State of Tennessee NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems, p.16

[1] Town of Farragut Stormwater, 11408 Municipal Center Dr. Farragut, TN 3934, jason.scott@townoffarragut.org
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[3] City of Knoxville Stormwater Engineering Division, Suite 480, City County Building, P.O. Box 1631, Knoxville, TN 37901, jshubzda@cityofknoxville.org

THE POTENTIAL OF RAINWATER HARVESTING IN TENNESSEE

Joanne Logan
University of Tennessee

By collecting rain from a roof during rain events and storing it in a barrel or cistern, homeowners and businesses can create an alternative supply for their home gardens, landscaping, and gray water supply that won't overpump the groundwater or increase the water bill. The typical homeowner rain barrel is a 50-gallon heavy-duty plastic barrel with a spigot located near the bottom of the tank. Often they are installed at the bottom of a downspout, and some are used with diverters that both allow an initial flushing of the roof water away from the barrel, as well as diverting the rainwater when the barrel is full. Commercial rainwater harvesting equipment may include cisterns or plastic containers with capacities of 5000 gallons or more. The objectives of this study were 1) create a spreadsheet that will allow user input to set the parameters such as the size of catchment area (ie. roof) and container, system efficiency, watering habits, and daily rainfall data for the period 1981-2010. 2) use this spreadsheet to develop a cross-section of rainwater harvesting scenarios for 50 locations across Tennessee 3) spatially interpolate the results for the entire state and present the results in a series of maps. Results show that only very large collection systems divert enough water to make an impact on water usage or stormwater runoff. However, the educational benefits of homeowner rain barrels should also be taken into account when developing a rainwater harvesting program.

THE CREATION OF NASHVILLE'S LOW IMPACT DEVELOPMENT MANUAL

Rebecca Dohn, Metro Water Services

The Metropolitan Government of Nashville and Davidson County's (Metro's) Department of Water and Sewerage Services (Metro Water Services) has developed a new Volume of its Stormwater Management Manual to encourage Low Impact Development (LID) in Nashville. LID is a planning and engineering design approach to land development that includes conservation of natural features and the infiltration, evapotranspiration, and re-use of stormwater on the site where it is generated. LID practices can also be referred to as Green Infrastructure (GI) and include strategies such as green roofs, bioretention, and pervious pavement.

The EPA's Water Quality Scorecard was used to identify barriers to the utilization of LID in Metro's existing codes, regulations, and policies. Each Department with development responsibilities evaluated their processes, earning Metro a combined score of 150 out of a possible 262 points. Since the completion of the Scorecard, Metro has already improved on some highlighted deficiencies. Metro Water Services will continue to meet with other Departments over the next few years to assess where changes to codes, regulations, and policies could improve water quality.

A Stakeholder group consisting of local professionals was convened to evaluate the current utilization of LID in Nashville and brainstorm means to increase its prevalence. This included an assessment of (the current local and national incentives offered for various LID practices. The Manual incorporates updated design specifications for green infrastructure BMPs already used in Nashville along with new design specifications for BMPs such as cisterns and reforestation. The stakeholders reviewed these specifications and offered suggestions for their improvement.

The design methodology in the new LID Manual is also intended to meet the one inch retention site design requirement of Metro's new MS4 permit. Incentives will be offered to projects that utilize the new Manual before it becomes mandatory. These incentives include: waiving plan review fees, decreasing water quality requirements for infill development, reducing a site's stormwater user fee, and an additional runoff reduction credit for using green roofs. This voluntary period will be used to identify problems and make any needed adjustments. Metro will provide training and tools to the development community to ease the transition.

SIMULATION OF TIME-VARYING LAND USE WITH LSPC

Jeremy Wyss[1], John Riverson[2], and Brian Watson[1]

Watershed models are often utilized to determine sources of impairment in Total Maximum Daily Load (TMDL) studies. The watershed model typically includes all point source contributions, nonpoint source contributions and transport dynamics, which results in providing a very useful tool to managers when making decisions about restoring impaired water-bodies. Typically, when assessing a TMDL, multiple scenarios are prepared and analyzed. These scenarios can include: an all forest condition, removing all point sources, looking at future or past land use, etc. The purposes of this paper are to demonstrate the utility of the Time-Varying land use component of the Loading Simulation Program C++ (LSPC) watershed model and also investigate watershed response to Time-Varying land use.

The LSPC model developed for Georgia Environmental Protection Division (GAEPD) for the Lake Lanier TMDL, was utilized to perform an analysis on Time-Varying land use impacts to hydrology and water quality. LSPC is configured with Time-Varying land use, which allows for the land use to change throughout the course of the simulation. Two time snapshots of land use, representing 2005 and projected 2040 conditions, were utilized. The model was simulated for five decades and land use was linearly changed from the 2005 snapshot to the 2040 snapshot through the middle three decades. This type of simulation allows for investigation on how the watershed may respond to land use change by looking at year over year changes, decade over decade changes, and could potentially be utilized for narrowing into a tipping point of watershed response.

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A NEW TOOL FOR CE-QUAL-W2 MODEL CALIBRATION

Gerald A. Burnette[1]* and Jeffrey S. Gregory[2]

Most of us are familiar with the phases associated with developing a model of a given scenario: 1) select the modeling framework – the model software, 2) describe the physical configuration and other inputs to the software, 3) run the model, 4) compare the output to observed data, and 5) tweak model inputs for better calibration. Repeat steps 3 through 5 *ad nauseaum* until you are satisfied that the model is the best approximation you're going to get to the real world. Then you can finally move to step 6 – running the model for the analysis you wanted to do in the first place.

Each of these steps can require a lot of time and effort. Fortunately, there are tools that can help with the various tasks. Many models have pre-processors which help you define your physical conditions (step 2) without having to immerse yourself in the often arcane structure of the actual model input files. Popular models often have many pre-processors available. There might also be post-processors to help you analyze the results of your calibrated model as well (step 6). It's the middle steps that tend to have fewer tools for assisting users.

This is perhaps understandable given the myriad of options for storing the observed data needed for comparison. It is unreasonable to expect a software tool to possess the flexibility to address more than maybe a dozen potential data sources and formats. If you are fortunate to be associated with a large organization with data standards, though, this might become less of a concern.

At least that's what you would think. The US Army Corps of Engineers (USACE) is faced with modeling water quality in numerous reservoirs around the country, and the most widely-used model for this purpose within USACE is CE-QUAL-W2. However, even given the fact that USACE promulgates standards for water quality data, even they have previously had limited success with the development of tools to assist in the model calibration phase.

Perhaps this is because, on the surface at least, the process seems so simple. All you have to do is:

- extract results from the model output files,
- obtain observed data from your water quality database or spreadsheet, and
- put them together within a program that allows you to compare the two.

Let's see just how this simple process plays out in reality. Everybody has Microsoft Excel, and most people are pretty comfortable using it for comparing values both textually and graphically, so let's assume we'll use that for the calibration comparison. W2 provides output in a series of ASCII files, so the first order of business is to wade through those files and extract the predicted constituent values. W2 is a 2D model, so we'll need a matrix (river km x depth) for each

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constituent. Next we have to obtain our observed data and put that in the spreadsheet as well. Luckily that can follow the same matrix definition as the model data, it's just that there will be a lot less of it due to fewer observation points. Now all we have to do is match up the locations in each data set and compare the values. We'd better be familiar with the lookup functions in Excel. We'd also better be prepared for some extensive data reviews because with so many manual steps involved, there's plenty of room for human error.

You might think there's software out there that makes at least some of this work easier, and you would be right. One example is a program called the Animation Graphics Portfolio Manager (AGPM). AGPM is essentially an add-on for W2 – it generates some binary files that mirror the model output. This eliminates the need to mine the ASCII W2 output files for predicted parameter values, which is definitely a time saver. Unfortunately, though, AGPM reads the observed data for each parameter from a different file. You must generate an ASCII file in a predefined format for each parameter in each branch. So, for instance, if you have 6 branches and 20 constituents, you now have to generate 120 separate ASCII files. Also, the fact that AGPM sits on top of W2 means that each verison of AGPM is tied to a specific version of W2. And since AGPM is sold as commercial software, each new iteration of W2 requires purchasing a new version of AGPM.

In an effort to overcome the expenditure of time and money in excessive generation of model calibration data, USACE has recently chosen to leverage their investment in another software package. USACE possesses a comprehensive surface water quality data management tool called the Data Management and Analysis System for Lakes, Estuaries, and Rivers (DASLER). DASLER consists of a database backend and a graphical user interface Many USACE Districts use DASLER for managing their water quality data, so it makes sense to develop a tool that automates the extraction of observed data for model calibration comparisons. Work is currently under way to develop just such a tool. The new program will link directly to the DASLER database and extract water quality observations. It will also automate the extraction of model predictions by directly reading the W2 ASCII output files. Finally, since all the data retrieval will be performed within a single program, it will eliminate the need to actually generate external files to store the various components. All data analysis is done within the new calibration tool, so storing data in external files would be redundant.

DASLER already has extensive graphics and text reporting capabilities, so the new calibration program can generate both text and plots of data comparisons. Text reports range from side-by-side comparisons of data to statistical assessments of data fitness. The graphical capabilities include the option of loading multiple W2 model runs simultaneously and showing comparisons to observed data. These comparisons can be shown in individual plot windows or can be overlaid into a single plot for best case analysis.

The obvious follow-on question is "how does this help other organizations?" USACE offers the W2 model for use by other organizations, but what about the data management component? Fortunately, DASLER is also available to organizations other than USACE. The USACE-specific version of DASLER can be obtained directly from the Corps. A commercial version of DASLER is also available.

WATER REUSE AND CONSERVATION CONSIDERATIONS IN DROUGHT PLANNING USING OASIS® MODELING

Benjamin Fennell[1], Dennis George[2] and Yvette Clark[2]

INTRODUCTION

In 2007, several Tennessee water utilities were affected by a severe drought across the state. The Tennessee Department of Environment and Conservation (TDEC) created a Water Resources Task Force in 2007 to address the water supply issues in Tennessee. The Task Force initiated two case studies, the North Central Pilot Study (USACE, 2011) and the South Cumberland Pilot Study (USACE, 2011), to develop a systematic planning process for utilities that will alleviate water supply problems during future drought conditions. The North Central Pilot Study analyzed several drought mitigation alternatives for the city of Portland, Tennessee.

Portland experienced a drastic impact from the 2007 drought mainly due to its location from additional surface water supply sources as seen in Figure 1. Portland currently uses West

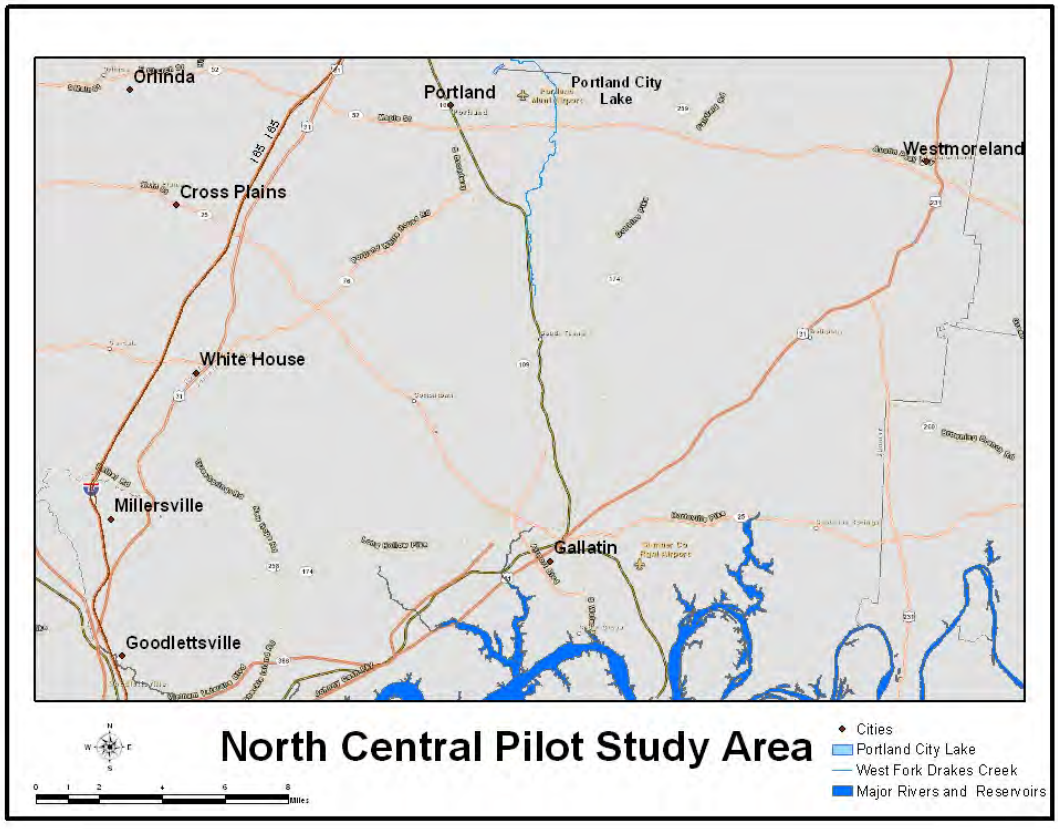


Figure 1. *Surface Water Supply Source for Portland, TN*

Fork Drakes Creek as its primary water source, while Portland City Lake provides additional water during extenuating circumstances (Figure 1). The North Central Pilot Study produced an in-depth analysis of regionalization and development of new water sources but neglected an in-depth analysis of conservation and demand management (USACE, 2011). Developing a drought planning process involves the analysis of both water supply and water demand for a specific region to select the most viable alternative(s) for that region. The current planning process for Tennessee drought-prone regions includes analyzing water supply issues but does not fully assess the impact of water reuse and water conservation on water supply. While regionalization of water supply and development of new water supply sources are essential to any water planning process, water conservation and water use efficiency (reuse) should also be considered.

APPROACH

The drought prone region of Portland, TN, was used as a case study to analyze water demand reduction through water reuse and water conservation alternatives. Conducting a water reuse study for Portland first involved determining which of the following six EPA water reuse categories could be implemented: urban reuse, industrial reuse, agricultural reuse, environmental and recreational reuse, groundwater recharge, and augmentation of potable supplies (EPA, 2004). Land use maps and parcel information provided through state and Portland Geographical Information Services identified Portland as having urban reuse, industrial reuse, and agricultural reuse. The use of reclaimed water for urban and agricultural irrigation was further determined by calculating the hydraulic loading rate and nitrogen loading rate. Hydraulic loading rates were calculated for Portland by determining how much water would be needed to meet specific crop evapotranspiration requirements. Calculations for the nitrogen loading rate involved limiting the amount of applied reclaimed water within specific nitrogen requirements as identified by TDEC (2008). Precipitation data, solar radiation data, and temperature data extending from 1961 to 2005 provided by NOAA were used to produce an average monthly irrigation schedule for each potential site. The lower of the two calculated rates (hydraulic loading or nitrogen loading) governed the amount of reclaimed water to be applied for each water reuse category. The total amount of reclaimed water required was then determined by multiplying the lowest monthly irrigation rate by the amount of irrigated area.

The EPA (2004) further identifies four water reuse subcategories for industrial reuse which include process water replacement, cooling water replacement, boiler make-up water replacement, and sanitary water replacement. In the Portland area, both process water replacement and sanitary water replacement were applicable for industrial reuse alternatives. The quantity of water for each subcategory was determined by first calculating sanitary water use for each industry. A secondary data acquisition method involving the total number of employees and industrial SIC code determined the water quantity for an industry (EPA, 2012). Each industry was requested to complete a survey to gather information about industrial process water replacement. Only industries interested in industrial process water replacement as indicated through the survey were included in the industrial reuse analysis.

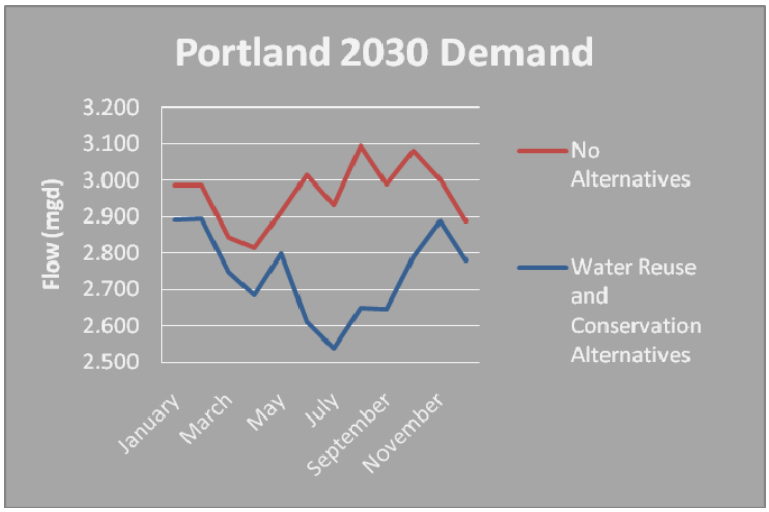
Water conservation alternatives were also determined for the city of Portland by administering a water audit for the city. Retrofit and rebate replacement programs for water-efficient toilets were used for conservation analysis. The replacement programs aimed at replacing existing

residential toilets with more water efficient toilets. An assumed 40% public participation was included in this analysis due to past retrofit and rebate replacement studies (Whitman, 2002).

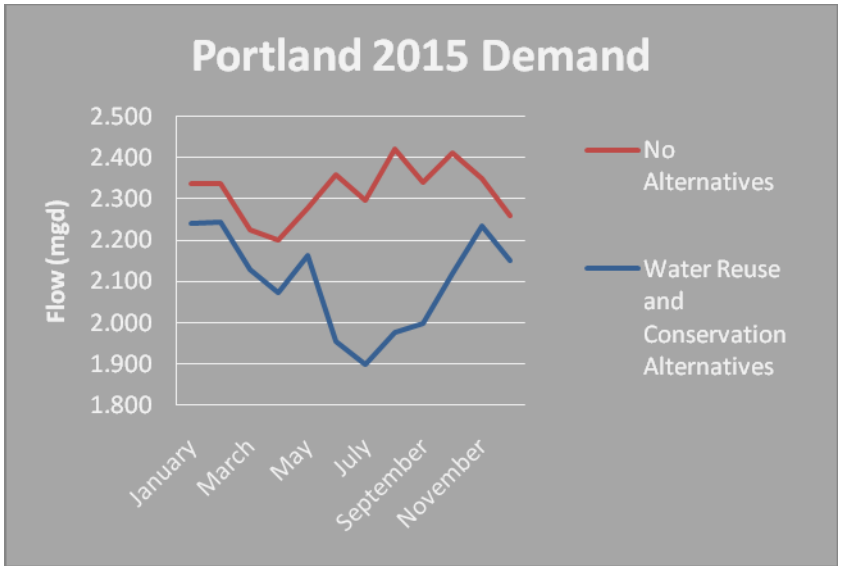
Each water reuse and water conservation alternative was then analyzed using OASIS®, a water optimization model developed by Hydrologics, Inc. (Columbia, MD). The OASIS model was used to evaluate regional water supply alternatives for the North Central Pilot Study to sustain Portland's reliable yield for the year 2030. Reliable yield was defined as "the maximum amount of water that can be delivered every day during the worst drought in recorded history while preserving 20% of its usable storage in a reservoir" (USACE, 2011). Thus, analysis of each water reuse and water conservation alternative was conducted with the goal of preserving 20% of Portland City Lake's usable storage under the 2030 projected water demand. Cost estimates were determined for each of these alternatives with the assistance of J. R. Wauford & Company, Consulting Engineers, Inc., Nashville, TN.

RESULTS

Water reuse and water conservation alternatives were evaluated using OASIS® to compare both water supply and water demand alternatives for Portland, TN under the projected water demand. Hydraulic loading rates controlled the design for the Portland reuse of reclaimed water. Monthly irrigation schedules for urban reuse and agricultural reuse scenarios would reduce the water demand for Portland by a maximum of 355,000 gallons per day (Figure 2). Industrial process water replacement and industrial sanitary water replacement were predicted to decrease more than 49,800 gallons per day from Portland's demand (Figure 2). Introducing a water conservation strategy of residential toilet water replacement would potentially reduce Portland's demand by 41,000 gallons per day (Figure 2). The water demand scenarios were evaluated for the severe drought that was experienced during 1953-1954 (GKY & Associates, Inc., 2009). Under these conditions, OASIS® analysis indicated that the reliable yield for Portland City Lake would not be sustained for the projected twenty year (2030) future demand (Figure 3a). Further OASIS® analysis results revealed the reliable yield for Portland City Lake to be only sustained through the projected year of 2015. Figure 3b indicates that Portland City Lake would retain sufficient storage even while experiencing devastating drought conditions for the projected 2015 water demand. Water reuse and water conservation alternatives thus provide additional alternatives for water provision when planning for drought scenarios. Both water demand and water supply alternatives are essential in planning for future drought conditions.

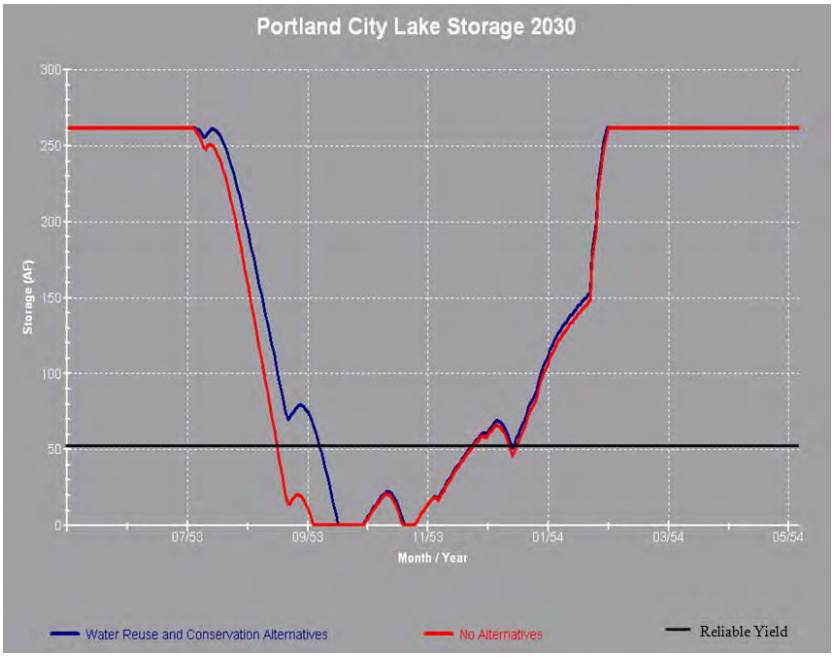


(a)

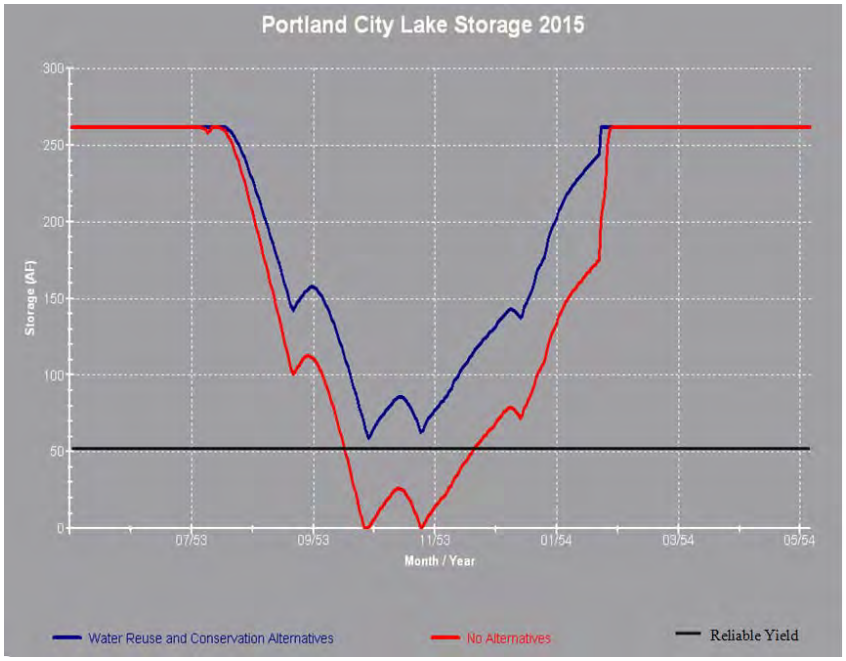


(b)

Figure 2. *Portland's water demand for years 2030 (a) and 2015 (b) as provided through implementing water demand alternatives.*



(a)



(b)

Figure 3. *Portland's reliable yield storage for years 2030 (a) and 2015 (b) as provided through implementing water demand alternatives.*

CONCLUSION

Water reuse and water conservation alternatives reduce the impact observed during extenuating drought conditions by reducing the projected water demand for a specific region. As seen through the Portland Case Study, water demand alternatives provide mitigation to short-term drought conditions when used exclusively. The additional 445,800 gallons per day, as provided through the water demand alternatives, can further complement long-term water supply alternatives by decreasing the water demand needed for design. Water demand alternatives can therein supplement long-term water supply alternatives by decreasing the projected water demand used for planning purposes.

Secondary advantages of water demand alternatives include the reduction of nutrient-rich effluent discharges to surface waters and the preservation of discharge capacity. Diversification of water supply and water demand alternatives provide an entity the ability to be flexible during drought conditions. Figure 4 reveals the proposed Tennessee drought planning process which includes an in-depth analysis of both water demand and water supply alternatives. OASIS® further provides the tools necessary to evaluate both water demand and water supply alternatives under simulated drought conditions for utilities, cities, regions, and states.

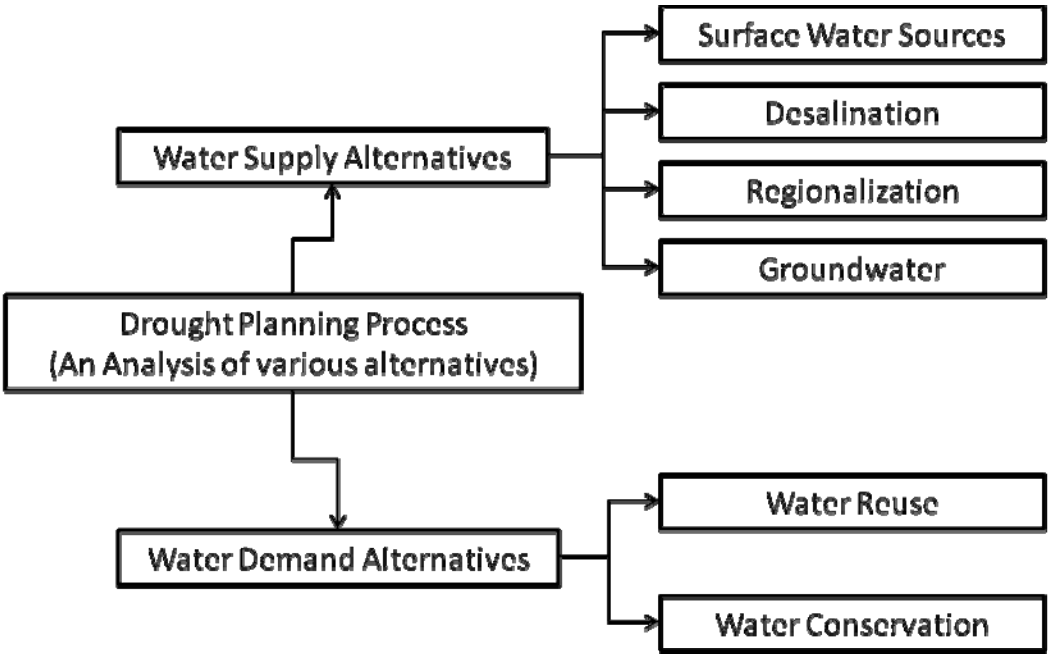


Figure 4. *Tennessee Drought Planning Process*

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WHAT IS AFFECTING THE MUSSEL POPULATIONS ON THE CLINCH RIVER?

Gregory C. Johnson[1*]

ABSTRACT

The Clinch River, flowing from southwestern Virginia through East Tennessee, supports unique and nationally significant endemic and endangered populations of fresh-water mussels and other aquatic fauna. Surveys of mussel-community structure over past decades have shown a pattern of catastrophic declines in a 40-mile segment of the upper Clinch River, while mollusk assemblages downstream remain healthy, and upstream communities appear to be recovering.

In 2008, the U.S. Geological Survey, in cooperation with TWRA began an investigation of potential stressors which could explain the differences in the mussel populations. The various components of the study included: quantitative analysis of mussel habitat, continuous water quality monitors in an impaired reach at Dungannon, Virginia and in a healthy reach at Horton Ford, Tennessee, paired water quality samples at base flow and during storm events, sediment quality samples along the main stem of the river, in-situ mussel growth and mortality trials, histological evaluation of native mussels, and synoptic surveys of major ions along the main stem of the Clinch.

Preliminary results indicate that habitat differences are not significant between sites. Sediment chemistry results shows some elevated polycyclic aromatic hydrocarbons from coal throughout the study reach, but the distribution of constituent concentrations does not correspond to the mussel population distribution. Water quality results show differences between the fixed sites at Dungannon and Horton Ford, and the synoptic surveys show higher specific conductivity and major ion concentrations in the impaired reach of the Clinch River.

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CHEMICAL ANALYSIS OF TROUT OTOLITHS AS A MEASURE OF THE BIOLOGICAL IMPACT OF AQUEOUS ALUMINUM IN THE SMOKIES

Michelle H. Connolly*[1], Keil J. Neff[2], Matt A. Kulp[3], John S. Schwartz[2], Steve E. Moore[3], and Theodore B. Henry[1]

Stream acidification is recognized to be responsible for the extirpation of brook trout from many headwater streams of the Great Smoky Mountain National Park (GRSM). These streams are particularly susceptible to acidification events, due in part to the low buffering capacity of the geology in this region. Atmospheric acid deposition influences pH and the solubility of trace metals. Archival datasets indicate that aqueous Aluminum (Al) is especially prevalent under stormflow conditions; however it is unclear whether these Al levels bioaccumulate in fish. Our research is aimed to demonstrate the application of measuring trace aluminum levels in fish otoliths (ear bones) to inform on the biological impact of acidified streams in the GRSM. Otoliths continuously incorporate inorganic material (including trace metals) into their calcified matrix, creating a permanent record of metal exposure. Samples were collected from four elevations within the Park (1462-3820 feet above sea level), and analyzed using ICP analysis. While aluminum was detected among otoliths collected at all elevations under investigation, the greatest Al concentrations were found among the youngest fish at all four sites. When samples were normalized to Ca concentration, the Al:Ca ratio among one year old fish reflected the stormflow pattern found among archived water samples, suggesting that short-lived Al pulses are incorporated into otoliths of fish undergoing rapid growth.

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A NETWORK FOR MONITORING THE EFFECTS OF CLIMATE CHANGE ON MACROINVERTEBRATE POPULATIONS IN SOUTHEASTERN STREAMS

Deborah H. Arnwine[1]*

Changes in stream temperatures and hydrologic regimes due to climate change may affect aquatic communities throughout the southeast. Current monitoring programs and data are not ideal to detect and track effects based on climate change. Modifications to exisiting programs can help.

During their annual meeting, in November 2011, climate change was a focus of the Southeastern Water Pollution Biologist Association (SWPBA). The result was the creation of an interagency workgroup consisting of freshwater biologists interested in developing a climate change monitoring network. Two main goals of the group are to assess existing responses to climate change and identify climate-sensitive indicators

The group will identify data that are necessary for monitoring the effects of climate change on stream biota. Existing monitoring programs will be adjusted at key reference sites to include additional parameters so that monitoring will be consistent for all sites in the network. Existing data will be mined where available.

The monitoring network is still in the initial planning stages with sampling expected to start later this year. Factors the group will consider include:

- Identification of established long-term reference sites where data already exists.
- Possible need of additional monitoring sites.
- Feasibility of using stable impaired sites to identify climate change effects on stressed systems.
- Monitoring needs (parameters, frequency, season, target populations, sample size, taxonomic level etc.)
- Location of most vulnerable populations
- Hydrology/stream size
- Liklihood of land use changes that will effect long-term monitoring
- Potential confounders

Monitoring objectives include:

- Detecting climate-related changes early in a way that informs management strategies such as restoration and adaption.
- Distinguishing climate change effects from natural variation and other stressors.

By April, the group expects to have a preliminary plan. AWRA attendees are encouraged to provide additional input.

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USING SPECIES SENSITIVITY DISTRIBUTIONS IN A TENNESSEE WATERSHED ASSESSMENT

Dana Brooke Coffey, Susan M. Cormier, and John Harwood

Species Sensitivity Distributions (SSDs) are models of the relative sensitivity of species to natural and anthropogenic exposures. SSDs are the basis for most water quality criteria in the U.S. and abroad. Because SSDs require either extensive laboratory or field data, they have rarely been used in causal assessments. We developed and used SSDs based on responses of aquatic organisms for nutrients, conductivity, and cumulative metals to reassess the cause of reduced biological diversity in Pigeon Roost Creek, Caney Fork Watershed, TN. We developed SSDs from published laboratory results or field monitoring databases to make general SSD models used to determine if the concentration of a stressor in Pigeon Roost Creek was sufficient to cause the known level of taxa loss in the creek. We also developed site-specific SSDs using the published effect levels for the genera in Spring Creek, the reference stream, and Pigeon Roost Creek. Using these site-specific SSDs, we compared the distribution of genera along the exposure gradient to evaluate if genera susceptible to a stressor were absent in the impaired stream. To evaluate sediment, we used a published regression model of the effect of sediment on a composite metric; total number of Ephemeroptera, Plecoptera, and Trichoptera. The new evidence supports results from a screening assessment completed in 2010 and found that nutrients and sediment are the probable causes of biological impairment in Pigeon Roost Creek. The general SSDs developed for this assessment should be applicable for causal assessments in Middle and East Tennessee.

The views expressed in this abstract are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

FISH COMMUNITY RESPONSE TO ALTERED ECOLOGICAL FLOW REGIMES

Rodney R. Knight and Jennifer C. Murphy

The relationships between hydrologic change and the composition, diversity, and resilience of aquatic ecosystems constitute a complex series of interactions connecting landscape and climate variables to ecosystem function. Evaluating linkages between hydrologic alteration and aquatic community response begins with the definition of a hydrologic reference condition, often termed the 'natural flow condition'. We explored three different methods to characterize reference hydrologic conditions expressed through 18 streamflow characteristics for 662 fish-community sampling sites in the Blue Ridge, Ridge and Valley, and Interior Plateau ecoregions. Maximized Spearman rank correlation was used to identify characteristics most important for defining fish-community diversity and structure. This presentation will highlight preliminary results for ungaged, free-flowing streams in the Tennessee River basin.

WHICH TYPES OF HYDROLOGIC MODELS BEST ADDRESS THE NEEDS OF ECOLOGICAL FLOW RESEARCH?

Jennifer C. Murphy[1], Rodney R. Knight[1], William J. Wolfe[1], and W. Scott Gain[1]

Estimates of 19 ecologically-relevant streamflow characteristics from a published rainfall-runoff model and a regional regression model were compared to values calculated from observed records for 6 sites in Kentucky. Across all six sites, the regional regression model produced median estimates closer to the observed median for all but two characteristics. The variability of predictions from both models was generally less than the observed variability. The variability of the predictions from the rainfall-runoff model was greater than that from the regional regression model for all but three characteristics. Eight characteristics predicted by the rainfall-runoff model display positive or negative bias across all six sites; biases are not as pronounced for the regional regression model. Results suggest that when compared to a rainfall-runoff model, a regional regression model is a better predictor of flow regime (a range of streamflow characteristics). The rainfall-runoff model was calibrated on a single characteristic whereas the regional regression model was calibrated individually on multiple characteristics. Poor model performance may misrepresent hydrologic conditions, potentially distorting the perceived risk of ecological degradation. Without prior selection of streamflow characteristics, targeted calibration, and error quantification, the widespread application of general hydrologic models to ecological flow studies should be approached with caution.

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SESSION 3A

MUNICIPAL STORMWATER
8:30 a.m. – 10:00 a.m.

Environmental Stewardship Program: Sustainable Approaches to the Age Old Public Works Requests for Pipe and Rip Rap
Michael Hamrick, Parci Gibson, and Martin Pleasant

Lessons Learned: Stormwater Utility Development and Implementation for the City of Kingsport, TN to Address NPDES Phase Updates and Customer Expectations
David Mason

The City of Chattanooga Green Infrastructure Urban Retrofit Initiative
Don Green and Mounir Minkara

GIS
10:30 a.m. – 12:00 p.m.

Geomorphology from the GIS Desktop: Interpretation of High-Resolution DEMs for Urban Watershed Assessment
Nick Jokay

Development of a GIS-Based Geomorphic Classification System for West Tennessee Streams: Implications for Watershed Analysis and River Restoration
Christopher A. Bridges

Your "WebMobile" GIS: The New Era Explained
Richard Duncan

ENVIRONMENTAL STEWARDSHIP PROGRAM: SUSTAINABLE APPROACHES TO THE AGE OLD PUBLIC WORKS REQUESTS FOR PIPE AND RIP RAP

Michael Hamrick, Parci Gibson, and Martin Pleasant

INTRODUCTION

Failing stormwater infrastructure is a common cause for citizen complaints to local governments. In addition to being a nuisance for homeowners, failing infrastructure can cause excessive sedimentation, nutrient loading and an increase in pathogens and other organics to the local stream system. Often, public works crews attempt to fix stormwater infrastructure problems by installing pipe, rip rap or concrete. Citizens are frequently forced to remedy problems on their private property using the same techniques with little to no avail. This presentation will demonstrate how Knox County's Environmental Stewardship Program provides opportunities for the use of environmentally friendly techniques to solve private property drainage problems.

APPROACH

Working with local partners, Knox County has developed a program to provide Knox County citizens with solutions for off-Right-Of-Way requests addressing erosion and nuisance flooding. The Environmental Stewardship Program, or ESP, is a cooperatively sponsored cost-share program that allows community organizations and citizens access to professional expertise required to implement drainage related projects while protecting water quality. ESP projects address age-old drainage problems (bank erosion, flooding, and increased flows) using engineered sustainable and bioengineered approaches to the traditional civil engineering "fixes" that rely solely on rock or pipe.

The ESP program is administered through the Knox County Stormwater Management Department. The department provides all technical and oversight services for the program. Knox County Stormwater Management staff design the projects and Knox County cost shares with homeowners on the cost of supplies and labor for all projects.

RESULTS AND DISCUSSION

The ESP program allows Knox County to:

- focus on reducing erosion by restoring stream banks,
- protect riparian areas in urban watersheds,
- foster a community stewardship approach to stormwater management,
- promote the use of environmentally friendly maintenance/management techniques for urban stormwater systems,
- Demonstrate and provide education for the general public on environmentally-friendly stormwater management techniques.

Knox County has been supporting the Environmental Stewardship Program for over ten years. In that time, over fifty projects have been completed that include installing grassy swales, constructing pocket wetlands, stream bank restoration projects and rain garden installations. In

addition to providing real life solutions, the Environmental Stewardship Program is an excellent education tool for citizens, landscape professionals, contractors and public works/utility employees to illustrate how water quantity problems can be solved while providing tangible benefits to water quality.

LESSONS LEARNED: STORMWATER UTILITY DEVELOPMENT AND IMPLEMENTATION FOR THE CITY OF KINGSPORT, TN TO ADDRESS NPDES PHASE UPDATES AND CUSTOMER EXPECTATIONS

David Mason, PE, D.WRE
CDM Smith

In the early 2000's, the City of Kingsport briefly considered the notion of developing a stormwater utility funding program to implement along with their first NPDES Phase II MS4 permit. However, the political will did not exist at the time to move forward. Fortunately, the City survived the initial implementation of their permit. However, subsequent audits identified some program deficiencies that needed to be addressed and the City realized they were not adequately staffed or prepared to address the pending MS4 permit updates proposed by TDEC in 2010. In addition, the City experienced mounting complaints from customers regarding unmet expectations in stormwater management. In response to this growing need, the City reconsidered and initiated a stormwater utility feasibility study in 2010. This presentation will summarize the process untaken by the City to build public support for the program and will highlight the lessons learned during implementation of the program, which will begin billing in February 2012. Lessons learned include management of the stakeholder effort, education of elected officials along with the public, timely scheduling of public outreach efforts following the approval of the ordinance, and response to public comments on the implementation.

THE CITY OF CHATTANOOGA GREEN INFRASTRUCTURE URBAN RETROFIT INITIATIVE

Don Green[1] and Mounir Minkara[2]

ABSTRACT

The City of Chattanooga (City) was the first urbanized area in Tennessee to receive a Phase I MS4 permit in 1996. The City is making a concerted effort to address urbanization problems by implementing retrofit projects to address stormwater problems with green infrastructure (GI) practices. These projects are planned to be used as models to apply to other parts of the City and region.

The built urban landscape has high percentage of impervious surfaces and potential for pollutants in the environment. Urbanization has resulted in drastic changes to the hydrology surface water quality of City. Implementation of GI practices will address the water quality and reduce imperviousness; this will aid in reducing the volume and peak storm levels reducing the adverse effects it has on stream integrity.

Chattanooga has identified GI practices, infiltration technology, as an important method to recreate hydrology, as much as possible. It is also the method the City is using to address the water quality requirements in its new Phase I MS4 permit.

This presentation is going to give an overview of four projects currently underway, in different stages of development:

- Anderson Ave: mixed urban residential/institutional area.
  a. To document change in water quality and quantity,
  b. To educate stakeholders on water quality issues, and
  c. To reduce urban stormwater impact into receiving streams.
- Brainerd Green - Community - Connections (SEP) Supplemental Environmental Project;
  a. Provide a model for retrofitting the city commercial districts with GI practices.
  b. To work with a wide range of land uses: airport, small retail, to big box commercial and shopping malls.
  c. To work with stakeholders to create a stormwater management system resulting in changing the area to place of destination, and
  d. To develop cost benefit analysis for retrofitting GI
- Manufacturers Road: Plan for the gateway to Moccasin Bend Park: National Archeological District. The gateway design would connect the park to Stringers Ridge Park including a reinvented U.S. 27/Manufacturers Road interchange tree-lined and art-studded streetscaping, as well as paths and bicycle routes.
- Highway 58: Retrofitting a state route with GI practices and multimodal paths. The future Enterprise South Corridor and Chickamauga Creek Greenway connector.

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GEOMORPHOLOGY FROM THE GIS DESKTOP: INTERPRETATION OF HIGH-RESOLUTION DEMS FOR URBAN WATERSHED ASSESSMENT

Nick Jokay[1*]

The recent advent of high resolution Digital Elevation Models (DEM) now make it possible for the geomorphologist to locate potential features of interest before entering the field. Watershed assessments frequently include a component in which field scientists explore the watershed through streamwalks with a goal of locating points of severe erosion or other interest that potentially impair watershed health. Project budgets are often insufficient to allow field personnel to walk all the stream miles in a watershed. Present methods of designing field investigations involve using USGS topographic maps, GIS stream layers, and aerial photographs to locate perennial streams and other features of interest. These methods tend to ignore ephemeral streams or completely overlook features hidden under tree canopy. Within the past decade, DEMs with grid sizes less than 2 meters, or elevation contours from one to two feet can be generated using LiDAR (Light Detection and Ranging) datasets. The cost is typically prohibitive for widespread data collection. However, cities and counties that serve moderately large populations often have both the need and the budget to collect the LiDAR data and to generate the high resolution DEMs. When available to the geomorphologist, the high resolution DEM can be used to generate maps that can be interpreted in terms of geomorphic features. Observable features include but are not limited to: steep stream banks, escarpments, mass wasted materials, headcutting gullies, culvert headwalls, abandoned terraces, dredging spoils, retaining walls, historic areas of earth moving, and the exact location and pattern of the stream channel.

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DEVELOPMENT OF A GIS-BASED GEOMORPHIC CLASSIFICATION SYSTEM FOR WEST TENNESSEE STREAMS: IMPLICATIONS FOR WATERSHED ANALYSIS AND RIVER RESTORATION

Christopher A. Bridges[1]*

Sustainable river system management in West Tennessee requires an understanding of complex geomorphic processes related to land use change, historic stream alteration and channel evolution. Stream channel instability has been identified as a major problem for aquatic habitat, water quality and communities throughout the region. Although great progress has been made by multiple agencies and organizations in restoring ecological functions in small tributaries, the successful application of river restoration strategies at the watershed-scale necessitates reliable data to identify problems and develop appropriate solutions. Therefore, this project presents a novel Automated Geospatial Stream Channel Assessment Technique (AGSCAT) to rapidly classify streams according to geomorphic characteristics using basic geographic information system data and spatial analysis methods.

Over 22,000 West Tennessee stream reaches were categorized along 19,576 miles according to channel sinuosity, longitudinal slope and substrate geology, which are primary physical indicators used in Rosgen's (1994) river classification system. AGSCAT results were compared to previously-conducted surveys in the Hatchie and Obion watersheds, revealing substantial consistency in findings. Applications of this technique include stream habitat assessment and the identification of reference reaches for natural channel design approaches to stream restoration. Given emerging interest in sediment source identification to guide stormwater management and the implementation of TMDL's for siltation, this automated technique provides an additional tool for reconnaissance-level watershed analysis. By integrating an enhanced understanding of fluvial dynamics into stream restoration planning, great advances can be made in the improvement of channel stability, aquatic habitat and the long-term function of low-gradient rivers throughout the Southeast.

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YOUR "*WEBMOBILE*" GIS: THE NEW ERA EXPLAINED

Richard Duncan
Geo-Jobe GIS Consulting

Mapping your infrastructure is essential to the future management of your assets. GIS technologies are moving quickly toward web-based editors, viewers and hosted data solutions. How many times have you heard of the "Cloud?" GIS is utilizing the internet to better manage, share, and communicate the daily undertakings of your organization. As quickly as technology changes, it is important to understand the differences and benefits of new web-based GIS solutions and how they can impact your organization.

GPS applications are utilizing the internet to collect, edit, and navigate to water infrastructure. Unfortunately, most utilities are not utilizing the internet to manage, view, and process their GIS data. Data is being uploaded to GPS devices in the office, where it is connected via USB to a computer running mapping software. The GPS devices are not connected to the internet and field crews are utilizing a local copy of their data while in the field. In addition, field crews usually postprocess their data. They take their new or updated GPS data that was collected for that day, week, or month and postprocess that data back at the office. The data is then loaded into the map (usually a desktop application such as ArcView or ArcEditor).

With the increase in web access across the United States, GIS and GPS software and hardware has seen a dramatic shift in functionality and even more importantly, efficiency. A perfect example is our Field-to-Finish *WebMobile* solution that has greatly simplified the data collection, editing, and viewing of GIS data for utilities. We have created a seamless solution to maximize the efficiency of new technology while minimizing a utilities processing and management of their GIS. The solution is described below:

High Accuracy Mapping Data: The Field-to-Finish Mobile solution utilizes the latest advances in GPS technology. With Trimble's GeoXH 6000 Series utilities will be able to take advantage of GNSS and floodlight technology, receiving the best MGIS accuracies available including consistent sub-foot to decimeter accuracies and high accuracies even under canopy.

ArcMobile Setup & Configuration: GEO-Jobe GIS builds custom Trimble ArcMobile data dictionaries that match your organization's workflow and naming conventions. This standard method of data entry means quick, accurate and efficient data collection that is correctly represented on your map.

Wi-Fi Enabled Synchronization: GEO-Jobe GIS's solution enables your field crew to quickly and easily upload newly created or updated mapping data from the field to the office automatically. The Wi-Fi enabled solution means that your data can be saved without internet access and then synced back to the server once Wi-Fi is automatically connected allowing you to see infrastructure changes on your desktop and web map immediately. This means that you don't have to have Wi-Fi locked the entire time you are collecting your data.

Customized ArcServer Internet Map: GEO-Jobe GIS creates customized internet maps that offer viewing and editing capabilities of your utility's infrastructure. View your infrastructure from your computer in the office, on a tablet at home, or on your mobile phone in the field. Security settings can be setup to manage your data amongst staff.

GEOpowered.com Hosting: GEO-Jobe GIS provide a hosting service that helps to facilitate viewing and querying of GIS data through your Internet browser via the custom designed web map viewer. The solution enables you to simply manage your data, not your server. GEOpowered also provides maintenance and updates to insure the most up-to-date web hosting and services are available.

SESSION 3B

GEOMORPHOLOGY
8:30 a.m. – 10:00 a.m.

Streambank Video Mapping to Determine Erosion Susceptible Areas
Brett Connell and Paul Ayers

Geomorphology and Ecology of a Middle Tennessee Flat-Rock Stream: Effects of High-Magnitude, Low Frequency Discharge
William J. Wolfe, Gregg E. Hileman, Timothy H. Diehl, and Michael W. Bradley

Mapping Tennessee River Systems with Sensor Technology and Georeferenced Above and Below Water Video
Paul Ayers, Ken Swinson, Brett Connell, Bryan McConkey, J.R. Candlish, Matt Ellison, and Chanci King

TN'S NUTRIENT REDUCTION STRATEGY
10:30 a.m. – 12:00 p.m.

Application of Regional Regression Models of Nutrient Transport to Water-Quality Assessments in the Southeastern U.S.
Anne B. Hoos and AnaMaria Garcia

State of Tennessee Nutrient Reduction Strategy for Rivers and Streams
S. Qualls

Developing Tennessee's Nutrient Reduction Plans for Agricultural Watersheds in West Tennessee
Forbes R. Walker, David M. Duhl, John McClurkan, Shawn Hawkins, Andrea Ludwig, and Sherry H. Wang

STREAMBANK VIDEO MAPPING TO DETERMINE EROSION SUSCEPTIBLE AREAS

Brett Connell and Paul Ayers[1]

Abstract: A kayak-mounted GPS-based videomapping system was used to map streambank erodibility on 6.5 km of the New River in Tennessee. A GIS-based Bank Erosion Susceptibility Index (BESI) was developed to predict landscape-scale streambank erodibility based on quantification of bank height, bank angle, riparian diversity, surface protection, water velocity and river sinuosity. Georeferenced and calibrated river left and right streambank video cameras provide continuous visual interpretation of streambank conditions. River width and depth sensors were utilized to determine the hydraulic characteristics. The method demonstrates a technique to generate landscape scale streambank erodibility mapping.

Key Terms: GPS, GIS, bank erosion, video.

INTRODUCTION

With sediment being the number one stream pollutant in US Rivers (Albright, 2010), determining the areas of river where erosion is the highest should provide valuable information. Methods of streambank monitoring have been improving in terms of accuracy and effectiveness when measuring a stream banks health. There are numerous methods to being used to predict and document streambank erosion, with each focusing on a single or several parameters. There is, however, a need to combine these proven parameters for an overall erosion susceptibility value. As improvements in methods continue, a few important factors seem to have been ignored. Determining the length of streambank to assess in order to get a representative sample and the validity of a representative sample itself, has always been an issue. The ability to re-assess by numerous individuals at a later time as well as the need for a year by year archive would also be useful. Another ignored aspect of sampling is the impact of the method itself, and the detrimental effects towards river mechanics, chemistry, and biology. Time and funding will always be an influence and may also be the reason for many of the incomplete river assessments done in the past. There is a great need for watershed scale, erosion susceptibility mapping techniques.

The objective of this study is to develop a Bank Erosion Susceptibility Index (BESI) to map landscape scale streambank erosion susceptibility. Specific objectives include:
1) Development of Video Mapping System equipment to focus on measuring georeferenced streambank erosion indicators,
2) Creation of a suitable index based on already proven parameters for predicting streambank erosion through the assessment of video,
3) Characterization of large scale reaches and identification of highly erosive areas targeted for restoration and/or more in-depth documentation through the use of ArcGIS.

LITERATURE REVIEW

Streambank angles were one of the first parameters to be used as an indicator in determining bank stability. Pfankuch (1975), used bank angle as one of several factors to evaluate the stability of mountain streams in Montana. Specifically, one streambank angle is measured from the bottom of the bank to the top of the bank. Foster (2010), studied the relationship between streambank angles and shapes while using the erosion pin method to take measurements. Wynn (2006), focused on the presence and abundance of vegetation in relation to streambank erosion. Statistical analysis showed that riparian vegetation had multiple significant effects on soil erodibility. To evaluate the effects of vegetation on stream bank soil erodibility and critical shear stress, the upper and lower banks at each site were tested in situ using a multiangle submerged jet test device (Wynn, 2006). Each test was run for 45 minutes, with readings taken at 5 minute intervals. Three tests were conducted on both the upper and lower bank at each site, the data were analyzed following the procedures of Hanson and Cook (1997), and the results were averaged to produce two sets of Kd (soil erodibility) and τc (soil critical shear stress for each site. This information proved valuable and led to both "Surface Protection" and "Riparian Diversity" being used in the final scoring method.

The BEHI (Bank Erosion Hazard Index) is part of a bigger, total river assessment/ classification that is very accepted throughout academia and governmental organizations. The BEHI (Rosgen, 2001) does however focus on the erodibility of the actual bank and is the most widely accepted method today. The five parameters that he uses are the 1) ratio of bank height to bank full height, 2) root depth which is measured as a percentage of bank full height, 3) root density percentage, 4) surface protection percentage, and 5) bank angle degrees. Each parameter is separated into six possible scores, very low, low, moderate, high, very high, and extreme. The BEHI method is very in-depth and proven to be accurate in the prediction of soil erosion (Rosgen, 2001).

EQUIPMENT

SVMS (Streambank Video Mapping System, (Fig. 1) consists of a Tarpon 100 sit-on-top kayak, two distance sensors, depth sensor, Trimble GPS, and 3 Contour GPS video cameras. Camera Calibration chart is used for accuracy while assessing stream bank height. The Trimble 132 (1Hz) will be used for sub meter GPS accuracy that will be recorded onto a flash drive along with distance and depth output data so that each point will have the associated UTC (Coordinated Universal Time) and location. Depth while in the kayak will be measured using a flush mounted Cruz-Pro ATU-120S. The width sensors being used will be the Opti-logic RS-100 running at 10 Hz with a range of 100 yds. The Contour GPS camera uses the Neo-6 GPS module and a 1280x720 video resolution.

Figure 1. Streambank Video Mapping System.

BESI DEVELOPMENT

The proposed BESI (Bank Erosion Susceptibility Index) method uses four attributes that can be seen from video and is heavily based on the BEHI (Rosgen, 2001). To increase accuracy and reduce subjectivity, the number of possible scores for each parameter was reduced from six to four. Low and very low were combined as well as very high and extreme in all of the parameters for consistency. The related values were then averaged to reflect the original BEHI (Rosgen, 2001) as much as possible. Figure 5 shows the BESI score sheet for bank angle, bank height, surface protection, and riparian diversity. Scores for each streambank location will range from 9.8 - 36 for each side of the stream. River left, river right and BESI total will be the 3 different scores for each GPS point.

Bank Angle (degrees) was divided into four sections instead of 6 to increase accuracy. Bank angles will be grouped as, 0-60, 61-80, 81-90, >90. The corresponding scores for each angle group received are of 2.45, 4.95, 6.95, and 9.

Bank height to bankfull ratio (m) is determined by using visual assessment and the calibrated lines on the screen while reviewing the video. Focus of the measurement will be from the water surface to bank full. Measurements of 1.0-1.19, 1.2-1.5, 1.6-2, >2.1 will have the associated score for each bank height group of 2.45, 4.95, 6.95, and 9.

Surface protection (%) is divided into four sections which relate to how much soil is exposed to moving water and rainfall directly on the stream bank. Ranges for surface protection are 70-100, 30-69, 11-29, <10. The associated points are 2.45, 4.95, 6.95, and 9.

Root depth and root density are both part of the BEHI (Rosgen, 2001) which would prove to be impossible to measure from video. Using riparian diversity, a score is determined that reflects the same score produced in the BEHI.

- Optimal- Surrounding area consists of several sizes of trees, shrubs, and grasses of all sizes. High diversity indicates very high root depth and density. BESI score = 2.45.
-Sub-Optimal- Surrounding area consists of low diversity trees with some understory and grasses. Indicates good root depth and density. BESI score = 4.95.
-Marginal- Surrounding area consists of a few trees with a few shrubs and grass. Indicates moderate root depth and density. BESI score = 6.95.
-Poor- Surrounding area consists of short grass or bare soil. Indicates poor root depth and density. BESI score = 9.

APPLICATIONS AND RESULTS

The BESI (Bank Erosion Susceptibility Index) was applied to the video captured while on the New River. The New River which flows into the Big South Fork National Forest (BISO) was kayaked on July 27, 2011 with the SVMS system. This first float is the "leaf on" survey. A leaf off survey was conducted in December, 2011. With just over 500 cfs (cubic feet per second), SVMS equipped kayaks were put in at the River Road Bridge (36.389264, -84.487873) directly South of Huntsville, TN, and floated a mostly flat water section of the New River. 6.5 kilometers of streambank was documented until the Low Gap Road Bridge (36.384298, -84.528134) just before the park boundary. Video was captured and matched with corresponding GPS, width and depth data.

The results of the video survey are shown below. For examples, figures of river depth (Fig. 2), bank angle (Fig. 3), surface protection (Fig. 4) and riparian diversity (Fig. 5) are shown below. This technique provides an alternate procedure for determining landscape-scale streambank erodibility mapping.

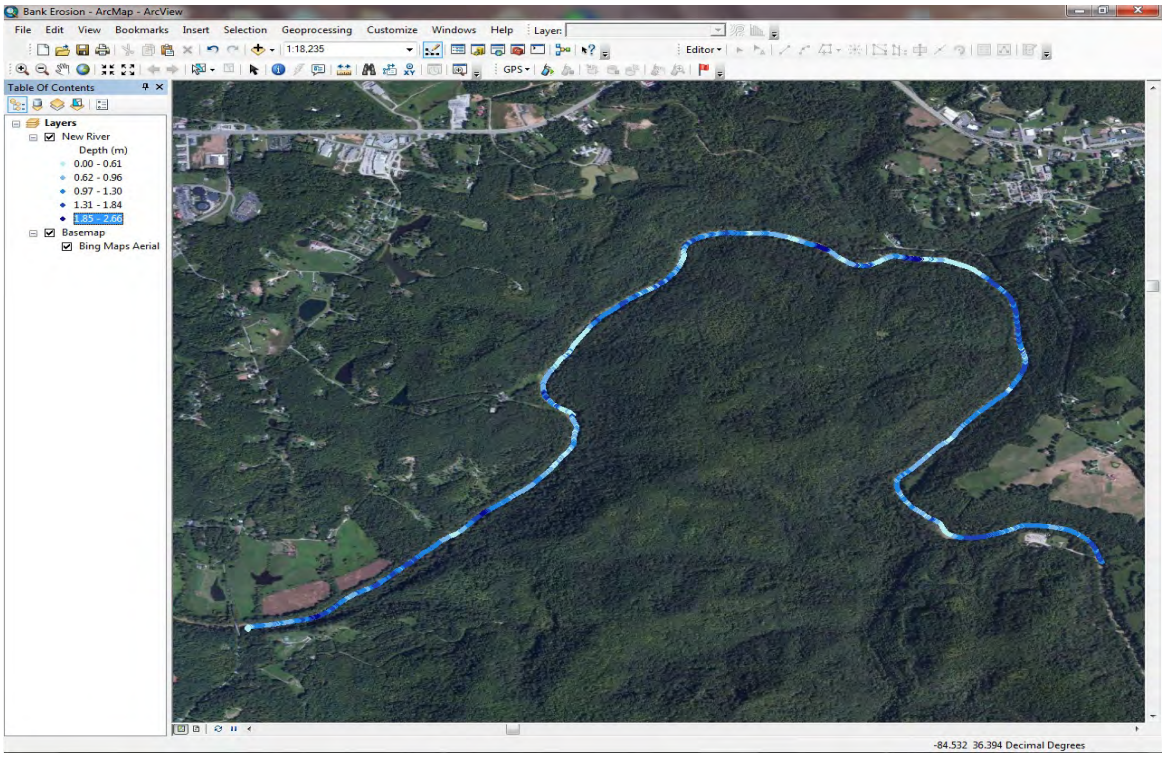

Figure 2. River depth map.

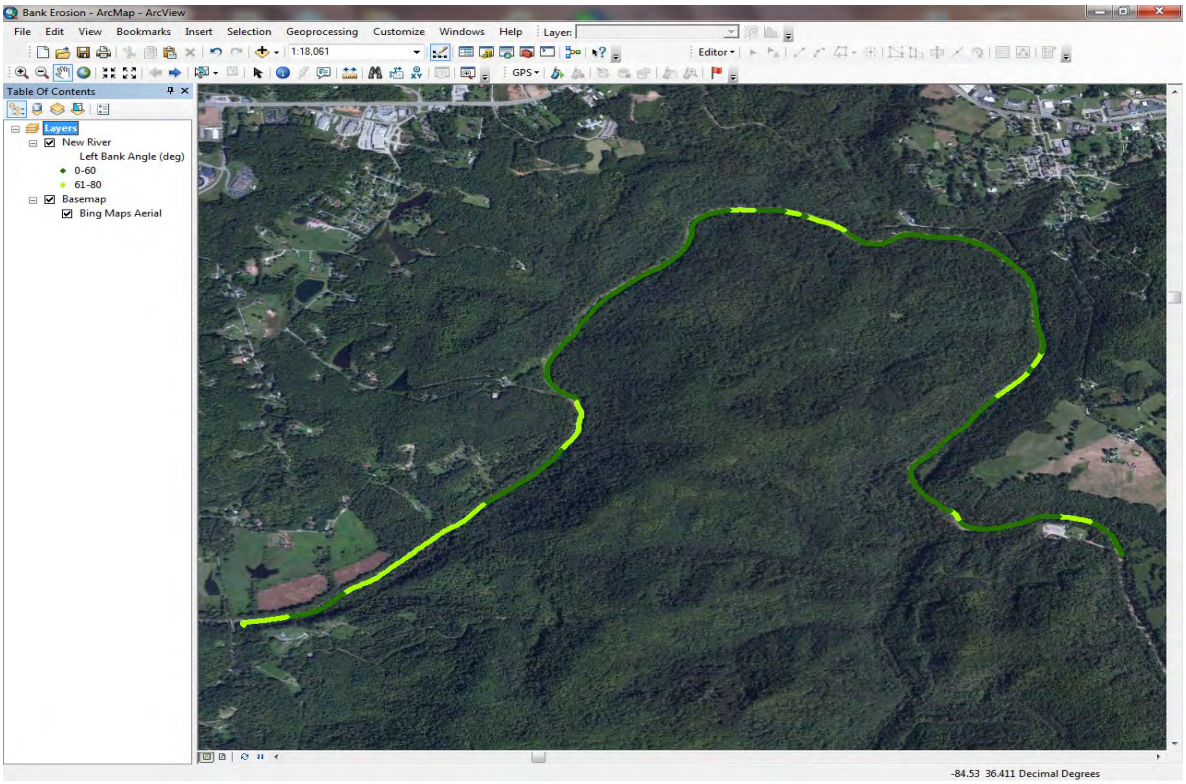

Figure 3. Bank angle map.

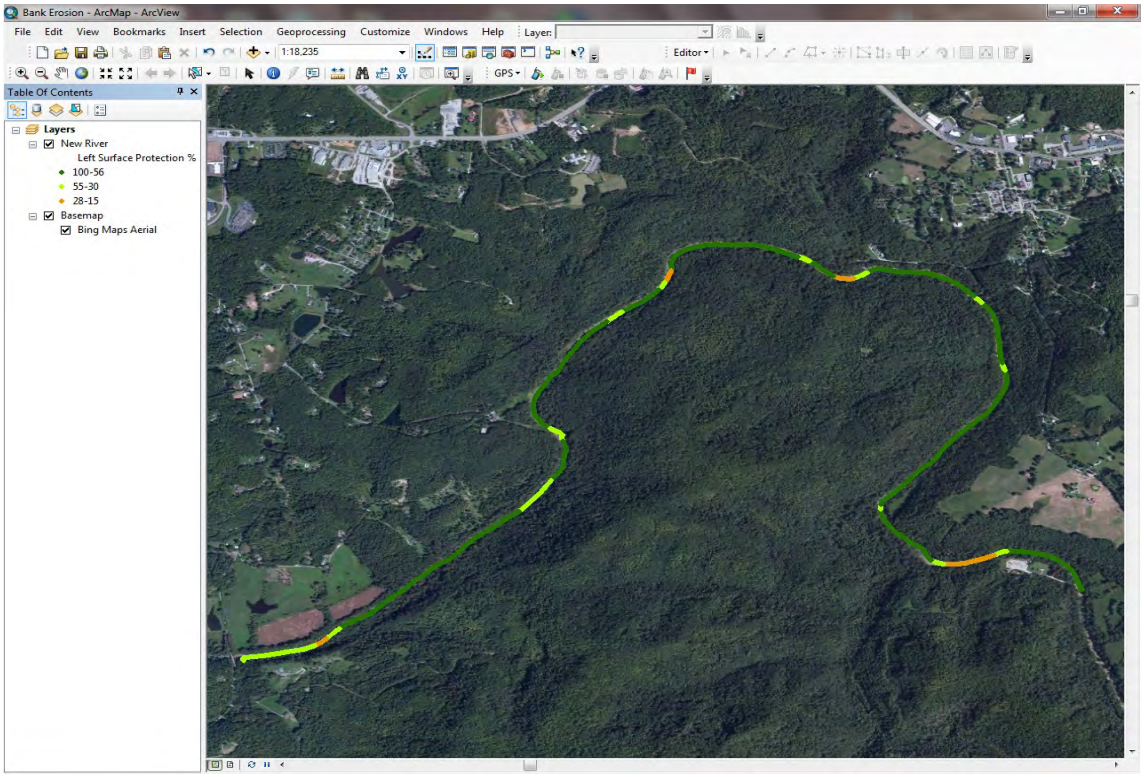

Figure 4. Surface protection map.

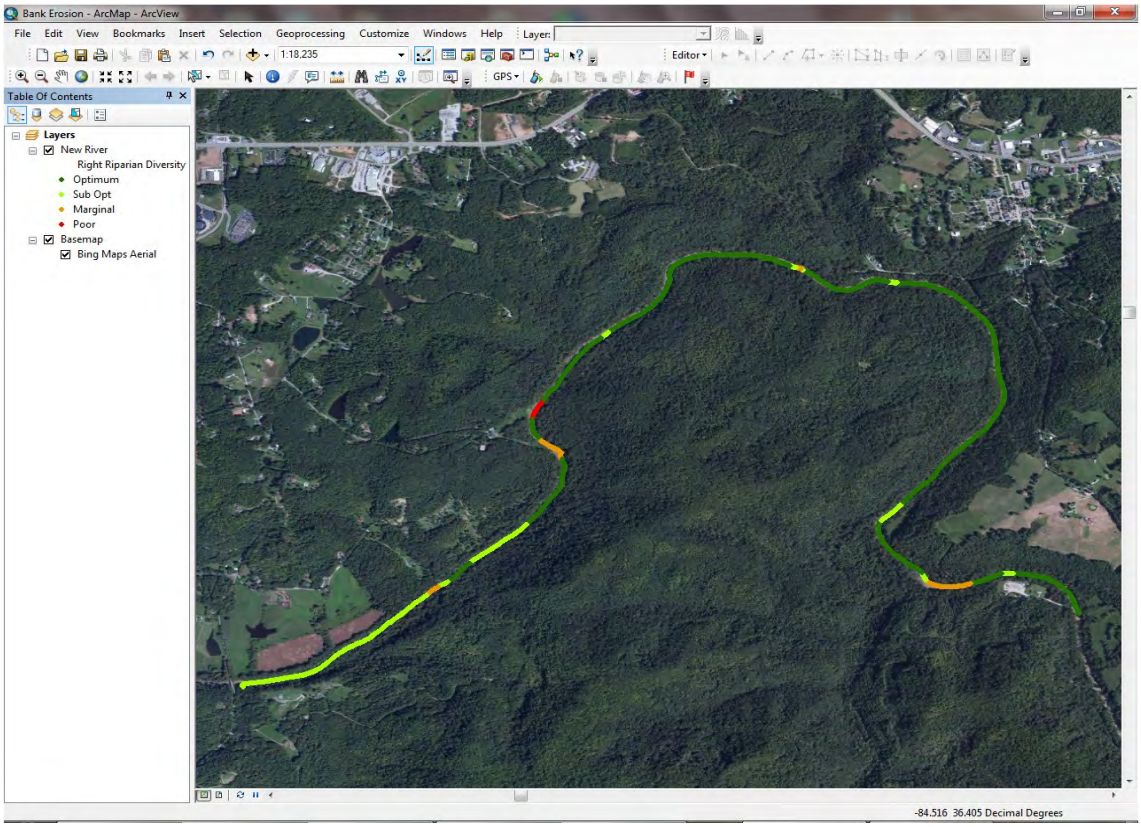

Figure 5. Riparian diversity map.

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GEOMORPHOLOGY AND ECOLOGY OF A MIDDLE TENNESSEE FLAT-ROCK STREAM: EFFECTS OF HIGH-MAGNITUDE, LOW FREQUENCY DISCHARGE

William J. Wolfe[1,2], Gregg E. Hileman[1], Timothy H. Diehl[1], and Michael W. Bradley[1]

Effects of highway construction on headwater streams were examined through repeat geomorphic surveys along Copperas Branch, a stream flowing over flat-lying bedrock and discrete deposits of cobbles and gravel, draining a 1.62-square-mile (mi^2) basin in Williamson County, TN. The surveys were conducted in 2006, 2007, 2008, and 2010. In addition, particle size analysis was conducted annually at selected riffles from 2006 through 2011, fish were sampled in 2005 and 2011, and invertebrates were sampled in 2005, 2006, 2007, and 2010. In 2011, fish were sampled in Kelley Creek, a similar channel draining an adjacent basin of 2.18 mi^2, for comparison to fish-community data published in 1998.

Streamflow records collected during the period 2004-2009 show typical winter and spring storm peaks of about 100-200 cubic feet per second (cfs) or roughly 60-120 cfs per mi^2 (cfsm). The highest observed flow during this period was 263 cfs (162 cfsm) in October 2004. In May 2010, approximately 20 inches of rain fell on the Copperas Branch basin in less than 2 days, triggering a flood having a peak discharge of 2,500 cfs (about 1,500 cfsm) and an estimated recurrence interval greater than 500 years.

The May 2010 produced large-scale changes to channel morphology dramatically greater than the sum of geomorphic changes observed during the previous 4 years. Geomorphic surveys and particle-size analysis showed little change in the distribution, location, or composition of major channel features between 2006 and 2009, a period that saw the beginning and near-completion of construction. In contrast, the 2010 flood redistributed virtually all coarse sediment on the bed of Copperas Branch, detached and moved slabs of limestone as large as 300 cubic feet, and produced extensive bank retreat. Fish communities sampled in 2010 in Copperas Branch and Kelley Creek showed little change from samples reported for both streams in 1998 and from Copperas Branch in 2005. Comparison of invertebrate data was complicated by severe drought in 2007-2008 and by massive habitat change produced by the May 2010 flood, including the scouring to bedrock of three cobble riffles previously used as invertebrate sampling sites.

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MAPPING TENNESSEE RIVER SYSTEMS WITH SENSOR TECHNOLOGY AND GEOREFERENCED ABOVE AND BELOW WATER VIDEO

Paul Ayers[1], Ken Swinson, Brett Connell, Bryan McConkey, J.R. Candlish, Matt Ellison, and Chanci King

A GPS-based underwater videomapping system (UVMS) was used to map 45 river miles of the NPS Obed Wild and Scenic River (OBRI) river system, 81 miles of the NPS Big South Fork River and Recreation Area (BISO) river system, 16 miles of the NPS Great Smoky Mountains (GRSM) Abrams creek and 12 miles of the USFS Cherokee National Forest Citico creek. The objective was to develop and utilize a system to generate landscape-scale aquatic habitat and hydraulic characteristics maps. The UVMS is canoe and kayak-mounted with georeferenced under and above water cameras, depth sounder, width sensors and underwater lasers. GIS maps of substrate (modified Wentworth scale), embeddedness (EPA classification), width, depth and river characteristic (pool, riffle, run) were developed. A technique to define optimum habitat locations for endangered fish and mussel species was implemented. Habitat suitability indexes algorithm for endangered fish species were also developed. A GPS-based snorkel-cam video system was used to conduct endangered species population counts and detailed aquatic habitat maps. The system is also used to conduct georeferenced streambank mapping to estimate streambank erosion potential. Sonar-based river thalweg and cross-section (performed at 150 foot intervals along a 16-mile river section) provide land-scape scale river hydraulic parameters (thalweg profile, rugosity, sinuosity, wetted perimeter, cross-section area, water velocity). GIS-based video tours of the above and below water river features will be demonstrated.

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APPLICATION OF REGIONAL REGRESSION MODELS OF NUTRIENT TRANSPORT TO WATER-QUALITY ASSESSMENTS IN THE SOUTHEASTERN U.S.

Anne B. Hoos[1] and Ana Maria Garcia[2]

The National Water-Quality Assessment Program of the U.S. Geological Survey has developed regional water-quality models in the southeastern U.S. to investigate the transport and fate of nitrogen and phosphorus from watershed landscapes to streams and through stream networks. The models integrate water-quality monitoring data with geospatial information describing nutrient sources and physical landscape characteristics to estimate mean annual rates of combined overland and subsurface nutrient transport from watershed sources to receiving stream channels; model predictions are reported by individual stream reach and catchment. The nitrogen model for the Southeast relates in-stream nitrogen load to the watershed sources atmospheric deposition, fertilizer applied to agricultural lands, manure from livestock operations, urban land, and wastewater discharges. The phosphorus model for the Southeast relates in-stream phosphorus load to the watershed sources agricultural land, manure from livestock operations, urban land, wastewater discharges, phosphate minerals in parent rock, and mined lands. The models developed for 2002 have been incorporated into an interactive, online decision support system (DSS) so that water managers, researchers, and the general public can map predictions of nutrient water-quality conditions in streams, track transport to downstream receiving waters, evaluate contributions of nutrients from different sources in watersheds, and evaluate nutrient-reduction scenarios (http://water.usgs.gov/nawqa/sparrow/dss/). Links to online tutorials and help pages guide the user through applications of the DSS to example watersheds and example nutrient-reduction scenarios. An example nitrogen-reduction scenario for the Tennessee River basin shows that reducing fertilizer applied to agricultural lands and manure from livestock operations by 40 percent throughout the basin will reduce the amount of nitrogen transported to the Ohio River by 13 percent.

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STATE OF TENNESSEE NUTRIENT REDUCTION STRATEGY FOR RIVERS AND STREAMS

S. Qualls

The presence of excessive nutrients is one of the most common causes of stream impairment in Tennessee. The 2010 305(b) Report states that nutrients account for approximately 13 % of stream impairments in the state. Tennessee's Water Quality Standards include narrative nutrient criteria for the protection of fish and aquatic life that integrate reference nutrient concentrations and biological integrity. We use ecoregion-specific numeric goals for nitrate-nitrite, phosphorus and biological integrity to assess rivers and streams for nutrient impairment.

Tennessee's pollution control strategy for streams impaired by nutrients is tailored to address the multiple factors that work together to result in nutrient impairment and relies heavily on the assessment methodology to determine its success or failure on a watershed level. Our strategy will use output from regional USGS SPARROW models. This presentation will describe how we are using the South Atlantic Gulf and Tennessee (SAGT) model output to implement the strategy in the Tennessee River Basin. We plan to extract Tennessee-specific data from the SPARROW Great Lakes, Ohio, Upper Mississippi and Souris-Red-Rainy (MRB3) model output for use in the Cumberland River Basin and SPARROW Lower Mississippi, Arkansas-White-Red and Texas-Gulf 5 (MRB5) output for use in the Tennessee portion of the Lower Mississippi River Basin.

Tennessee's nutrient reduction strategy is consistent with state and federal statue, regulation and guidance. 40 CFR § 130.7 describes water quality segments requiring total maximum daily loads (TMDLs) as those for which the application of technology-based effluent limitations, other more stringent effluent limitations along with other pollution control requirements will not result in the attainment of use support. This strategy provides a methodology for the application comprehensive pollution control measures listed in 40 CFR § 130.7. In that sense, this is considered a pre-TMDL approach with the goal of attaining use support.

Further, this strategy reflects the goals of EPA's March 16, 2011, Memorandum: Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions. The document states "Of most importance is prioritizing watersheds on a state-wide basis, setting load-reduction goals for these watersheds based on available water quality information, and then reducing loadings through a combination of strengthened permits for point-sources and reduction measures for nonpoint sources and other point sources of stormwater not designated for regulation." To summarize, through the strategy the division will:

- Prioritize watersheds
- Set watershed load reduction goals
- Ensure effectiveness of point source permits
- Ensure nutrient reductions from MS4s
- Develop implementable watershed-scale plans that maximize the effectiveness of agricultural BMPs
- Ensure nutrient reductions from non-MS4 developed communities
- Watershed based monitoring programs to gage effectiveness

This approach employs the concept of an enrichment factor (EF) which is the ratio of the existing pollutant load (including effects of human activity) to the "natural" background or baseline condition. The enrichment factor is then used to prioritize watersheds for nutrient reduction. The "best attainable condition" or BAC reflects the ecological condition at the least disturbed sites - if the best possible management practices were in use for some period of time.

The USGS SPARROW model output is produced from a nonlinear least squares multiple regression on hydrologic elements and is calibrated using long-term discharge and water quality data. The SAGT model output provides the source loadings used to derive the enrichment factor and the best attainable condition. For nitrogen source loadings include wastewater treatment plant (WWTP) discharges, atmospheric deposition, fertilizer, manure and urban (i.e. impervious surface). For phosphorus those include soil-parent rock, manure, agricultural land, WWTP discharges, urban sources and phosphate mines. In this approach, atmospheric deposition load represents "baseline" for nitrogen and soil-parent rock load represents "baseline" for phosphorus.

The enrichment factor is the ratio of the existing watershed load (including effects of human activity) to the baseline condition. The specific loadings used were derived from a subset of the SAGT output that only included the 129 HUC 10 Tennessee River watersheds within the state's borders. Tennessee will use the enrichment factor to prioritize the impaired watersheds for strategy implementation. (higher to lower)

Enrichment Factor (TN):

$$\frac{\mathbf{Load_{WWTP} + Load_{AtmDep} + Load_{Fertilizer} + Load_{Manure} + Load_{Urban}}}{\mathbf{Load_{AtmDep}}}$$

Enrichment Factor (TP):

$$\frac{\mathbf{Load_{WWTP} + Load_{SPR} + Load_{Ag.\ Land} + Load_{Manure} + Load_{Urban\ Land} + Load_{Mines}}}{\mathbf{Load_{Soil\text{-}Parent\ Rock}}}$$

Total Nitrogen Contribution Tennessee River Basin (Percent)			
Source	**Range**	**Median**	**Average**
Atm. Deposition	24- 92%	56%	57%
Wastewater	0 - 43%	2%	5%
Urban	1- 29 %	5%	7%
Fertilizer	2 - 41 %	17%	17%
Manure	3 - 37 %	13%	14%
Enrichment Factor (EF)	**1.1 – 4.1**	**1.8**	**1.9**

Table 1 SPARROW SAGT Model Sources Contribution (HUC 10s, n = 129)

Total Phosphorus Contribution Tennessee River Basin (Percent)			
	Range	**Median**	**Average**
Soil-Parent Rock	11 - 92%	37%	38%
Wastewater	0 - 48%	3%	8%
Urban Land	1 - 52 %	16%	16%
Agricultural Land	5 - 52 %	21%	23%
Manure	2 - 23 %	8%	9%
Mines	0 - 7 %	0%	0.3%
Enrichment Factor (EF)	**1.1 – 9.1**	**2.7**	**2.9**

Table 2 SPARROW SAGT Model Sources Contribution (HUC 10s, n = 129)

We also use the output to determine the percent WWTP contribution (aggregated) in each HUC-10. This number along with the enrichment factor is used in a decision making matrix to determine the required performance level from the WWTPs within the watershed. There are 3 levels; low, medium & high. For facilities in the low range, their existing performance level is capped. Facilities in the medium range are assigned a TP limit of 1 mg/l and a TN limit of 8 mg/l. Facilities in the high range are assigned a TP limit of 0.3 mg/l and a TN limit of 5 mg/l.

% WWTF Contribution	**1.6≤EF**	**1.6≤EF<2.0**	**EF≥2.0**
%C≥9.5%	Low	Medium	High
3.0≤% C<9.5%	Low	Medium	Medium
%C<3.0%	Low	Low	Low

Table 3 – Total Nitrogen Evaluation Matrix

WWTP Contribution	**2.1≤EF**	**2.1≤EF<3.3**	**EF≥3.3**
%C≥12.5%	Low	Medium	High
4.0≤% C<12.5%	Low	Medium	Medium
%C<4.0%	Low	Low	Low

Table 4 – Total Phosphorus Evaluation Matrix

Treatment Level			
	Low	**Medium**	**High**
Total Phosphorus	Cap @ current level	1 mg/l	0.3 mg/l
Total Nitrogen	Cap @ current level	8 mg/l	5 mg/l

Table 5

The strategy also includes aggressive BMP implementation for both urban and agricultural sources where those sources are the primary contributors. Urban corrective actions will include sanitary sewer overflow elimination, designating unpermitted developed areas as MS4s & requiring that

they implement a specific nutrient reduction plan that builds upon current permit requirements to include measures such as retrofits on existing developed sites. Table 6 lists commonly used BMPs observed removal efficiencies. Agricultural BMPs will primarily be implemented on a voluntary basis with the agricultural contribution as indicated by the model output to be used as a basis for funding priorities.

(see attached graphics file)
Table 6 Median removal effectiveness and number of sites analyzed for 4 BMPs from Studies in the Southeast and Mid-Atlantic11

The best attainable condition is the total nutrient load for the HUC 10 watershed after the implementation of measures that are estimated to achieve 40 % to 60 % load reduction from urban and agricultural sources and the application of the required performance level for WWTPs. The WWTPs will be given compliance schedules to upgrade their treatment capabilities. Even so, these reductions should provide improvement in the near term while the urban and and agricultural measures may take several years of implementation to achieve desired results.

The estimated BAC is the sum of the new WWTP load, urban & ag loads x estimated reduction + the background load.

For nitrogen:

$$BAC = Load_{WWTPs@\ Req'd\ PL} + (Load_{Urban} + Load_{Fertilizer} + Load_{Manure})xBMP\ Reduction + Load_{Atm\ Dep}$$

For phosphorus

$$BAC = Load_{WWTPs@\ Req'd\ PL} + (Load_{Urban} + Load_{Ag\ Land} + Load_{Manure})xBMP\ Reduction + Load_{SPR} + Load_{Mines}$$

Where:

Expected BMP Reduction =40 % to 60 %; and

$Load_{Urban}$, $Load_{Fertilizer}$, $Load_{Manure}$, $Load_{Ag\ Land}$, $Load_{Atm\ Dep}$ and $Load_{SPR}$ are from SPARROW Model output

$$Load_{WWTPs@\ Req'd\ PL} = \sum(\text{WWTP effluent concentration x WWTP design flow})_{HUC\text{-}10,\ Outlet}$$

The division will continue to monitor these segments throughout implementation to determine the impact and effectiveness of controls. Additionally, the Phase II MS4 general permit requires permittees to conduct biological monitoring for stream segments within their jurisdictions that are impaired for siltation and/or habitat where MS4 discharges are listed as a source of the impairment. Since nutrient impaired waters often have siltation and/or habitat impairment, this monitoring should also provide a measure of BMP effectiveness.

For each HUC-10 evaluated, the division will prepare a report/plan that describes the findings and prescribes the necessary corrective actions. The report will also present a schedule for implementation and a plan for monitoring. The plans will be posted on the division's website and will be provided upon request in accordance with the State of Tennessee's Public Records Act.

This strategy will be implemented initially in the West Prong Little Pigeon River HUC-10 watershed. Table 7 gives the percent source contributions in the watershed.

	Total Nitrogen %	**Total Phosphorus %**
WWTPs	**4**	**52**
Urban land	**12**	**21**
Fertilizer/ Ag. land	**5**	**5**
Manure/ Animal Waste	**4**	**2**
Atm. Dep./ Soil-P Rock	**75**	**20**

Table 7 SPARROW-SAGT Model Source Contribution

An evaluation of the source loadings shows that phosphorus reduction in this watershed is necessary to achieve use attainment. The watershed has a phosphorus enrichment factor of 4.91 and the loading from the wastewater plants is in the high range. Therefore each of the wastewater plants will be assigned a total phosphorus limit of 0.3 mg/l.

			Wastewater	S-P Rock	Ag. Land	Manure	Urban Land	Total
SPARROW	Source (Existing) Load	lbs/yr	27,604	10,716	2,507	867	10,937	**52,631**
	Percent	%	52.4	20.4	4.8	1.6	20.8	**100.0**
HUC-10	**Enrichment Factor**							**4.91**
WWTFs	Σ Design Flow	MGD	7.00					
	Σ Existing Flow	MGD	4.97					
	Avg. TP Concentration	mg/L	2.57					
	Initial TBL Impact Level		High					
	Final TBL Requirement		High					
	Proposed TBL Treatment	mg/l	0.3					
	Allocation (WWTP #1)	lbs/yr	2,740					
	Allocation (WWTP #2)	lbs/yr	3,653					
	Allocation (Instream at HUC-10)	lbs/yr	4,566					
	Load Reduction (Gatlinburg)	%	83					
	Load Reduction (Pigeon Forge)	%	84					
Precipitation Based Sources	Proposed Reduction	%						**60**
	Proposed LA	lbs/yr			1,003	347	4,375	
HUC-10 Overall	**Best Attainable Condition (BAC)**	lbs/yr	**4,566**	**10,716**	**1,003**	**347**	**4,375**	**21,006**
	Overall Load Reduction (BAC)	%						**60.1**

Table 8 Total Phosphorus Load Analysis

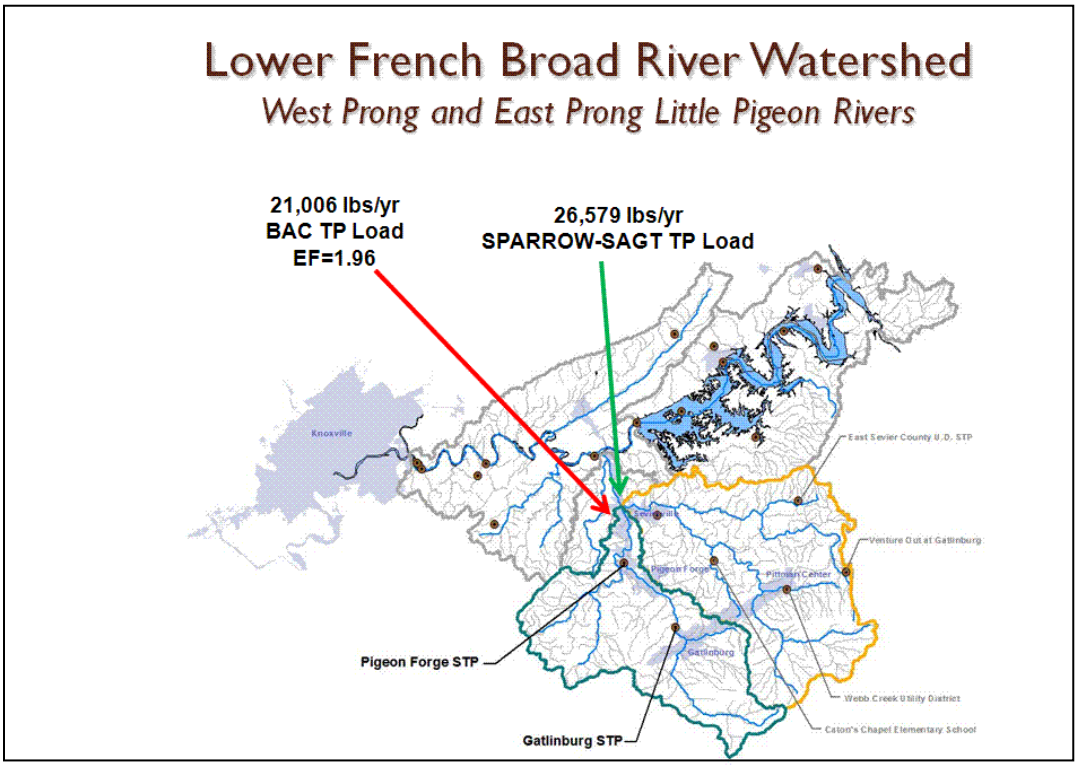

Figure 1 compares the BAC load for the West Prong Little Pigeon River (21,006 lbs/yr) with the SPARROW – SAGT load for the unimpaired East Prong Little Pigeon River (26,579 lbs/yr). This strongly suggests implementation of this strategy in the West Prong Little Pigeon River will likely remove nutrients as a source of impairment.

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DEVELOPING TENNESSEE'S NUTRIENT REDUCTION PLANS FOR AGRICULTURAL WATERSHEDS IN WEST TENNESSEE

Forbes R. Walker[1], David M. Duhl[2], John McClurkan[3], Shawn Hawkins[1], Andrea Ludwig[1], and Sherry H. Wang[2]

2001 MRLC (Multi-Resolution Land Cover) analysis shows that agriculture is the predominant land use in West Tennessee. A core group was formed among Tennessee Department of Environment and Conservation (TDEC), Tennessee Department of Agriculture (TDA), and University of Tennessee Extension (UT-Extension) to develop a process for effectively managing agricultural nutrient load reductions in West Tennessee Watersheds. This process is similar to the framework developed by the Lower Mississippi River Basin Initiative and has six components. The components of the process involving nutrient management practices will be coordinated by UT-Extension and TDA by working with farmers to analyze the source, timing, placement, and amount of fertilizer applied to production fields and to re-evaluate the system of incentives currently in place. The process focuses on collaborations between relevant partners and stakeholders in order to develop innovative solutions to reduce nutrient loading in Tennessee's Mississippi River Basin watersheds.

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[2] Tennessee Department of Environment and Conservation/Division of Water Pollution Control
[3] Tennessee Department of Agriculture

SESSION 3C

RESERVOIR I
8:30 a.m. – 10:00 a.m.

Permitting, Mitigation, and Monitoring of a Small Cumberland Plateau Reservoir
Richard D. Martin

Engineering Design and Construction Management of a Small Cumberland Plateau Reservoir
William E. Griggs

Creating Streams from Ponds: Two Approaches to the Problem
Michael Pannell, Brent C. Wood, and William K. Barry

RESERVOIR II
10:30 a.m. – 12:00 p.m.

Water Management in the Cumberland River Basin
Robert Dillingham

An Overview of Water Quality Impacts Resulting from Pool Level Restrictions Imposed within the Cumberland River Basin Reservoir System
Richard N. Tippit and Mark D. Campbell

Center Hill Lake Hydrodynamic and Water Quality Model Development Using CE-QUAL-W2 Version 3.6
Jeffrey S. Gregory

PERMITTING, MITIGATION, AND MONITORING OF A SMALL CUMBERLAND PLATEAU RESERVOIR

Richard D. Martin, P.G.[1]

INTRODUCTION

In 2007, the Boy Scouts of America-Middle Tennessee Council (BSA) purchased 1,550 acres of property in Van Buren County, Tennessee. Located near the community of Lonewood, the property lies adjacent to the TWRA Bridgestone / Firestone Wilderness, flanked by the Caney Fork River and Bee Creek, and is in close proximity to Virgin Falls. The site's location on the Cumberland Plateau (with the associated geology, topography, flora, and fauna) creates an ideal setting for the BSA facility (subsequently named the Latimer High Adventure Reservation). One essential component that was missing at the site was a permanent water body that would allow the myriad of aquatic sports that is part of the scouting experience. Realizing that stream impoundment is one of the most dramatic alterations to an aquatic resource, a step-wise approach was implemented to construct the reservoir in strict compliance with applicable state and federal environmental regulations.

APPROACH

The technical approach employed during the project consisted of the following primary elements:

- Evaluate several drainage basins within the Latimer boundary for reservoir construction suitability;
- Collaborate with environmental regulatory and permit review agencies during the feasibility study phase at the three alternate sites considered;
- Characterize the jurisdictional status of the waterway selected for impoundment and evaluate both its biotic and abiotic characteristics;
- Acquire the requisite permits that would allow lawful impoundment of the stream;
- Design and, following permits issuance, construct and monitor mitigation projects in the watershed;
- Develop reservoir operational methods that would minimize water quality impacts created by transforming a lotic aquatic system to a lentic system;
- Conduct post-impoundment studies of both the reservoir and downstream channel to assure that reservoir operation is not degrading water quality.

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DESCRIPTION OF THE IMPOUNDED STREAM

An unnamed, intermittent tributary to Bee Creek was selected as the preferred location for dam construction. As is typical in this area, the system exhibited extended periods of no surface discharge in late summer and early fall; however, a biological survey, conducted in May 2008, revealed the stream to possess a healthy assemblage (both in abundance and diversity) of aquatic macroinvertebrates. Moreover, applying the Tennessee Qualified Hydrologic Professional assessment criteria to the channel (after the fact), the stream's jurisdictional status was further confirmed.

The stream is located in the Cumberland Plateau Ecoregion (68a). Its headwaters form at approximate elevation 1,800 ft. AMSL and flowed in a slightly sinuous (1.2/1) pattern at a 1% gradient for 2,950 ft. to the location that the dam was constructed. The channel was well formed, incised through the sandy-silt regolith until reaching the sandstone/cobble substrate. The stream's riparian zone was well developed, possessing a successional (formerly harvested) stand of mixed hardwoods. Understory vegetation, where present, was dominated by mountain laurel. The channel, at the location of impoundment, possesses a drainage basin of 310 acres. Hydrologic charge for the reservoir is provided by surface runoff and regolith interflow; no groundwater connection to the stream was identified.

REGULATORY PERMITTING REQUIREMENTS

Following numerous pre-application meetings with the Tennessee Division of Water Pollution Control and U.S. Army Corps of Engineers-Nashville District, §401 and §404 permit applications were submitted to each respective agency. Submitted concurrently with the applications was the proposed mitigation plan that included design/construction of an Acid Mine Drainage (AMD) treatment system at three deep coal mines located on the adjacent Bridgestone/Firestone Wildlife Management Area, design/restoration of a severely eroded stream bank on the Collins River, and reservoir hypolimnetic aeration to ameliorate stratification and associated water quality degradation. A Construction Site NPDES permit, with associated Stormwater Pollution Prevention Plan/Erosion Control Plan was also obtained from the Tennessee Division of Water Pollution Control for the location that the dam was constructed, the entire 20.6 acres footprint cleared for inundation, and all soil borrow areas from which on-site fill material was obtained.

The aforementioned environmental permits were obtained approximately 18 months after submittal of the applications. The Collins River stream bank repair was performed immediately after the permits were issued and the AMD treatment system became operational in January 2012. Windmill reservoir aerators have been obtained and will be installed in spring 2012. Both completed mitigation projects were extremely successful is achieving their desired goals. Monitoring of the mitigation sites, reservoir, and stream segment located below the dam is required as a compliance component of both permits.

RESERVOIR CHARACTERISTICS

After contractor selection, the dam was constructed in approximately 8 months. Construction involved the excavation of about 400 cubic yards of rock for the dam keyway, fill and compaction of 47,000 cubic yards of soil, and placement of 2,000 tons of rip-rap. From the time the spillway was closed in January 2011, the reservoir filled to normal pool in approximately 2 months.

The reservoir is 20.6 surface acres in size, possesses 153 acre-feet of hydraulic storage capacity, and has 9,700 feet of shoreline. All discharge from the reservoir occurs from the epilimnion through the primary spillway, over which is constructed a bridge to allow access to remote parts of the reservation.

Based on the statistical average annual flow data predicted to occur at the location of dam construction (provided by the United States Geological Survey), the reservoir will have a hydraulic residence time of approximately 90 days, which has already been documented to result in well defined stratification.

SUMMARY

Obtaining the permits required for creation of the reservoir in a timely manner is directly attributable to maintaining a collaborative approach among all stakeholders during the project's planning, design, and permitting phases. The specific components employed included:

- Clearly and concisely articulating the need for the reservoir;
- Coordinating with regulatory and commenting agencies before submitting permit applications;
- Thoroughly characterizing the aquatic resource to be altered;
- Preparing and submitting complete applications with supporting technical addenda;
- Maintaining continuous dialogue with permitting/commenting agencies during the application(s) review and public notice periods;
- Preparing and implementing adequate mitigation and monitoring measures;

Lastly, The Boy Scouts of America have graciously granted permission for a graduate student at Middle Tennessee State University-Department of Biology to perform her thesis research by monitoring reservoir dynamics and downstream water / biological quality during the period from March 15 through November 15, 2012.

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ENGINEERING DESIGN & CONSTRUCTION MANAGEMENT OF A SMALL CUMBERLAND PLATEAU RESERVOIR

William E. Griggs, P.E.[1]

In 2007, the Boy Scouts of America-Middle Tennessee Council (BSA) purchased 1,550 acres of property in Van Buren County, Tennessee. Located near the community of Lonewood, the property lies adjacent to the TWRA Bridgestone / Firestone Wilderness, flanked by the Caney Fork River and Bee Creek, and is in close proximity to Virgin Falls. One essential component that was missing at the site was a permanent water body that would allow the myriad of aquatic sports that is part of the scouting experience.

The BSA retained Griggs & Maloney, Inc. (G&M) to perform the following tasks related to dam engineering and construction:

- Evaluate the hydrologic and geomorphic characteristics of several alternate drainage basins for reservoir construction;
- Perform geotechnical testing at the location of the proposed dam;
- Evaluate several locations within the boundary of the Latimer Reservation for soil quantity and construction characteristics;
- Perform engineering design of the dam and reservoir access areas;
- Acquire the required permits from State and Federal regulatory agencies;
- Perform geotechnical and civil engineering inspection services during the TEN month construction period;
- Perform periodic post-impoundment inspections of the dam and spillway.

The dam IS 685 ft. long, possesses a height of 30 ft. and has a crest elevation of 1,700 ft. AMSL. Construction of the dam required placement of 47,000 yd^3 of compacted soil fill, 2,000 tons of rip-rap, and 65 yd^3 of concrete. The 20.6 acre impoundment created by the dam has 153 acre-feet of hydraulic storage capacity, 9,700 ft. of shoreline and is 24 ft. deep at its deepest point.

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CREATING STREAMS FROM PONDS: TWO APPROACHES TO THE PROBLEM

Michael Pannell, CPESC[1]*, Brent C. Wood, PE, CPESC[2], and
William K. Barry, PE, D. WRE[3]

These two projects present two approaches to removing large ponds and restoring streams in the former impoundment areas. For each project, an earthen dam was breached to an elevation just below the elevation of sediment along the upstream face of the impoundment. The channel through the former impoundment was lined with a series of step pools. In the first project, initial plans were to construct the restored channel in the sediment remaining in the pond area. Difficulties in constructing the channel due to poor working conditions caused by near saturated sediment lead to realignment of some of the stream restoration to run in native soil along the edge of the sediment deosit. The restored stream was stabilized with vegatation, coir matting, and in-stream structures. The balance of the sediment in the former pond was converted to wetland. In the second project, water flowing through the remaining sediment found its own course to establish the stream channel. Again, the balance of the sediment in the former pond was allowed to form a wetland area. Monitoring results will be presented to illustrate the efficacy of each approach.

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WATER MANAGEMENT IN THE CUMBERLAND RIVER BASIN

Robert Dillingham[1]*

INTRODUCTION

The Cumberland River is formed in the foothills of the Appalachian Mountains with the confluence of the Poor Fork, Clover Fork and Martins Fork near Harlan, KY. From there, it flows 694 miles westwardly where it drains into the Ohio River at Smithland, KY. The drainage basin covers nearly 18,000 mi^2. It is the second largest tributary of the Ohio River and plays a major role in not only regional flood protection but also to the lower Ohio and Mississippi Rivers. It is also a major commercial navigation route connecting the ports of Nashville and Clarksville with the Ohio River. A series of ten dams all built, owned and operated by the US Army Corps of Engineers are on the Cumberland River and its tributaries. These dams were constructed to provide a wide array of benefits to the nation. Managing releases from these ten projects is a delicate balancing act. This presentation will discuss a general overview of the basin and its ten projects, explain the importance of proper water management practices, touch on the forecasting models used for water management and discuss the benefits provided by the projects.

DISCUSSION

The Corps of Engineers Nashville District (LRN) operates ten multi-purpose dams in the Cumberland River Basin. Flood control storage projects are: Wolf Creek, Dale Hollow, Center Hill, and J Percy Priest. Main-stem navigation projects are: Cordell Hull, Old Hickory, Cheatham, and Barkley. Barkley is considered a "hybrid" in that it is both a flood control project and navigation project. Martins Fork and Laurel are small projects in the upper Cumberland region with critical local roles but negligent impacts to the basin as a whole. The Tennessee Valley Authority (TVA) also operates Great Falls Dam which is located immediately upstream from Center Hill Lake.

These projects were authorized and constructed for a wide array of both primary and secondary objectives. Flood control, hydropower, navigation, water quality, water supply, recreation, and fish & wildlife are among the authorized purposes for the projects. With such a wide range of benefits, it is very common for conflicts of interest to arise. Flood protection is always the water managers chief concern; however, prioritizing the other benefits is not always black and white.

Property owners in and around the floodplain, power providers reliant on hydropower production, environmental groups concerned with fish and wildlife habitats, local municipilaties with water intakes in the lakes and rivers, the commercial navigation industry, amateur and commercial fisherman, the recreating public, and marina operators are among the countless stakeholders with a vested interest in LRN's water management operations. Although floods are generally the most publicized consequence, droughts can be even more stressful. Maintaining a

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navigable channel deep enough for commercial barge traffic, ensuring water quality above a state minimum guideline, and maintaining water temperatures below a set guideline around TVA's fossil plants are major concerns associated with droughts. This has been further complicated with recent pool restrictions at two LRN projects.

LRN's water management operations have been severely handicapped, particularly during the summer months, since 2007 when seepage concerns mandated a pool restriction at the two largest storage projects: Wolf Creek and Center Hill. These pool restrictions have compounded water quality issues throughout the basin. The mandate of maintaining a constant pool elevation means cool water deep in the lake is evacuated through the turbines following spring rains. This leads to a warmer and less oxygenated river during the hot and dry summer months. It is not uncommon for turbine releases to be supplemented with sluice gate releases/spillway gate releases during the summer months – or even for generating to be ceased and all water be passed through the gates. The violent act of water passing through a sluice gate or spillway gate oxygenates the water and provides for a much healthier tailwater. However, every ounce of water that passes through a gate can be considered lost revenue when it could have powered a turbine.

Forecasting dam releases and generation schedules requires (at a minimum) a daily evaluation of hydrologic and weather conditions. LRN currently uses a legacy RAI model that has been in place for nearly four decades. This text based model obtains rainfall, streamgage information, and project information in realtime from a network of gages throughout the basin. The model converts rainfall into surface runoff and groundwater and in turn calculates project inflows. Although this model has consistently proven its accuracy and reliability, there are some downfalls – the most glaring of which are its inability to easily incorporate forecasted rainfall, its inability to forecast river stages, and its default 12-hour time step. In recent years, a new modeling program, the Corps Water Management System (CWMS) has been developed.

CWMS is a new USACE developed modeling program that is in the intermediate stages of being implemented as LRN's primary modeling tool. CWMS operates in a GUI environment and is considerably more robust than the legacy RAI model. CWMS combines the proven Hydrologic Engineering Center (HEC) products of HMS, ResSim, and RAS with a meteorological model to calculate runoff and project inflows. It is also capable of modeling river stages between dams. CWMS; however, is not without it's deficiencies as well – the most glaring of which are its unyielding dependence on complete and accurate data sets. In addition, the user interface is somewhat cumbersome and comes with a steep learning curve.

Proper water management practices are critical to countless agencies and stakeholders. Although occassionaly conflicting interests occur, protecting lives and property from flood damage is the water managers top concern.

AN OVERVIEW OF WATER QUALITY IMPACTS RESULTING FROM POOL LEVEL RESTRICTIONS IMPOSED WITHIN THE CUMBERLAND RIVER BASIN RESERVOIR SYSTEM

Richard N. Tippit[1*] and Mark D. Campbell[2*]

A nationwide assessment of large dams conducted in the last few years identified at least two of the large, multi-purpose, dams operated by the Nashville District, Corps of Engineers to be in need of immediate and major rehabilitation. The impoundments contained by Wolf Creek Dam on the Cumberland River in south central Kentucky and Center Hill Dam on the Caney Fork River in middle Tennessee represent a significant amount of storage used by Corps of Engineers water managers to meet a variety of needs and provide systemwide, project benefits. Pool restrictions imposed to reduce structural failure risks and facilitate dam rehabilitation efforts have resulted in a range of water quality impacts within the Cumberland River reservoir system. Examples include rapid development of strong stratification patterns in main stem, previously riverine impoundments and warming of cold tailwaters. Water quality has been directly affected within the individual impoundments subject to the pool level restrictions, while cumulatively, impacts to water quality have extended over much of the Cumberland River Basin reservoir system as a consequence of reduced available storage. Faced with the challenges of managing a storage compromised river and reservoir system, Corps water managers have increased water quality data collection to improve efforts to anticipate development of problem areas, guide remedial action decisions, and assess environmental outcomes.

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CENTER HILL LAKE HYDRODYNAMIC AND WATER QUALITY MODEL DEVELOPMENT USING CE-QUAL-W2 VERSION 3.6

Jeffrey S. Gregory[1]*

Center Hill Dam is a U.S. Army Corps of Engineers multi-purpose project located in Dekalb County, Tennessee. The dam impounds the Caney Fork River at river mile 26.6 creating Center Hill Lake. Project purposes include flood damage reduction, hydrpower, recreation, water supply, water quality and fish and wildlife conservation. This reservoir is part of a system of flood damage reduction projects in the Cumberland River Basin. The total project drainage area is 2,174 sq. mi. with the majority of the Center Hill watershed (78%) above Great Falls Dam. This district monitors an array of water quality parameters in the reservoir, in-flow to the reservoir and releases from the dam. Sampling trips are typically twice a year but the sampling frequency has increased due to current pool level restrictions, Interim Risk Reduction Measures (IRRM). These IRRM are a result of dam safety concerns and on-going construction activities. Historically, Center Hill Lake thermal stratification begins in March and continues through November until the onset of fall overturn. The water column would be completely mixed from November until the start of spring stratification but pool restrictions have delayed fall overturn. The purposes of model development are to have a tool to better understand the reservoir's hydrodynamics and water quality, to provide support for project operational decisions and provide a tool for future studies.

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PROFESSIONAL POSTERS

Developing an Environmental Geosciences Master's Program at Middle Tennessee State University
Mark J. Abolins

Evaluation of Areas of Known Structure Deformation with VLF Geophysics in Middle Tennessee
Randy M. Curtis and Nathan Guessetto

A Synthetic Reference Standard for Sediment Acid-Volatile Sulfide (AVS) Analysis
Adrian Gonzalez

A Watershed-Scale Pathogen Reduction Model Using Variable Cost-Shares for Septic System Treatments
Dan Huser and Josh Smith

Geomorphic and Fish-Community Response to Disturbance in a Middle Tennessee Flat Rock Creek
Joyce Iwinski

Impacts of Nonpoint-Source Pollution on the Diatom Assemblage, Periphyton Characteristics, and Algae Growth in the West Fork of the Red River in North-Central Tennessee
Jefferson Lebkuecher, Kelly Anderson, Courtney Gorman, Anna Guyer, Alex Hall, Rebecca Johnson, Elizabeth Slade, Chelsea Williams, and Lyddia Wilson

A New Interdisciplinary Minor in Watershed Science, Engineering, and Policy at the University of Tennessee, Knoxville
John Schwartz, Chris Clark, Larry McKay, Tracy Moir-McClean, Becky Jacobs, Daniel Yoder, Andrea Ludwig, Carol Harden, Qiang He, and Joanne Logan

DEVELOPING AN ENVIRONMENTAL GEOSCIENCES MASTER'S PROGRAM AT MIDDLE TENNESSEE STATE UNIVERSITY

Mark J. Abolins[1]*

ABSTRACT

The Middle Tennessee State University Department of Geosciences is developing a master's program. The Department will likely offer a Geosciences concentration within MTSU's existing Master of Science in Professional Science (MS-PS) within a year or two. The concentration will allow specialization in either Environmental Geosystems (a hydrogeology-rich environmental specialization) or Geographic Information Systems (GIS) although students could choose not to specialize. The MTSU Master of Science in Professional Science is a Professional Science Master's (PSM), so students will complete an internship and a combination of discipline-specific and business courses. The MS-PS is a 36 semester hour coursework-only degree. MTSU Geosciences students will be able to complete an Accelerated Bachelor's-Master's (ABM) through five years of intensive study. To support the graduate concentration, the Geosciences Department is acquiring additional space and computing resources. MTSU Geosciences is also searching for a tenure-track GIS faculty member (open rank) who will teach graduate and advanced undergraduate GIS courses. The graduate concentration will require approval by the Tennessee Board of Regents. The concentration is an important step toward an independent comprehensive master's program in geology and geography.

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EVALUATION OF AREAS OF KNOWN STRUCTURAL DEFORMATION WITH VLF GEOPHYSICS IN MIDDLE TENNESSEE

Randy M. Curtis[1]* and Nathan Guessetto[2]

ABSTRACT

The Central Basin Aquifer System in Middle Tennessee is composed of several formations of very similar Ordovician limestones that are generally flat lying and dip gently away from a regional structural high in Rutherford County. In some areas, these formations have been broken by vertical fractures and faults. Very Low Frequency (VLF) geophysical investigation methods take advantage of the ubiquitous carrier wave signals from powerful remote radio transmitters set up in different parts of the world for military communications. The method uses relatively simple instruments and can be a useful reconnaissance tool. Potential targets include tabular conductors in a resistive host rock such as faults in limestone. In conjunction with water reources investigations in areas where detailed geologic mapping is sparse or outcropping rock is rare, two known faults and an area with a higher level of published geologic information were investigated to help determine the suitability and reliability of the procedure. The areas with observable fault planes had corresponding anomalies in the geophysical sections, and an area where a detailed investigation program sponsored by the United States Geological Survey (USGS) mapped an anticline/syncline pair showed corresponding anomalies in the area mapped as a local structural high. The method reliably indicates the location of small faults at the local level in the limestones of the Central Basin in Middle Tennessee.

INTRODUCTION

Water well locations are frequently determined using fracture trace alignments developed from maps or aerial photographs. This basic desk-top research technique is used to delimit areas of potential interest based on the assumption that the lineaments reflect subsurface structural conditions which may serve to increase rates of water movement in limestone aquifers where enhanced solution gives better yield. Sometimes, when existing water infrastructure, available property, land access, long term use agreements and contractual needs or other real-world factors intrude, the geologist may be faced with evaluating and justifying well locations (where there are no obvious surface guides to favor one spot over another). VLF geophysics is a relatively inexpensive, rapid and non-intrusive geophysical technique that may be used to identify subsurface anomalies on land that the client is interested in drilling or acquiring access to. This paper describes the use of VLF techniques in three areas where known structural elements could be placed in context within the thick Ordovician Limestone section of the Central Basin of Middle Tennessee, revealing how the geophysics reacted to small faults and folds.

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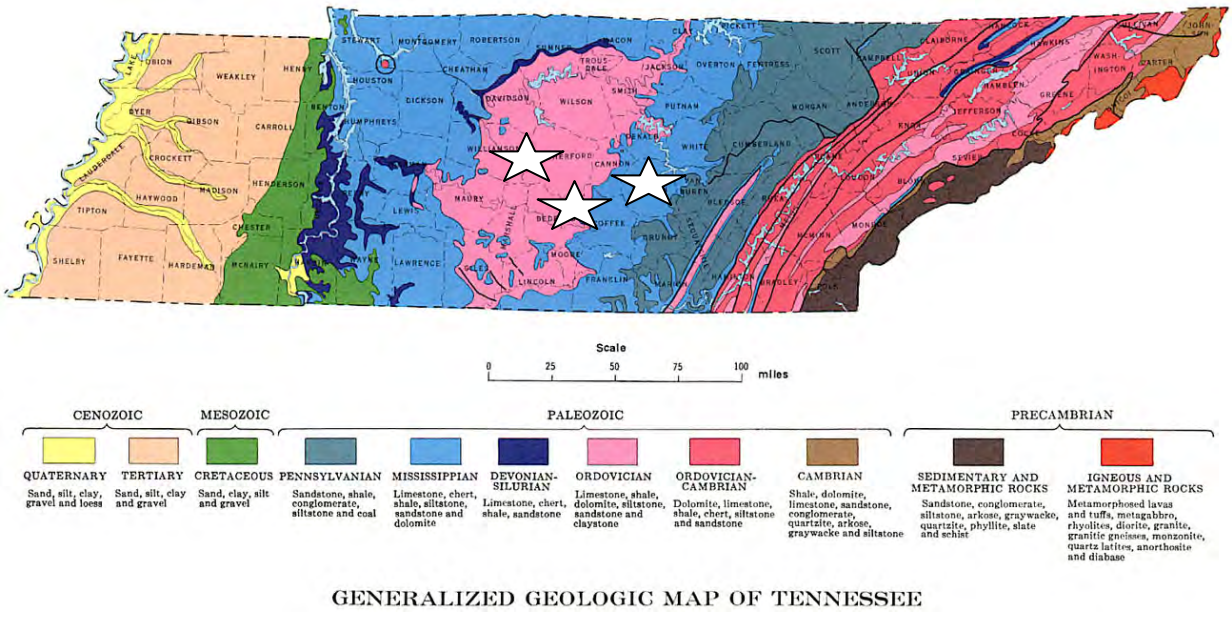
STUDY AREA

Two high-angle faults with a small amount of throw and, one relatively detailed map of local geologic conditions associated with a Superfund site investigation were used to evaluate the VLF devices capabilities in Middle Tennessee. The locations, as shown on Figure 1, were visited at various times as a means of pre-testing rented VLF devices before doing water resources evaluations in areas with little exposed bedrock where clients were interested in narrowing the choices for the best possible drilling locations. Location A is on Interstate 840 (I-840) about five miles from College Grove, Tennessee. The fault has about six feet of displacement and is visible in rock walls in the road cut about 8/10 of a mile from the Arno Road exit to the east and the Peytonsville-Trinity exit to the west. Location B is on a four-lane divided highway, Highway 70S, about three miles from Woodbury, one mile east of the Bradyville Road intersection; this is another high-angle fault with a small amount of displacement, visible in the rock cuts on both sides of the highway. Location C is south of Brentwood, Tennessee, where two VLF investigation lines were run across an alignment of small folds mapped as part of a joint USGS/ Division of Superfund site investigation in the 1980s.



GENERALIZED GEOLOGIC MAP OF TENNESSEE

Figure 1: Location of Three WADI Test Areas

VLF TECHNOLOGY AND USE

The Wadi Portable VLF Radio Wave Receiver calculates differences in the time of arrival of U.S. Navy submarine communications carrier wave signals—when the navy sends out radio signals to their submarines they use one of several transmitters capable of sending the signals into the Earth's surface. The rented Wadi receiver is a device that allows the user to hone in on the carrier waves from these transmitters and record the signal strength to monitor the deflection of the carrier wave(s) through the earth. Fault planes represent discontinuities in the bedrock that may deflect the carrier wave received by the Wadi, allowing the user to find fault traces hidden

to the naked eye. The rental unit is relatively inexpensive, ($50-75 dollars per day) but there are several barriers to its use by the layperson (not an expert in the field):

- The unit is both a collection and interface device. The user must have a computer system capable of receiving and storing the unit's output.
- The driver that allows the exchange of information and the software that presents the data in a graphical form are both rented along with the unit and may be used only as long as the rental period. Any tweaks or modifications to the output graphs must be finalized before the unit is returned.
- The data entry must be choreographed along lines dictated by the needs of the eventual output. Strict protocols for naming and positioning exist for the purpose of delivering an output which may be correctly interpreted.
- Glitches in the data entry, once a line or grid has been started, may impact the value of all subsequent entries, so any interruptions may necessitate re-starting the entire segment of field work from the beginning,
- The VLF method assumes some knowledge of the orientation of potential targets, as well as some idea of the maximum depth intended for the investigation.
- Profile and grid lines should be outlined in the office before field work commences and the method does dictate adherence to relatively straight line segments while walking (consider bushwhacking and terrain evaluation before renting the unit).
- A necessary adjunct is a global positioning unit to anchor at least the grid corners or the end of the line segments, which facilitates spotting the well at some later date if the VLF delivers a viable target anomaly.
- The VLF technique is susceptible to some interferences from to man-made objects and the vagaries of signal strength.
- The technique targets structural discontinuities in the rock, not groundwater itself, so the fault or deep joint may not guarantee a productive well.

A good technique is to target at least as many days in the office as in the field for the rental unit, plus at least one day of unpacking and familiarization with the device. Another consideration is the delay between the time the device is desired and the actual day it can be shipped for use; this technology is successful enough to be popular and a wait of several weeks during peak field seasons may be expected. It is better to have anticipated a slightly longer rental period in order to re-visit the site if the office download reveals an intractable issue for interpretation of the first round of data.

LOCATION A: INTERSTATE 840, WILLIAMSON COUNTY

The road bed for a cut through the hills between the headwaters of Starnes Creek and McCrory Creek in southeastern Williamson County (Refer to Figures 2 and 3) is aligned about N73°E. A small fault is visible across units of the Carters Limestone and Hermitage Formation in the cuts on both sides of the highway. The fault plane dips steeply to the west, about 65-degrees from vertical and is aligned roughly N10°E across the cut. Units of the limestone have been vertically offset by about six feet. The Wadi section lines were aligned parallel to the pavement, assuring that the stations were set up for readings more or less perpendicular to the fault plane. The stations were about 30 feet apart and the profile lines were about 300 feet long, starting about 90

feet east of the fault plane, proceeding west along the edge of the rock cut. The return leg of the grid was a profile along the edge of pavement, followed by one in the median, another along the edge of the pavement on the westbound lanes and a final leg along the edge of the face of the lowest bench in the northern rock cut. When traffic is not an issue, more consistent between-line spacing, equivalent to the along-line station distance or multiples thereof, should be considered.

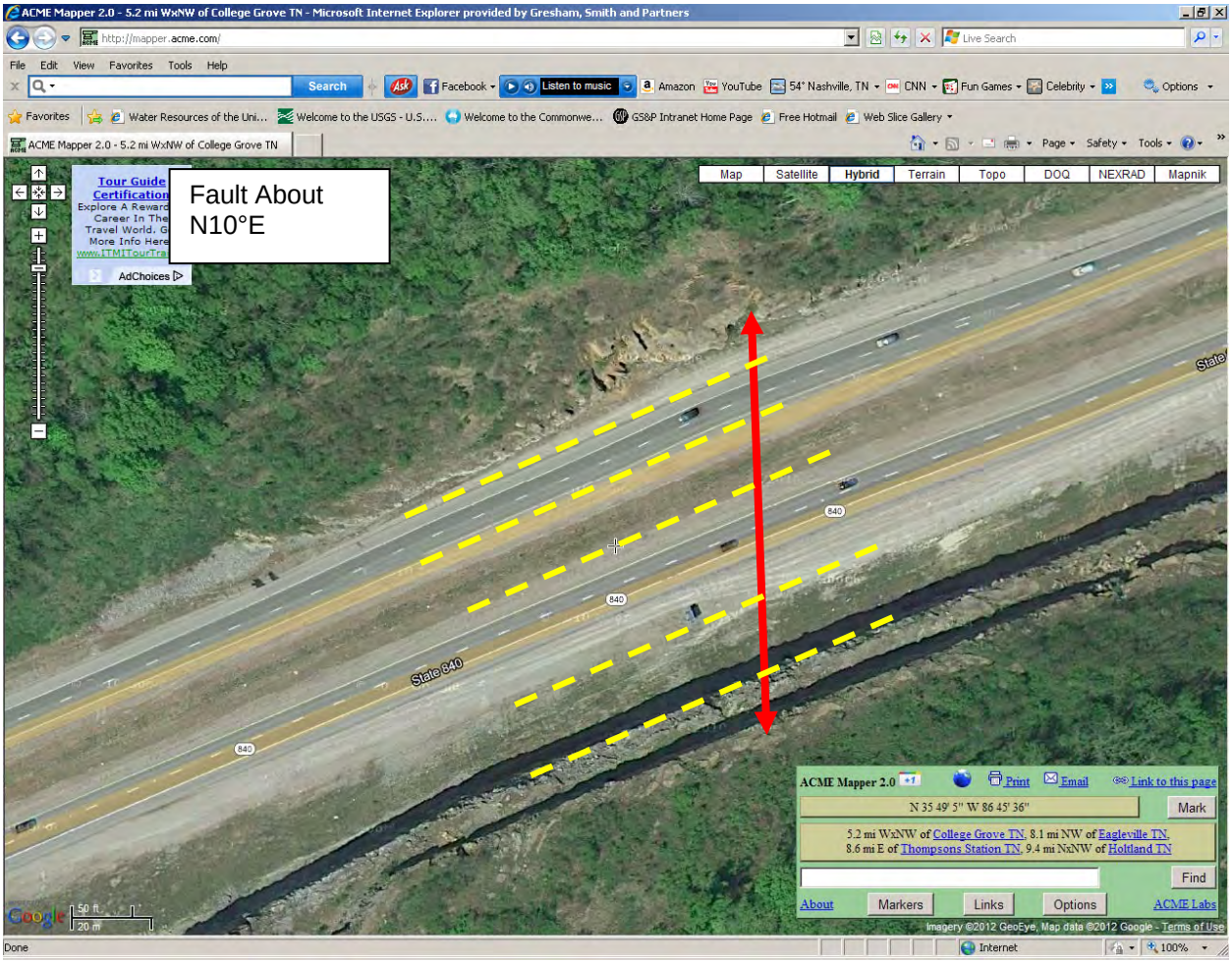


Figure 2: Fault Area on I-840 & WADI Profile Lines

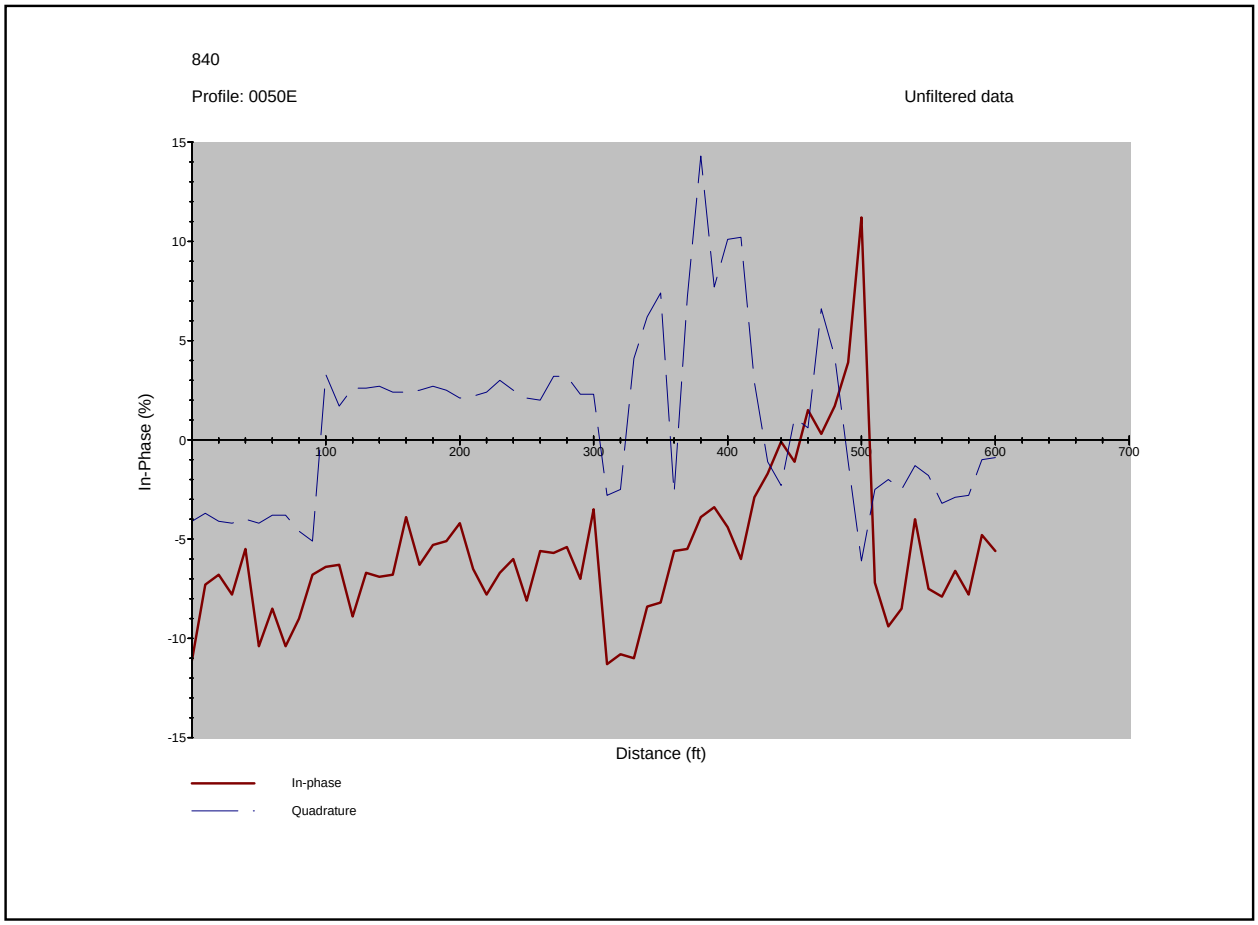


Figure 3: Unfiltered Data from I-840 Profile

LOCATION B: HIGHWAY 70S IN CANNON COUNTY

The small fault in the road cut for Highway 70S in the hill between Hollis Creek and Carson Creek in Cannon County only displaces the rock units about two feet (Refer to Figure 4). It is aligned N10° E and dips steeply to the west, nearly vertical at about 83-degrees. The paved lanes are aligned about N63°E and the rock units exposed are in the lower Carters Limestone at road level, working up through the Hermitage Formation and higher. The fault expression plays out in the cover over the Hermitage formation on both sides of the cut. The Wadi section lines were again aligned parallel to the pavement, assuring that the stations were positioned for readings more or less perpendicular to the fault plane. The stations were about 30 feet apart and the profile lines were about 300 feet long, starting about 90 feet east of the fault plane, proceeding west along the edge of the rock cut. The return leg of the grid was a profile along the edge of pavement, followed by one in the median, another along the edge of the pavement on the westbound lanes and a final leg along the edge of the face of the lowest bench in the northern rock cut.

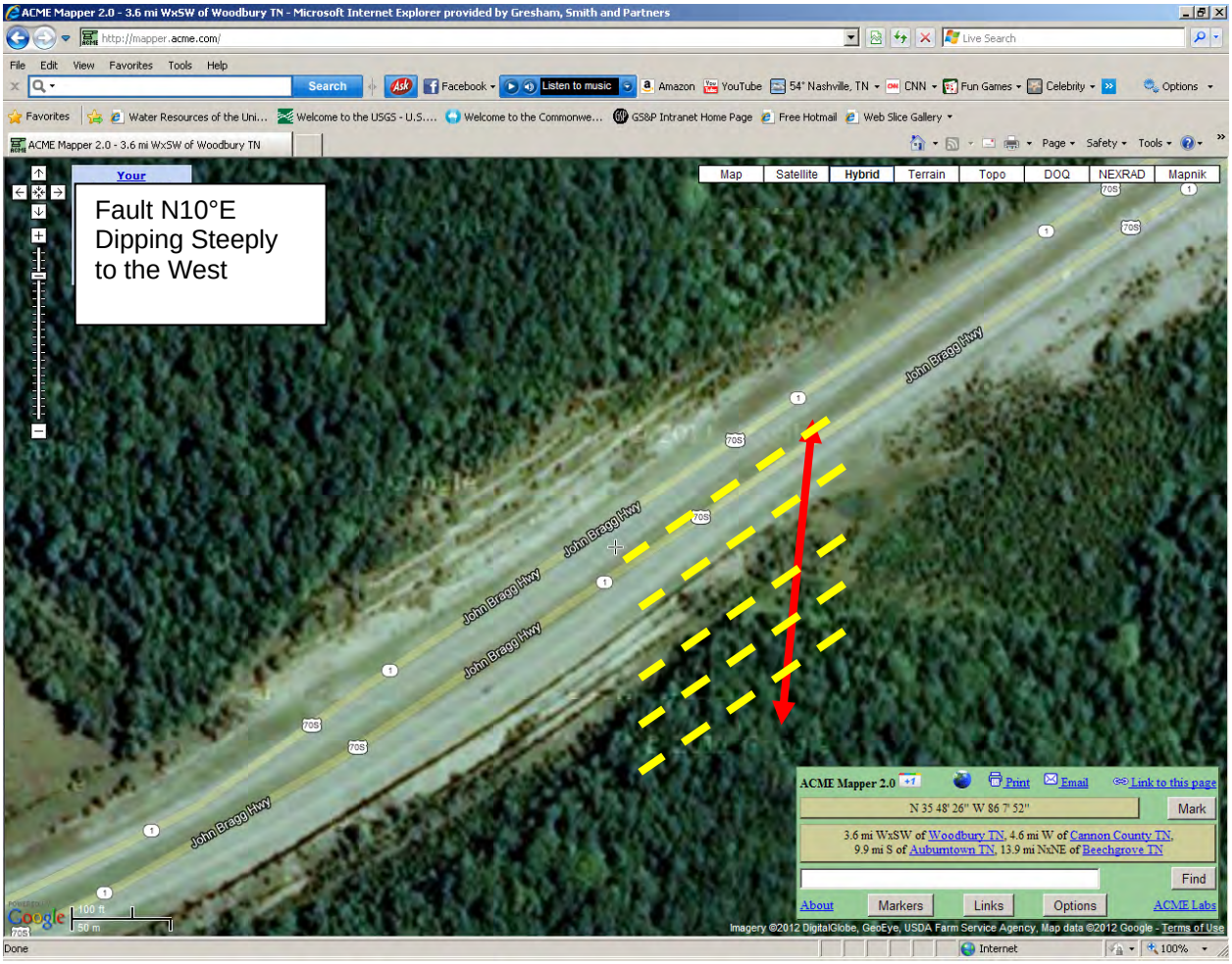


Figure 4: Highway 70S in Cannon County Study Area

LOCATION C: SEWARD HILLS, LITTLE HARPETH RIVER

Detailed study of the area around a farm south of Brentwood, Tennessee, was undertaken in the late 1980s after several thousand gallons of industrial chemical were improperly disposed of there. Detailed geologic work by the USGS identified several small folds in the limestones of the Little Harpeth River Valley between the disposal site and the uplands to the West. Two long section lines were done to evaluate the potential for structural deformation in the Carters Limestone in an area on either side of a strong natural spring flow at about N35°56'47" and W86°46'09" from the Bigby-Cannon Limestones. Detailed contour maps on the top of the T-3 bentonite, based on downhole geophysical logging in several local wells, were published by the USGS in 1988 and 1989. The Wadi profile lines were set up to cross undeveloped land over parts of the area mapped by the USGS through an agreement with the City of Brentwood Parks and Recreation Department. Local joint sets suggested a strong possibility for north-south structural features, so the Wadi profile lines were set up to run essentially east-west. Figure 5 shows the general orientation one of the sets of long profile lines, superimposed on the USGS interpretation of local bedrock structure. Figure 6 is a color graphic which is one of the display options using the WADI software.

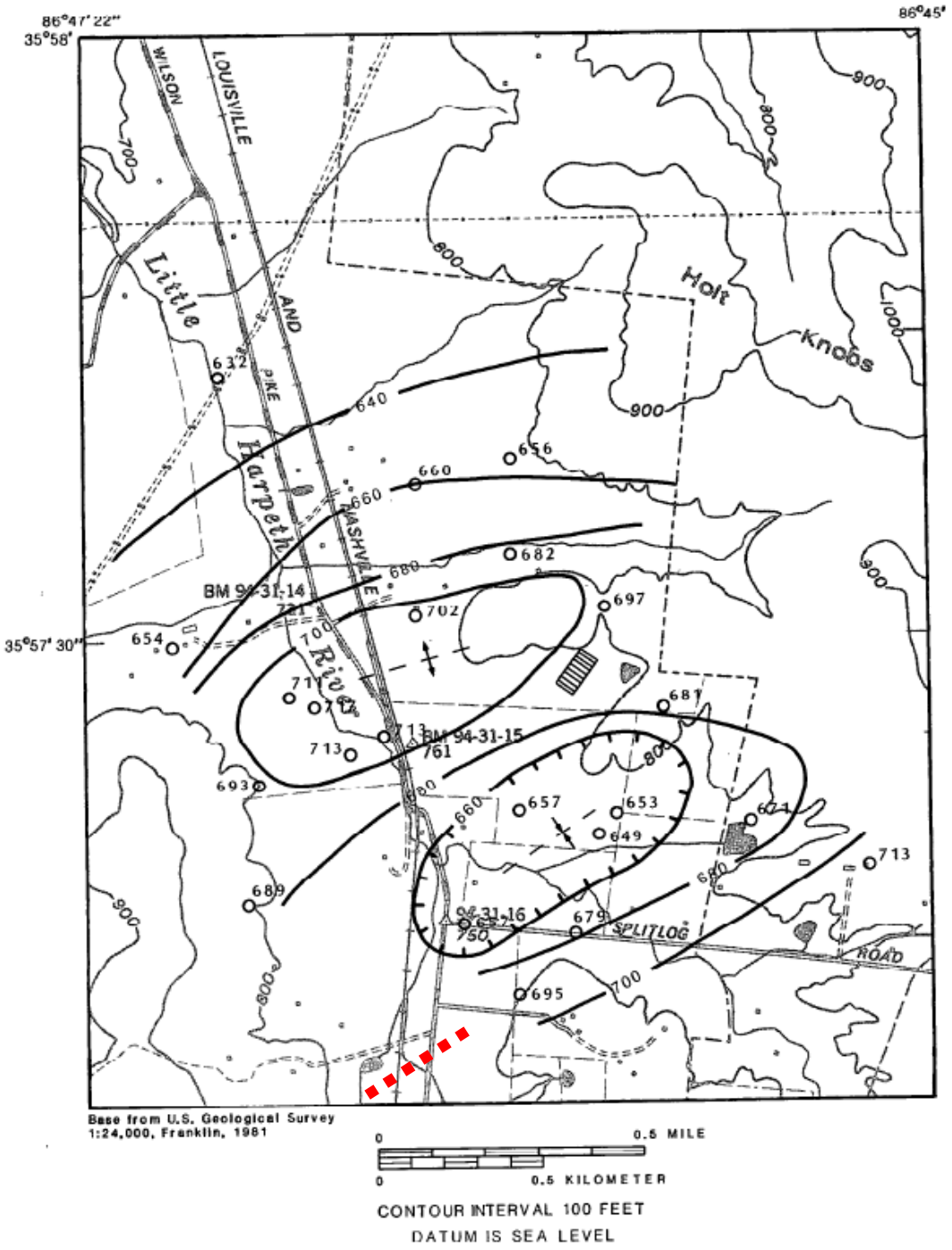


Figure 5: WADI Profile Lines Near Synclinal Axis, Base map From Hancar, 1988

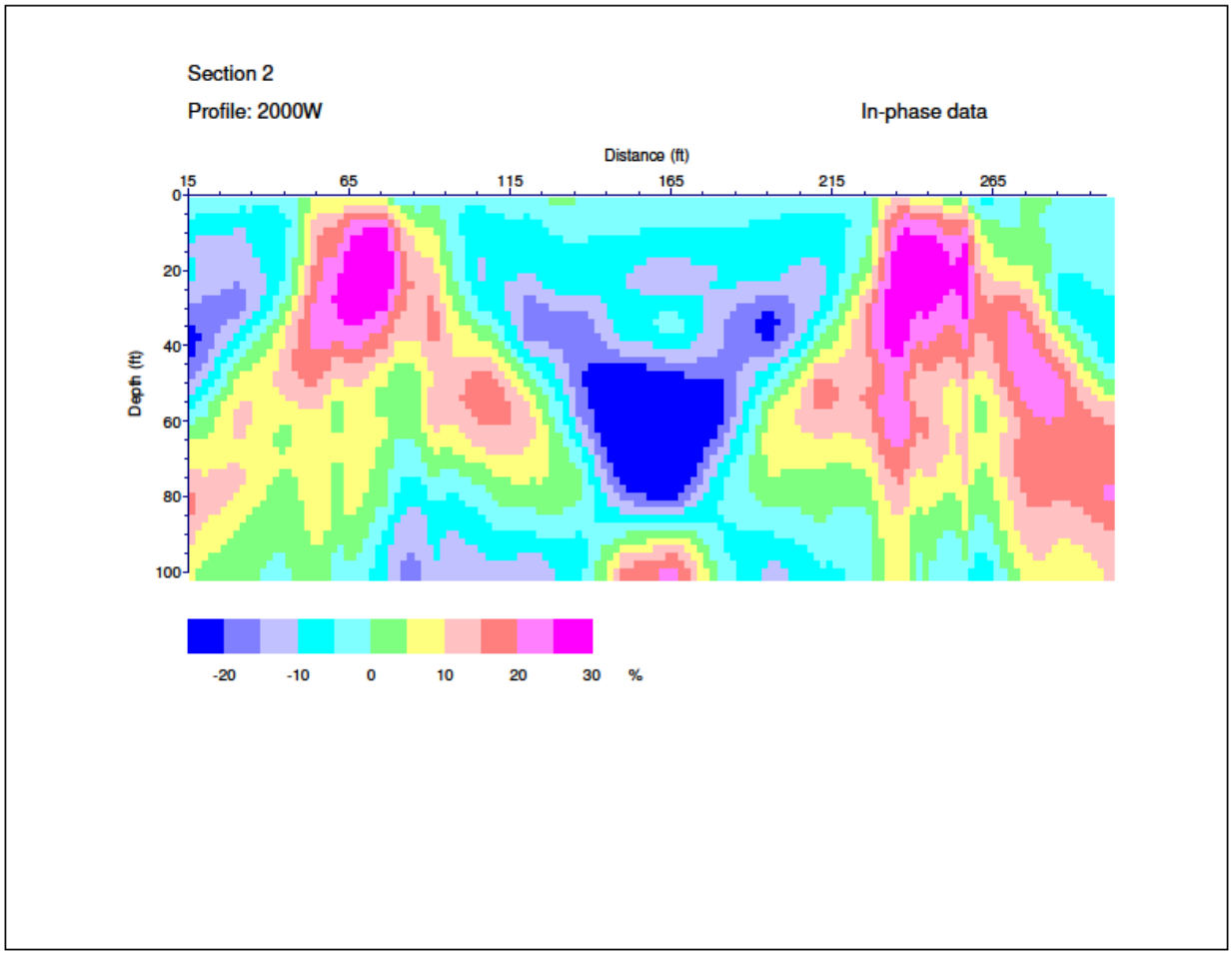


Figure 6: WADI Output Graphics from East-West Profiles (near Brentwood, Tennessee)

CONCLUSIONS

The VLF technique allows the rapid and relatively cheap evaluation of large surface areas but, in the context of targeting a well location, the actual input assumptions building toward the modeled output information can be quite variable. These multiple assumptions, depth to water, recharge area, structural controls, the interaction of recharge and structural control induce a stressful degree of ambiguity into the selection of a place to drill. In these three instances, extra project time was allocated for short surveys in areas where at least some of the unknown variables were accounted for in order to increase the overall confidence in reliance on the rented machine and the method. This ground-truth scenario assisted in evaluating data in the land areas where the target formation were equivalent but there were relatively few rock outcrops and lineaments and traces were obscured by the cover of deep soil or vegetation. Clear anomalies were seen in all instances, equating with the observable fault lines or inferred structural anomalies.

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A SYNTHETIC REFERENCE STANDARD FOR SEDIMENT ACID-VOLATILE SULFIDE (AVS) ANALYSIS

Mr. Adrian Gonzalez[1]

Sediment quality assessment has become integral to general water quality management efforts. Sediment quality assessment can include evaluating the role of inorganic contaminants (metals) on the degradation of sediment's ability to support a normally functioning, region-appropriate benthic habitat. Two geochemical parameters have been combined into a useful tool for assessing and describing the affect of metals on sediment quality: simultaneously extractable metals (SEM) and acid-volatile sulfide (AVS). Currently, data quality of SEM-AVS analyses is assessed indirectly by documenting the quality of the associated analytical steps. A direct method for assessing SEM-AVS data quality would strengthen the validity and reliability of inferences and decisions derived from SEM-AVS data, and should include analysis of a whole-sediment sample collected from the field containing known concentrations of AVS and of any associated metal(s). A plausible alternative to a natural field-collected sediment reference standard is a synthetic reference standard formulated with components of known purity and composition. This paper documents the development of a synthetic sediment material composed of readily available minerals, geochemical phases, and interstitial water components. Prototypes of this material were evaluated for stability over time, consistency in preparation, and relevance to natural sediment. Results of those evaluations indicate that this synthetic reference sediment material is an accurate analog to natural freshwater sediment containing AVS and associated metals. This synthetic sediment material also is shown to be both stabile and consistent over time, making it a suitable QA reference standard for direct QA assessment of SEM-AVS analyses.

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A WATERSHED-SCALE PATHOGEN REDUCTION MODEL USING VARIABLE COST-SHARES FOR SEPTIC SYSTEM TREATMENTS

Dan Huser[1] and Josh Smith

Several stream segments within the Conasauga River Watershed in Georgia are impaired for pathogens as a result of cattle grazing and failing septic systems according to local TMDL Implementation Plans. A new method was developed to reduce the fecal contamination that leads to pathogen impairments using cost-shares on septic system repairs. The method relies on a Clean Water Act (§319) funded variable cost-share rate to maximize repairs on systems that significantly contribute to the pollutant load. Properties that drain to impaired stream segments, and those in close proximity to state waters, receive higher cost-share rates. Inclusion of other property owners to be eligible for lower cost-share rates maximizes program participation and builds important momentum within communities. Over 120 septic systems in the watershed have been repaired using cost-share funds since the variable cost-share rate model was first used in 2009, more than doubling the targeted number while maximizing the use of federal dollars. De-listing of impaired segments has not yet occurred, presumably due to the size of the implementation area (406,000 acres). However, the number of septic system repairs, amount of community involvement, and project momentum have been maximized further due to this large implementation scale. Recently, the variable cost-share model has been adapted in the State of Tennessee for use in 319 Projects in the Conasauga River, Sequatchie River, and Guntersville Reservoir Watersheds. If the success within the Conasauga River Watershed in Georgia can be replicated, we anticipate the possibility of de-listing of stream segments in these areas since the method incentivizes program participation from those that bring about the greatest load reductions while maximizing the overall number of participants.

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GEOMORPHIC AND FISH-COMMUNITY RESPONSE TO DISTURBANCE IN A MIDDLE TENNESSEE FLAT ROCK CREEK

Joyce Iwinski, Applied Polymer Systems, Inc.

Sedimentation and excess nutrients such as phosphorous enter our water bodies from erosion, land disturbing activities, fertilizers, manures, and crop runoff. Fine particulates are a point of attachment for contaminants such as nutrients, phosphorous, bacteria, heavy metals, pesticides, and endocrine disruptors. This poster focuses on three studies outlining three major problems associated with water quality including highly turbid and sediment laden water, high nutrient and algal levels, and excess metals.

Using anionic water soluble polymer technologies to enhance our current best management practices (BMPs) we are able to greatly reduce sediment, metals, and nutrients (both organic and inorganic turbidity) from leaving a site as well as reduce the amount in a given water body. As the polymer particles are dispersed throughout the water column and come in contact with particulates, they bind with the metals, sediment, and nutrients to form a heavier, larger floc that settles out and can be removed.

Various studies have shown that as low as 10-100 NTU's will start to affect aquatic life and fish will begin to show signs of stress. Turbidity impacts aquatic life through decreased light, food, and oxygen, as well as mechanical effects and temperature increases. In addition to high levels of turbidity, excess nutrients entering into water bodies can lead to harmful algal blooms. Algal blooms not only cause aesthetic, odor, and taste problems, but many species of algae are capable of producing dangerous toxins that affect the liver or nervous system. Through various tests and case studies, using polymer enhancement in conjunction with other BMPs a 75-85 percent reduction in phosphorous has been found as well as a 95+ percent reduction in total suspended solids (TSS) and NTU's.

IMPACTS OF NONPOINT-SOURCE POLLUTION ON THE DIATOM ASSEMBLAGE, PERIPHYTON CHARACTERISTICS, AND ALGAE GROWTH IN THE WEST FORK OF THE RED RIVER IN NORTH-CENTRAL TENNESSEE

Jefferson Lebkuecher[1], Kelly Anderson, Courtney Gorman, Anna Guyer, Alex Hall, Rebecca Johnson, Elizabeth Slade, Chelsea Williams, and Lyddia Wilson

ABSTRACT

The ecological integrity of periphyton and growth characteristics of algae were assessed to better understand the effects of nonpoint-source pollution in the West Fork of the Red River. We used diatom indices to assess the structure of the diatom assemblage, measurements of pigment concentrations to evaluate the health of photoautotrophic periphyton, and growth dynamics of the green alga *Selenastrum capricornutum* to evaluate the potential for excessive algal growth. The three most abundant diatom taxa were *Cocconeis placentula* (38 %), *Rhoicosphenia curvata* (15 %), and *Navicula minima* (10 %). Habitat impairment by eutrophication is demonstrated by a low value of the Pollution Tolerance Index for the diatom assemblage. Poor physiological condition of photoautotrophic periphyton is indicated by high concentrations of pheophytin *a*. Low maximum specific growth rate and high carrying capacity for *S. capricornutum* reveal the presence of contaminants and eutrophic conditions, respectively. The results demonstrate that the periphyton community and growth of *S. capricornutum* are negatively impacted by poor quality water and that nutrient enrichment from nonpoint sources may be the most serious threat to the biotic integrity of the West Fork of the Red River.

INTRODUCTION

Nutrient enrichment from non-point sources and erosion are most responsible for the biological impairment of United States waters (Irvine and Murphy 2009). Assessments of pollution are prerequisites to developing watershed management plans to protect aquatic ecosystems (Smucker and Vis 2009). Biological monitoring is an essential method to characterize and quantify the influences of water quality because physical and chemical analyses do not reveal the impacts of pollution on biological integrity (Taylor *et* al. 2007).

Photoautotrophic periphyton are the most important primary producers in the majority of wadeable streams (Lambert and Steinman 1997). Eutrophication of streams changes photoautotrophic periphyton characteristics and affects whole-stream ecological relationships (Lebkuecher *et* al. 2000). The composition, biomass, and physiological status of photoautotrophic periphyton are excellent indicators of water quality and are used universally to follow changes in aquatic environments (Eaton *et* al., 2005).

Diatoms are excellent indicators of biotic stressors because of their sensitivity to pollutants. The great diversity of diatoms permits calculation of accurate indices which reveal specific environmental conditions. Information from diatom indices can be used to support proposed

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restoration and conservation policies because they often disclose the source of impairment (Smucker and Vis 2009). Many European countries and states including Oklahoma, Montana, Kentucky, and Texas use evaluations of diatom composition as a standardized protocol for monitoring changes in water quality (Szczepocka and Sule 2009).

Measurements of periphyton biomass and pigment concentrations help disclose the health of the periphyton community. Increases of periphyton biomass accompany eutrophication and signify poor quality water. Chlorophyll (chl) *a* is degraded to pheophytin (pheo) *a* as photoautotrophic periphyton senesce, hence high concentrations of pheo *a* indicate poor physiological condition.

The growth rate and carrying capacity of the green alga *Selenastrum capricornutum* Printz (Chlorophyceae) are widely used to evaluate the effects of nutrients and toxicants by institutions that discharge water into water bodies (Eaton *et* al., 2005). *S. capricornutum* is a non-motile unicell common in most fresh waters. This alga is a standard assay organism because it is sensitive to toxic substances, tolerates a wide range of nutrient levels, and exhibits rapid growth under ideal conditions.

The West Fork of the Red River is a fourth-order stream at the site sampled and joins the Red River two km upstream of the confluence of the Red and Cumberland Rivers in Clarksville, Tennessee. The West Fork of the Red River Watershed is in the Western Pennyroyal Karst Level IV Ecoregion. Approximately 60% of the watershed is used to produce agricultural products and is severely impacted by nonpoint-source pollution (TDEC 2009).

MATERIALS AND METHODS

Periphyton and water were sampled in the West Fork of the Red River at Billy Dunlop Park in Clarksville, Tennessee on Oct. 5, 2011 following 2 weeks without significant precipitation. Five midstream plots in a 10-m reach were established with 0.25 m^2 wire frames. The fractions of cobble (considered stable substrate) and gravel plus smaller substrate (considered unstable substrate) in each plot were recorded. Two cobbles nearest the plot center were removed: one for determination of periphyton dry weight and one for determination of pigment concentrations. One sample of unstable substrate from each plot was removed with a core sampler (30 cm^2) for determination of pigment concentrations associated with unstable substrate. Ash-free periphyton dry weight and concentrations of periphyton chlorophyll (chl) *a* and pheophytin (pheo) *a* were determined as described by Eaton *et* al. (2005). The surface area of cobble from which periphyton was removed was calculated by covering the upper surface with aluminum foil, weighing the foil, and extrapolating weight to surface area (Hauer and Lamberti 2006). Periphyton for analysis of diatom composition was sampled by collecting one cobble nearest the plot center in ten midstream plots in a 10-m reach. Identification of epilithic diatoms, calculation of diatom indices, and growth evaluations of *Selenastrum capricornutum* in collected water followed the methods described in Lebkuecher *et* al. (2011).

RESULTS AND DISCUSSION

We identified 47 diatom species in 22 genera from cobble sampled in the West Fork of the Red River (Appendix). The three most abundant taxa were C*occoneis placentula* (38 %), *Rhoicosphenia curvata* (15 %), and *Navicula minima* (10 %). The diatom assemblage is diverse as indicated by the high Shannon Diversity Index (Table 1). The Siltation Index (SI) estimates the percentage of motile diatoms (Bahls 1993). Motile diatoms are able to avoid being buried and are tolerant of sedimentation. SI values $\geq$ 50 denote habitat degradation by excessive sediments. The low SI value of the diatom assemblage at the West Fork of the Red River indicates the reach sampled is not sediment impaired.

The Pollution Tolerance Index (PTI) is based on the percent of diatoms tolerant of nutrient enrichment and reveals the trophic status of water (KDOW 2002). The PTI ranges from 1 to 4;

Table 1. Indices of the diatom assemblage in the West Fork of the Red River. The index scale is the range of values possible from very good to very poor quality water.

Index	Index scale	Index value
Shannon Diversity Index		2.4
Evenness	1 - 0	0.6
Siltation Index	0 - 100	25
Pollution Tolerance Index	4 - 1	2.5
Organic Pollution Index	0 - 100	14

low PTI values signify eutrophic conditions and high PTI values signify oligotrophic conditions. PTI values $\leq$ 2.6 designate nutrient-impaired conditions in the Western Pennyroyal Karst Level IV Ecoregion (Lebkuecher *et* al. 2011). The low PTI value of the diatom assemblage in the West Fork of the Red River indicates the river is adversely impacted by eutrophication.

The organic pollution Index (OPI) is the percentage of taxa tolerant of organic pollution (Kelly 1998). OPI values $\leq$ 20 indicate the absence of significant organic pollution, 21 - 40 infers some organic pollution present, and values > 40 suggest a significant influence of organic pollution. The low OPI value of the assemblage at West Fork of the Red River indicates organic pollution does not impact water quality. The trophic conditions of the West Fork of the Red River are atypical because nutrient-rich water is often polluted with high concentrations of organics. The OPI is criticized because several taxa used as indicators of organic pollution are also indicators of eutrophic conditions (Kelly 1998). Our results demonstrate the OPI is a useful index given the low OPI value indicates the absence of organic pollution in eutrophic conditions.

Periphyton biomass on cobble in the West Fork of the Red River (Table 2) is typical of periphyton biomass on stable substrate in other wadeable streams in Tennessee impacted by nonpoint-source pollution (i.e., Lebkuecher *et* al. 2000). The concentration of pheo *a* of photoautotrophic periphyton is similar to the concentration of chl *a* and indicates the photoautotrophic peiphyton is in poor physiological condition. Of course higher concentrations of pheo *a* are expected in samples from natural environments with algae at different stages of life history relative to samples collected from periphytometers following short sampling periods used by studies designed to measure the rate of biomass accumulation.

Table 2. Fraction of benthic substrate and characteristics of periphyton sampled from the West Fork of the Red River. Values represent means ± SE of five replicates.

Assay	Mean + SE
Fraction of benthic substrate	
Cobble	0.71 ± 0.10
Gravel, sand, silt	0.29 ± 0.10
Ash-free periphyton (g/m^2 cobble)	2.14 ± 0.2
Chl *a* (mg/m^2 stream bottom)	20.7 ± 6.7
Pheo *a* (mg/m^2 stream bottom)	18.9 ± 8.2
Cobble chl *a* (mg/m^2)	14.9 ± 4.7
Gravel, sand, silt chl *a* (mg/m^2)	34.8 + 23.2

The biomass of photoautotrophic periphyton associated with cobble is lower than the photoautotrophic biomass associated with gravel, sand, and silt. Stable substrate such as cobble typically supports greater periphyton biomass relative to unstable substrate (Myers *et* al. 2007). Our results illustrate that small substrate can be as important as large substrate for primary production in streams with heterogeneous benthic environments if undisturbed by a recent spate of high discharge.

The maximum specific growth rate (μ_{max}) of *Selenastrum capricornutum* in water collected from the West Fork of the Red River was 0.8 ± 0.1 SE. A specific growth rate (μ) value of 0.7 corresponds to one population doubling per day; a μ value of 1.5 corresponds to 2 population doublings per day. The μ_{max} of *S. capricornutum* in nutrient media or in oligotrophic to eutrophic water absent of toxicants is between 1.2 and 1.8 (Nyholm 1990). The low μ_{max} of *S. capricornutum* in water collected from the West Fork of the Red River reveals the presence of contaminants which reduce growth rate. Nutrient loading associated with stream bank erosion and agricultural runoff increases carrying capacity for *S. capricornutum* (Ellis and Stanford 1988). The carrying capacity for *S. capricornutum* in water collected from the West Fork of the Red River was 10.7 cells·mL^{-1} ± 1.4 SE. A carrying capacity > 1 x 10^5 cells·mL^{-1} indicates eutrophic conditions and values between 10 x 10^5 cells·mL^{-1} and 20 x 10^5 cells·mL^{-1} are common in samples collected in watersheds impacted by non-point source pollution (Flynt *et* al. 2001). The high carrying capacity of water collected from the West Fork of the Red River is consistent with the indication of eutrophic conditions by the low PTI value for the diatom assemblage.

Our results illustrate the benefits of biological monitoring to assess water quality. The impact of poor quality water is revealed by the structure of the diatom assemblage, biomass and physiological condition of periphyton, and growth dynamics of *S. capricornutum*. The results indicate that implementation of watershed management plans to reduce nutrient enrichment would improve the ecological integrity of the West Fork of the Red River.

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Appendix. Diatom taxa and percent taxon composition sampled from cobble in the West Fork of the Red River listed in alphabetical order.

Taxon name	Percent composition
Achnanthes pinnata Hustedt	0.7
Achnanthidium deflexa Reimer	0.2
Achnanthidium minutissimum (Kützing) Czarnecki	0.4
Achnanthidium rivulare Potapova and Ponander	0.2
Amphora ovalis (Kütz.) Kützing	0.4
Amphora perpusilla Grunow	1.3
Cocconeis pediculus Ehrenberg	2.0
C*occoneis placentula* Ehrenberg	38.1
Cymbella tumida (Brébisson) Van Heurck	0.2
Diatoma vulgaris Bory	1.3
Encyonema silesiacum (Bleisch) Mann	0.4
Gomphoneis olivacea (Hornemann) Dawson	0.2
Gomphonema minutum Agardh	1.3
Gomphonema parvulum (Kützing) Kützing	0.2
Gomphonema pumilum (Grunow) Reichardt and Lange-Bertalot.	0.7
Gomphonema truncatum Ehrenberg	0.2
Gyrosigma acuminatum (Kütz.) Rabenhorst	0.4
Gyrosigma attentuatum (Kütz.) Rabenhorst	2.2
Gyrosigma scalproides (Rabenhorst) Cleve	0.2
Karayeva clevei (Grunow) Round and Bukht	0.4
Melosira varians Agardh	0.2
Meridion circulare var. *constrictum* (Ralfs) Van Heurck	0.4
Navicula cryptotenella Lange-Bertalot	0.4
Navicula crytptocephala Kutzing	2.9
Navicula crytptocephala var. veneta (Kützing) Rabenhorst	0.2
Navicula gregaria Donkin	0.4
Navicula minima Grunow	10.4
Navicula radiosa var. *parva* Wallace	0.2
Navicula reichardtiana Lange-Bertalot	1.6
Navicula rhomboidies Grunow	0.4
Navicula symmetrica Patrick	0.2
Navicula tripunctata (Müller) Bory	6.0
Navicula viridula (Kützing) Ehrenberg	0.2
Nitzschia capitellata Hustedt	0.2
Nitzschia dissipata (Kützing) Grunow	0.4
Nitzschia frustulum (Kützing) Grunow	0.2
Nitzschia perminuta (Grunow) M. Peragallo	0.4
Nitzschia sociabilis Hustedt	0.7
Pinnularia abaujensis (Pantoscek) Ross	0.7
Planothidium lanceolatum Brébison	0.7
Planothidium lanceolatum var. dubia Grunow	0.9
Psammothidium subatomoides Hustedt.	3.3
Reimeria sinuata (Gregory) Kociolek and Stoermer	1.1
Rhoicosphenia curvata (Kützing) Grunow	14.9
Sellaphora pupula Kützing	0.2
Synedra rumpens Kützing	0.2
Synedra ulna (Nitzsch) Ehrenberg	0.9

A NEW INTERDISCIPLINARY MINOR IN WATERSHED SCIENCE, ENGINEERING, AND POLICY AT THE UNIVERSITY OF TENNESSEE - KNOXVILLE

John Schwartz[1], Chris Clark[2], Larry McKay[3], Tracy Moir-McClean[4], Becky Jacobs[5], Daniel Yoder[6], Andrea Ludwig[6], Carol Harden[7], Qiang He[1], and Joanne Logan[6]

The complexity of water quantity and quality issues related to human activities requires dealing with those issues on a watershed scale. Students wishing to develop expanded skills in watershed science/engineering, planning and design, and culture and policy issues related to water can now do so through newly established Watershed minors for undergraduate and graduate degrees at the University of Tennessee, Knoxville. Watershed-oriented skills are especially useful for careers in natural resource policy, water and land management, as well as sustainable development, design, and stormwater management for private industry, government agencies and non-governmental organizations. The minors require at least one course from the Watershed core list, courses with a hydrology focus that introduce concepts associated with watershed-scale processes. This poster describes the requirements for the minors, and lists the courses and instructors. It is presented as a means to stimulate dialogue and elicit feedback from water resources professionals in the state of Tennessee.

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STUDENT POSTERS

Presence of Diarrheal Disease Pathogens in Bangladesh Surface and Well Water
Kati A. Ayers, Alice Layton, Abby Smartt, Brian Mailloux, Larry McKay, Alexander van Green, and Gary Sayler

Hydraulic Connections Between the Cumberland River and Groundwater in Nearby Wells in Nashville, Tennessee – Implications for the Effects of Surface Water on Water-Supply Wells
Aras Barzanji, Mike Bradley, and Tom Byl

Hydrology and Soil Biology of Cedar Glade Ecosystems, 2012
Jennifer M. Cartwright, William J. Wolfe, Dafeng Hui, Thomas D. Byl, and E. Kudjo Dzantor

Streambank Video Mapping to Determine Erosion Susceptible Areas
Brett A. Connell

Investigating the Mesoscale Impact of Artificial Reservoirs on Frequency of Rain
Ahmed M. Degu and Faisal Hossain

Effectiveness of Stormwater Filters at Mammoth Cave National Park, Kentucky
Roger Diehl, Rick Toomey, Victor Roland, Irucka Embry, and Ashley West

Understanding Nature of Satellite Rainfall Errors to Advance Water Resource Management in Tennessee River Basin
Abebe Gebregiorgis and Faisal Hossain

Methodology to Determine Aquifer Compartmentalization and Its Potential Effects on Groundwater Flow and Quality in the Davis Well Field, Memphis, TN
Darren Beal, Sarah Girdner, Ryan Csontos, and Brian Waldron

Modeling Nitrate Leaching in the Richland Creek Watershed
Jiahe Gu, Ravikanth Konjeti, and Schuyler Sanderson

Reducing Bias in Nutrient Load Estimates for Small Streams by Incorporating Antecedent Discharge Information
Marquan D. Martin

SWAT Model Calibration and Validation in the Oostanaula Creek Watershed
Sean Nester, Hawkins, Williams, Layton, and Walker

Synthesis of Nano-Zero Valent Iron in Sand Matrix and Impact on Microbial Community
Victor Roland and Kudjo Dzantor

Hydrologic, Sediment, and Water Quality Impacts of Growing Switchgrass in Tennessee
Zachariah Seiden and John Schwarts

Continuous Monitoring of Hormonally Active Compounds in Effluents from Hallsdale-Powell Wastewater Treatment Facility at Knoxville, TN—Application of Standardized Bioluminescent Yeast-Based High Throughput Bioassay
Jun Wang, Melanie Eldridge, Fu-min Menn, and Gary Sayler

Fate of Chemicals Carried from the Surface into a Cave
Ashley West, Rick Toomey, Tyesha Martin, Sean McMillian, David Solomon, and Tom Byl

Impact of Artificial Reservoir Size and Land Use Land Cover on Probable Maximum Flood
Wondmagegn Yigzaw and Faisal Hossain

Adaptation of a Google-Earth Based Education Tool for Place-Based Learning of Hydrologic Concepts Using a Campus Watershed and Wi-Fi Connectivity at Tennessee Technological University
Wondmagegn Yigzaw, Faisal Hossain, and E. Habib

PRESENCE OF DIARRHEAL DISEASE PATHOGENS IN BANGLADESH SURFACE AND WELL WATER

Kati A. Ayers*[1], Alice Layton[2], Abby Smartt[3], Brian Mailloux[4], Larry McKay[5], Alexander van Geen[6], and Gary Sayler[7]

Diarrheal disease pathogens can be transmitted by multiple routes including direct person-to-person and waterborne transmission. Although waterborne transmission is more common in countries with poor sanitation than in the United States, detection of Hepatitis A in wells in Tennessee reminds us that vigilance is needed to protect Tennessee drinking waters. Rotavirus is the leading cause of viral gastroenteritis in infants and young children under five worldwide and is a major concern in Bangladesh due to its poor sanitation and limited resources. Although the viruses of concern differ between countries, a common mechanism of viral transmission from surface water to groundwater to drinking water seems to exist. In this study, quantitative PCR was used to measure the concentrations of several bacterial and viral pathogens and fecal indicators, including *E. coli, Shigella, Bacteroides,* rotavirus, and adenovirus in surface water and in well water in three months for a total of 145 well and 25 surface water samples. In well water samples, the viral pathogen (primarily rotavirus) frequency of occurrence and concentration greatly exceeded the bacterial pathogen frequency of occurrence and concentration. In addition rotavirus concentrations present in well water samples were high enough to cause disease suggesting that in Bangladesh rotavirus may have a waterborne transmission component. The application of quantitative PCR methods used in this study will further our ability to monitor contamination in Tennessee waters. In addition, understanding the transmission of viruses from surface to groundwater in Bangladesh aquifers may further our understanding of parallel transmission routes in Tennessee.

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HYDRAULIC CONNECTIONS BETWEEN THE CUMBERLAND RIVER AND GROUNDWATER IN NEARBY WELLS IN NASHVILLE, TENNESSEE - IMPLICATIONS FOR THE EFFECTS OF SURFACE WATER ON WATER-SUPPLY WELLS

Aras Barzanji[1], Mike Bradley[2], and Tom Byl[1,2]

ABSTRACT

Several communities in the Cumberland River watershed are interested in using groundwater as their water supply instead of surface water. The LaGuardo community placed their extraction wells within a mile of the Cumberland River near the Old Hickory reservoir. It is not known if they are pulling surface water from the reservoir or intercepting groundwater with their supply wells. Tennessee State University (TSU) has an analogous situation with three unused wells that are located within a mile of the Cumberland River, although they are further downstream on the Cumberland River in the Cheatham reservoir. This study was conducted to determine the hydraulic gradient of groundwater in the limestone-bedrock aquifer and to ascertain groundwater flow directions during different weather conditions at TSU in Nashville, Tennessee. The three wells used in this study are located along the flood plain, approximately 0.5 mile east of the Cumberland River near river mile 185 on the TSU Research Farm and range from 200 to 250 feet deep. The wells are constructed of 6-inch steel casings that extend to the top of rock, with open boreholes in the bedrock. Geophysical logging of the wells indicates the top of bedrock in the wells at approximately 40 to 60 feet below ground surface, as well as the presence of two sets of primary openings in the bedrock at approximately 72- and 108-feet below land surface. Water elevations were measured in the wells and compared to Cumberland River elevations as reported by the U.S. Geological Survey gage near Bordeaux, Tennessee. The hydraulic gradient was calculated using the triangulation or "three-point" method based on the water elevations in the three TSU wells. Water levels, measured under different weather conditions, ranged from 6 to 22 feet below land surface in the three wells. Continuous water levels also were monitored at 1 hour intervals during the winter and spring of 2010 in one of the wells, using a pressure transducer and data recorder. Results indicate recharge from rainfall events rapidly influenced the hydraulic gradients and flow directions of groundwater beneathe the study site. Less than 24 hours after a 1.5 inch rain event, groundwater levels rose from 1 to 3 feet in the wells. The rain event increased the groundwater hydraulic gradient by 11 percent and changed the flow direction from north to northwest across the site. Water elevations in the well with the continuous monitor were compared to the Cumberland River stage data (USGS, Bordeaux). It was apparent that water in the well and river would rise and fall almost simultaneously. The general water gradients suggests groundwater in the study area is moving toward the Cumberland River. On rare occassions, such as the flood of May 2010, the river rises faster than the groundwater and the gradient reverses.

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HYDROLOGY AND SOIL BIOLOGY OF CEDAR GLADE ECOSYSTEMS, 2012

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INTRODUCTION

Cedar glades are distinct ecosystems, characterized by very thin soil and extreme hydrologic conditions (seasonally ranging from xeric to saturated) that support a number of critically endangered plant species (Quarterman, 1950a, Freeman, 1933). Stones River National Battlefield outside Murfreesboro, Tennessee include a large number of high-quality, well preserved cedar glades. In their spatial pattern, these glades are similar to the "hillside" glades of the Edwards Plateau, which lie in narrow concentric bands cropping out at the contacts between different units of bedrock. (Terletzky and Van Auken, 1996). The role of hydrology in limestone-glade ecology is widely recognized but poorly understood. The U.S. Geological Survey is cooperating with the National Park Service and Tennessee State University to characterize the hydrology and soil biology of cedar glades in the National Battlefield.

METHODS

Sampling sites for this study were selected and located using stratified random sampling and GIS-enabled geostatistical analysis. Site characterization includes physical properties: soil thickness, temperature, pH, and texture; and ground cover: presence or absence of soil, vegetation, rock fragments, biological soil crusts and *Nostoc commun a* soil-dwelling, nitrogen-fixing communal cyanobacterum. Data collection includes seasonal observations of precipitation, soil water content (measured using time-domain reflectometry where soils are sufficiently deep and thermogravimetric analysis elsewhere), the presence or absence surface runoff, and soil biological characteristics, including organic matter content, nitrate levels, and soil respiration. Community-level physiological profiling of soil samples will enable comparisons of microbial metabolic potential expressed by indices of diversity and overall microbial activity. Data collection is ongoing and will continue through early 2013.

PRELIMINARY RESULTS AND DISCUSSION

Preliminary results for soil thickness and ground cover confirm that points in glade interiors have significantly thinner soils (mean of 7.2 cm) than in a 3-meter buffer in surrounding forest (mean of 14.0 cm). Of 120 points in glade interiors, 36 percent have mean soil depths less than 5cm and 10 percent have mean soil depths less than 2cm. Such extremely thin soils are thought to constrain plant growth (Freeman, 1933; Quarterman, 1950), and indeed observed thickness of both grass and forbs was inversely related to soil thickness. The presence of both *N. commune* and biological soil crusts were largely confined to areas of particularly shallow soil.

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Quantitative analysis of seasonal hydrologic conditions and soil biological processes may add a key component to our evolving conception of how plant associations in limestone cedar glades are formed and maintained. Understanding the role of hydrology in limestone cedar-glade ecology is important for management of the glades, given the globally rare and imperiled plant associations found there, the high density of well-developed karst features, and the rapid pace of suburban development in the area surrounding Stones River National Battlefield.

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STREAMBANK VIDEO MAPPING TO DETERMINE EROSION SUSCEPTIBLE AREAS

Brett A. Connell[1]

According to the U.S. EPA, excess sediment is a significant cause of water quality impairment for rivers. Therefore, determining the areas of river where streambank erosion is the highest should prove as valuable information. Considering the amount of funds being spent on river restoration and storm flow retention, there needs to be a more efficient method to document annual progress, on a large scale. Traditional streambank survey methods are limited in characterized area, time consuming, intrusive, and expensive. The objective of this study was to develop a Bank Erosion Susceptibility Index (BESI) to map landscape scale, streambank erosion susceptibility through video assessment. The VMS (Video Mapping System) equipped kayak provides georeferenced video footage correlated with GPS (global positioning systems) for GIS (geographic information systems) mapping applications. BESI is then applied to the video with erosion susceptibility scores being displayed within ArcGIS. Parameters being assessed while watching video include bank angle, bank height to bankfull ratio, surface protection, and riparian diversity. A 6.5 km section of the New River in the Big South Fork National Forest has been documented using the VMS system and shows BESI scores comparative to traditional techniques. Field time, cost, and environmental impact are all reduced, with the most erosion-susceptible areas being highlighted to further focus restoration efforts.

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INVESTIGATING THE MESOSCALE IMPACT OF ARTIFICIAL RESERVOIRS ON FREQUENCY OF RAIN

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INTRODUCTION

According to Global Climate Change Impacts in the United States (Karl and et al,2009) , the south east region of United states has experienced a 30 percent increase in fall precipitation in most part of the region but a decrease in Florida however a general decrease in summer precipitation has been observed in the region since 1970s. In the same report its noted that number of areas showing a change in degree of drought from moderate to severe has increased in the region. The report was in relation with global climate change impact in the Southeast region of United States.

There is a large amount of observational and model analyses published in literature that stress the need to improve our understanding of how the extremes of climate and water availability are changing. Of the many important factors, land use and land cover (LULC) change represents a major human induced activity critical to availability of fresh water (Chase et al, 2000; Vörösmarty and Sahagian, 2000; Hossain et al., 2011). One example of human-induced LULC change is the construction of engineering facilities for irrigation, hydroelectric power generation, industrial and domestic water supply, In particular, irrigation is one of the major drivers of change in the water cycle. During the last century, irrigable land increased from 40 million hectares (Mha) to 215 Mha (Freydank and Sieber, 2008). About 40% of the current irrigable land is supplied with surface water that is impounded by large artificial reservoirs and dams built on rivers (Lempérière, 2006). In this study, an attempt has been made to investigate the impact of large reservoirs on frequency of precipitation.

APPROACH

The specific question that this study pursued is: "*Have large dams increased the downwind frequency of rainfall?"* Precipitation stations from the Global Historical Climatology Network (GHCN) around 92 large dams in the US were analyzed. Using 30 years of atmospheric reanalysis data, the wind rose diagram for each dam was derived. Around 96 (78) GHCN downwind (upwind) precipitation stations were identified that were within 100 km of dams.

RESULTS AND DISCUSSION

Our analysis indicates that the Mediterranean climate, as a region, has experienced the highest increase in precipitation frequency. The Warm Summer Continental climatic region was found to have exhibited the next most increase. The same two regions have experienced a comparatively higher increase for higher magnitude events (> 15 mm/day) compared to other climates. Paired

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analyses were performed as a function of pre-dam and post-dam and at upwind and downwind locations. For Mediterranean climates, considered stations were found to have experienced a systematically decreasing trend in precipitation frequency before the construction of a dam and a systematically increasing trend during the post-dam period. Our analyses also revealed that the increase in precipitation frequency downwind of dams has been greater than that at upwind of dams for those stations located in semi-arid and Mediterranean climates. Even though the analysis according to wind direction helped elucidate the impact of dams, the specific role played by irrigation dams could not be distinguished from other types of dams in this study. Moreover, almost equal proportion of stations showed positive and negative slope suggesting that it is difficult to ascertain for sure whether there is a change in frequency of rain throughout the regions.

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EFFECTIVENESS OF STORMWATER FILTERS AT MAMMOTH CAVE NATIONAL PARK, KENTUCKY

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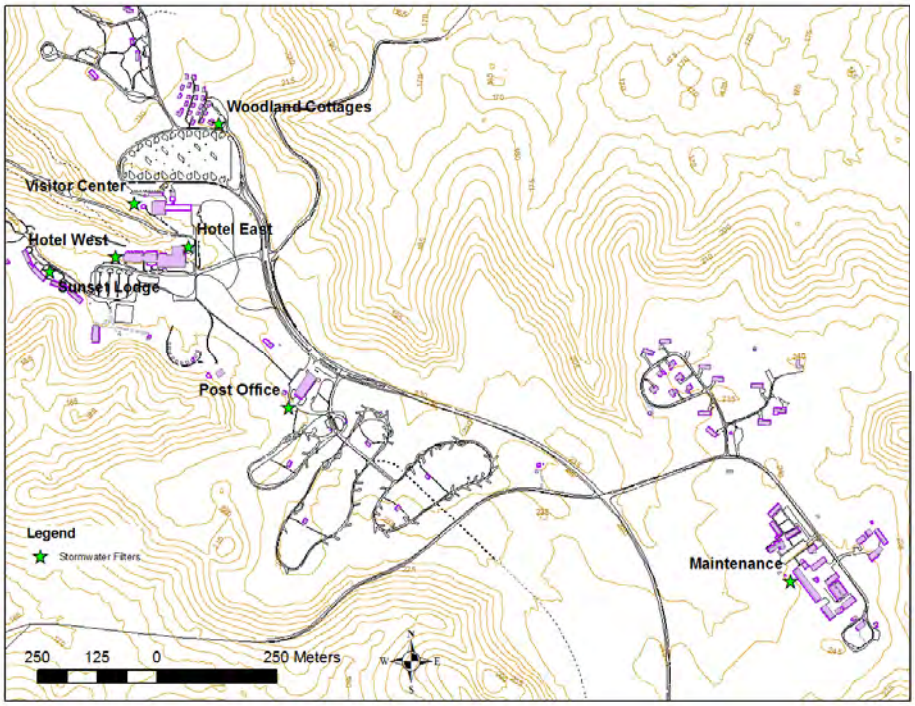
Acknowledgement – the authors thank Tom Byl, USGS, and Shannon Trimboli, MCISCL, for field assistance, guidance and manuscript review

INTRODUCTION

Mammoth Cave in Central Kentucky is the world's largest cave system and has been designated an international biosphere reserve. It has unique organisms that live in the cave system and need clean water, supplied from rain on the surface (Olson, 2008). Barr (1967) reported that potentially toxic levels of metals were entering the cave system. Meimen and others (2005) confirmed that stormwater from parking lots flows directly into the cave system. The Park's management responded to these findings by installing storm runoff filter systems on the large parking lots in 2001 (see map for location of filters studied). The Park entered an agreement (2007-11) with Tennessee State University, the USGS, and WKU-Mammoth Cave International Center for Science and Learning to evaluate the filter systems to determine if they were removing hazardous compounds from stormwater runoff.



Map – Developed area near the Visitor Center at Mammoth Cave National Park. Storm filter system locations are indicated with green stars.

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The parking lot storm filter systems use an oil and grit separator followed by filters filled with cartridges containing zeolite-perlite-activated carbon granules. The filter systems vary in size, depending on the size of the parking lots. The filters are designed to trap suspended particles and dissolved constituents, such as metals and oils, as runoff flows through the filter units. The manufacturer suggests swapping filter cartridges every 2 years. The main pollution concerns at Mammoth Cave are aromatic hydrocarbons leaked from vehicles, quaternary ammonia compounds (QAC) from the White Nose Syndrome disinfection stations, zinc and copper from vehicle brakes. This study aimed to determine how good these filters were at removing these pollutants, especially in the first water to run off the parking lots during a storm, which tends to be more polluted than later flow.

METHODS & MATERIALS

In the first round of sampling, natural and simulated storms were sampled, and the waters were collected via grab sampling. Also, datasondes equipped with continuous specific conductance and turbidity probes were used to optimize the sampling strategy. It became apparent that most of the suspended solids (measured as turbidity) were carried in during the first flush of the storm (Figure 1). Based on this information, passive first-flush samplers were designed, constructed, and installed for the 2011 study.

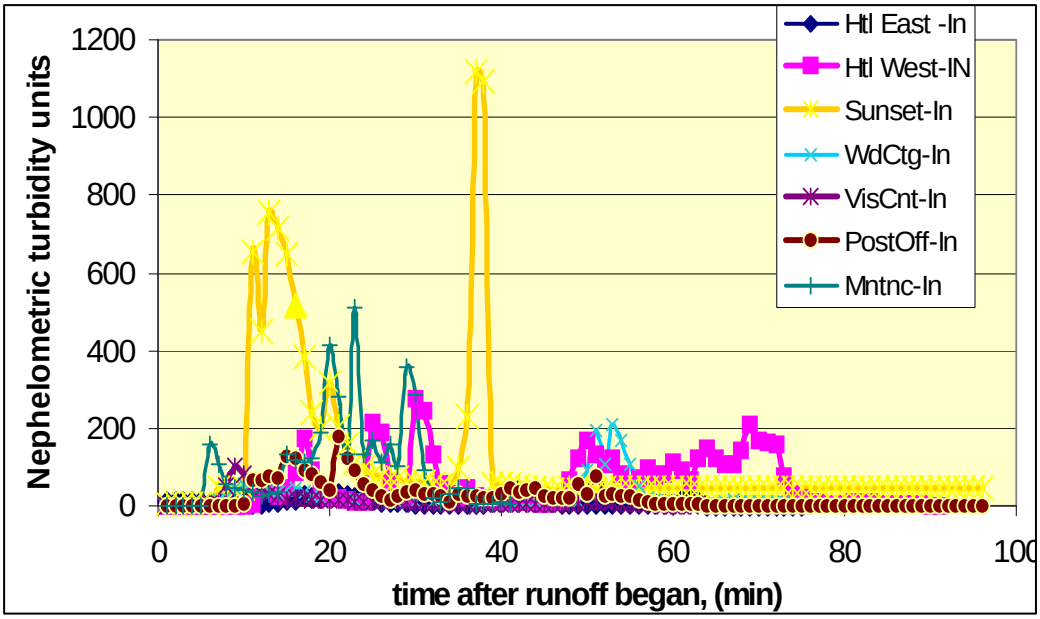


Figure 1. Turbidity of storm runoff from seven parking lots at Mammoth Cave National Park.

The storms were monitored at the inlet to the filters, 2008-2009.

Electronic monitoring devices called datasondes, equipped with specific conductivity and temperature, were placed at various filter inlets and outlets. Some of the datasondes could also measure pH, turbidity, rhodamine WT, dissolved oxygen, and water depth. These data were useful for determining the start and finish time of the storms, as well as, water chemistry. First flush samplers, based on a design by Diehl (2007), were placed near the inlet and outlet of the filter systems (photo 1). During and after rain storms, the samples were retrieved. Additional grab samples were often collected if runoff was still flowing. Samples were stored at 4^{o}C until they could be analyzed for constituents listed in table 1.

Photo 1. Siphon sampler

Analysis included:	Method	Range
Quaternary ammonia compounds	Hach 8337	0.2-5.0 mg/L
chemical oxygen demand	Hach 8000	0-1500 mg/L
Aromatic compounds (diesel range)	Fluorometry	0-10 mg/L
Ammonia (Nessler's)	Hach 8075	0-70 mg/L
Zinc	Hach 8009	0 - 3.00 mg/L
Copper (Porphyrin Method)	Hach 8143	0 - 210.0 ug/L
Nitrate	Hach 8171	0 - 5.0 mg/L
Phosphate (reactive, PO4^3-)	Hach 8048	0 - 2.50 mg/L
Sulfate (modified)	Hach 8051	0 - 70 mg/L
Specific conductance	YSI meters	0 - 1416 uS/cm
Hardness, Calcium (as CaCO3)	Hach titration 8204	10-4000 mg/L

RESULTS & DISCUSSION

The goal was to determine if the filters were effective at removing contaminants that could harm the indigenous organisms in the cave. The storm sampling was designed to collect first flush samples from the parking lots going into the inlet and discharging from the outlet of the filter systems. Three to ten storms were sampled per site. Table 1 lists eleven water-quality constituents that were analyzed, however, this paper focuses on the four most serious contaminants – QAC, aromatic compounds, zinc and copper.

Quaternary Ammonium Compounds (QAC)

QACs are biocides related to Lysol that are intended to kill bacteria, fungi, and other microbes, but they can also be toxic to animals (Tezel, 2009). As shown in Figure 2a, the filters at the Post Office and Woodland Cottages received the most QACs in their runoff. Those filters also provided greater than 50% QAC removal. The other filters received less QAC in their runoff waters, and they provided no significant reduction in QAC. When the efficiency of QAC removal was correlated to parking lot basin size, (Figure 2b) it appears that parking lot size had no connection to QAC-removal efficiency.

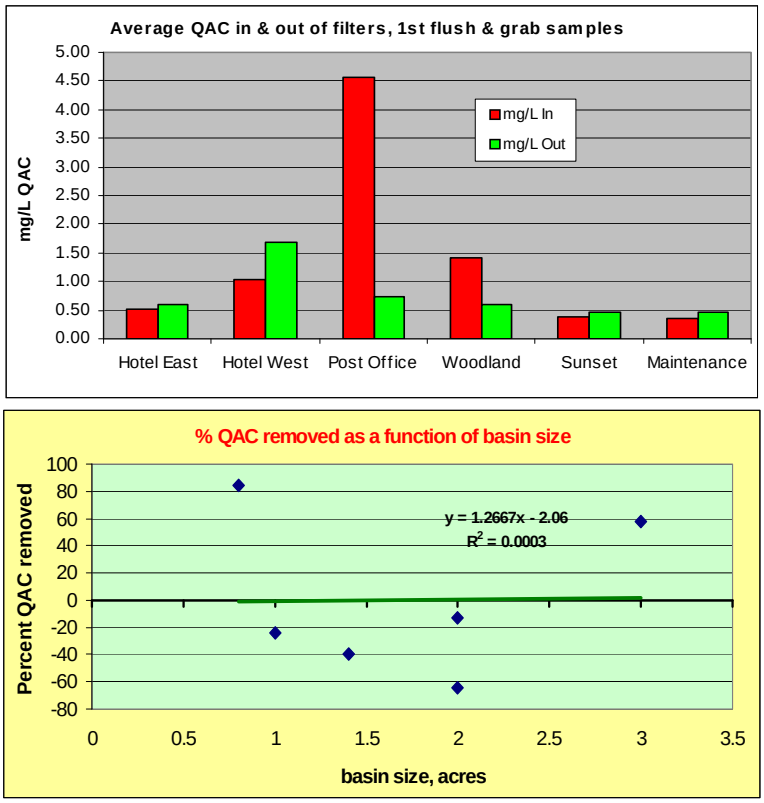
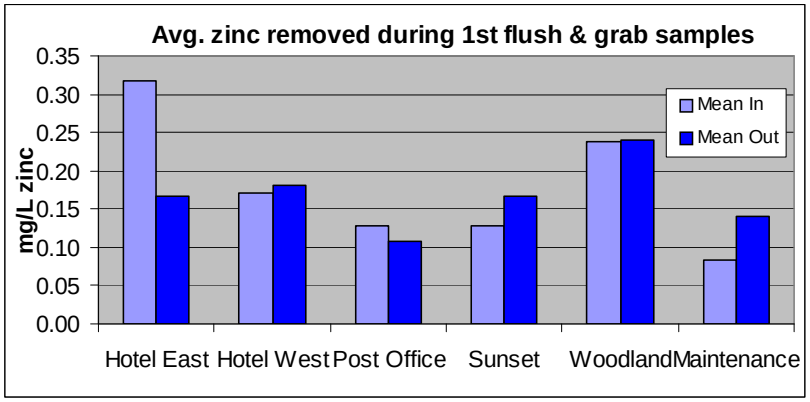


Figure 2a & b. (a, top) Average concentrations of quaternary ammonium compounds at inlet and outflow of stormwater filters and (b, bottom) relation between removal efficiency and basin size.

Zinc - Zinc can leach from galvanized metals, car treatments, vulcanized rubber, and brake pads. Zinc has been shown to be toxic at less than 1 mg/L to aquatic organisms including fish and crustaceans (Lussier, 1985; Wu, 2004). Fortunately, increased hardness reduces the toxicity, and the limestone habitat is able to provide calcium into the water. The 2-year old filters appeared to have little effect on zinc removal, with the exception of Htoel-East filters (Figure 3a). Regression analysis (Figure 3b) found no significant correlation between basin size and filter efficiency.



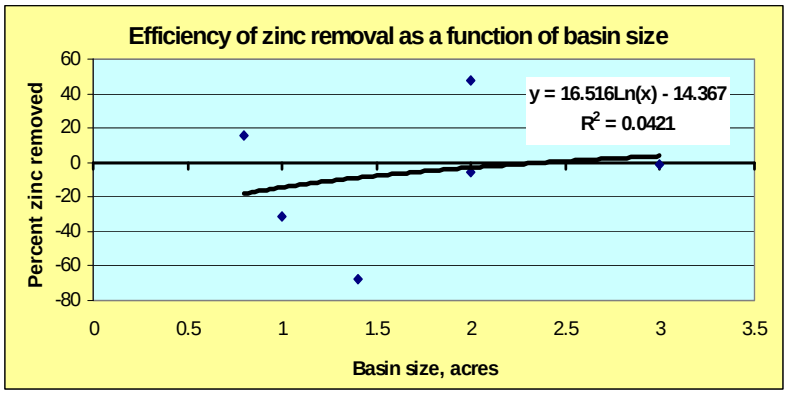


Figure 3a & b. (2a, previous page) Average concentrations of zinc at inlet and outflow of stormwater filters and (b) relation between zinc removal efficiency and basin size.

Copper - Potential copper sources include vehicle brake pads, coins and pipes. Copper was been shown to be toxic to fish, crustaceans, bivalves at concentrations less than 1 ppm (Bhat, et al., 1993; Lussier, 1985). Increased hardness reduces this toxicity. The two hotel filters had the highest concentrations of copper in their first flush runoff, but were ineffective at removing the copper. The other filter systems did a much better job at removing copper from the runoff (Figure 4a). Regression analysis of basin size and filter efficiency (Figure 4b) found filter efficiency decreased with increasing basin size. This may indicate that the filter system is too small for the large parking lots with regards to copper.

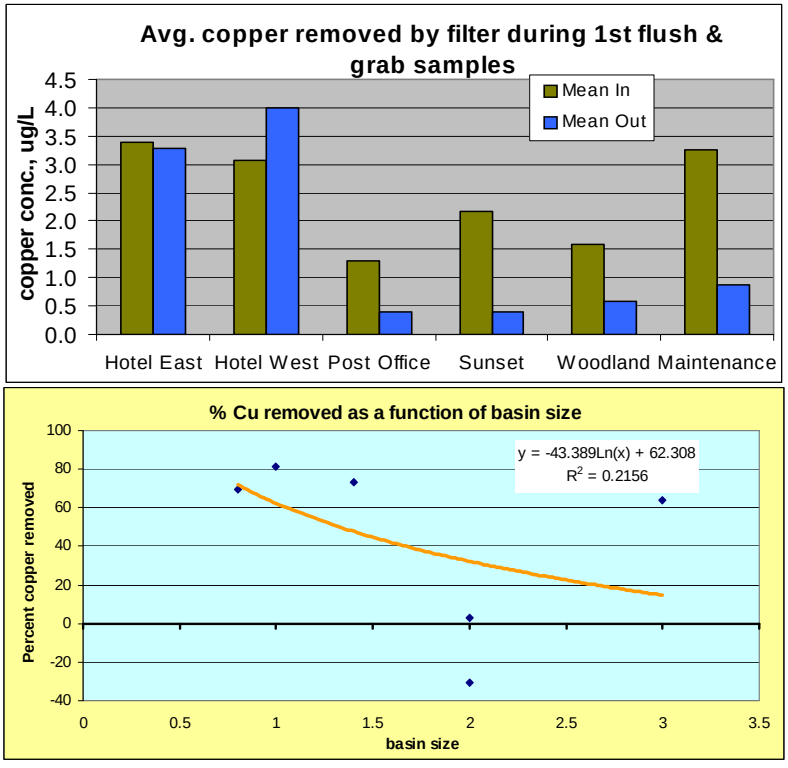


Figure 4a & b. (a, top) Average concentrations of copper at inlet and outflow of stormwater filters and (b, bottom) relation between copper removal efficiency and basin size

Diesel-range Aromatic compounds - Diesel range aromatic compounds are petroleum ring compounds related to benzene that are found in vehicle fuels. They are a class of compounds

that are of concern because they are toxic and dissolve easier than the branched alkane compounds also found in fuels. The filter systems did an excellent job removing these compounds at all the parking lot sites (Figure 5a). Filter efficiency actually improved with increasing basin size (Figure 5b)

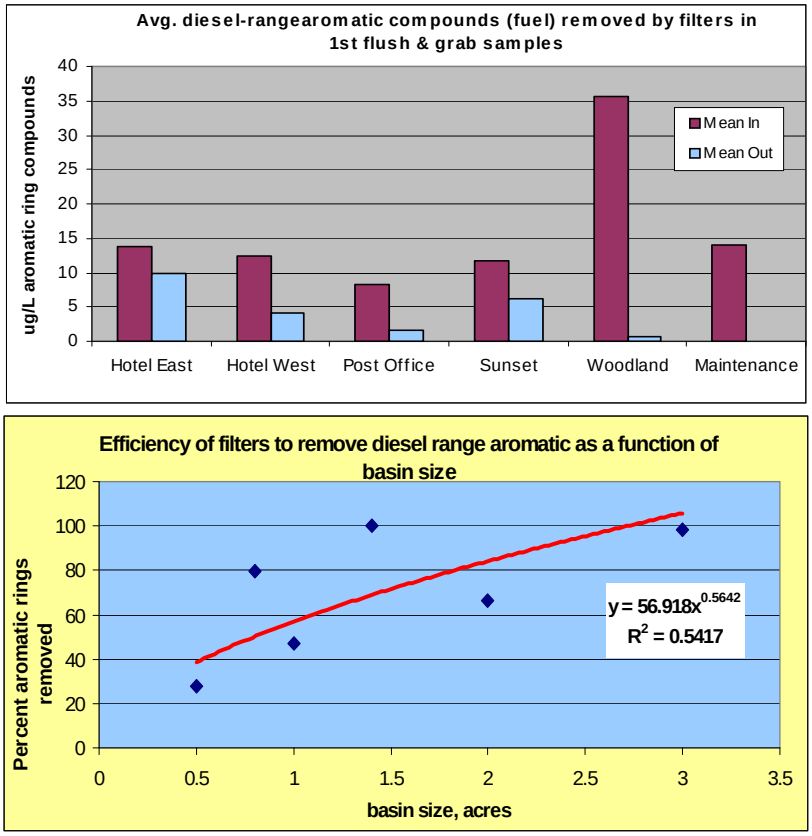


Figure 5a & b: (a, top) Average concentrations of diesel range aromatic compounds at inlet and outflow of stormwater filters and (b, bottom) relation between removal of diesel range aromatic compounds and parking lot basin size.

Sources of contaminant in storm runoff

In order to assist in managing contaminants at Mammoth Cave National Park, we tried to identify the sources of each contaminant. In the case of the high concentrations of quaternary ammonium compounds at the Post Office, a visual examination of the parking lot revealed stains on the pavement similar near the Recreational Vehicle dump station. QACs are used in RV sanitation tanks to prevent bacteria growth and gas build up. Thus, it is reasonable to assume that spills during RV dumping were the source of QACs at the Post Office parking lot. The source of QAC contamination at other sites has yet to be determined. As no obvious source of metal contamination was visible, we examined several possible correlations between copper concentration and physical conditions of each parking lot. The most notable correlation, shown in Figure 6, is a linear regression between copper concentration and car capacity in the drainage basin, supporting the idea that brake dust from vehicles contributes to copper sources.

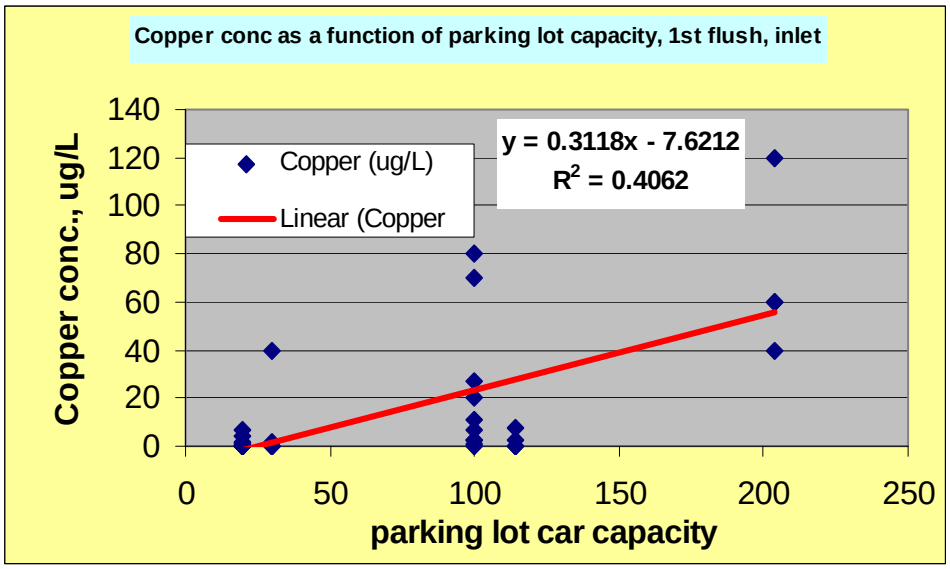


Figure 5. Linear correlation between parking lot capacity and the copper concentrations in the first flush of storm runoff.

Summary and conclusions – Two-year old stormwater filters were evaluated at Mammoth Cave National Park. The study focused on the first runoff waters during the storms. The filters were effective at removing petroleum aromatic ring compounds, but were less effective at removing zinc and copper. Regression analysis shows a decreasing filter efficiency for copper with increasing parking lot size. Also, there was a positive correlation between increasing parking lot size and increasing copper in the runoff. QACs are a new concern because of their use in White Nose Syndrome disinfection stations and in RV sanitation tanks. The filters that received the highest QAC concentrations during storm runoff were effective at reducing the QAC concentrations. Additional work is continuing to determine if new cartridge filters improve the efficacy of the storm water filter systems.

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UNDERSTANDING NATURE OF SATELLITE RAINFALL ERRORS TO ADVANCE WATER RESOURCE MANAGEMENT IN TENNESSEE RIVER BASIN

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ABSTRACT

Operational production of high resolution satellite rainfall products have significant contribution in design, planning, and management of water resource. The global coverage, near-real time availability, spatial and temporal sampling resolutions of precipitation products have advanced the application of physically based semi-distributed and distributed hydrologic models for wide range of environmental decision making processes. Despite this success, the existence of uncertainties inherent in the indirect way of satellite rainfall estimation and hydrologic models pose a challenge in making meaningful and practical predictions. The existence of substantial uncertainty in satellite rainfall increases the complexity of hydrologic modeling and water resources management strategies. This study addresses the characterization of satellite rainfall uncertainty as function of topography, land use land cover (LULC), and climate and evaluates its impact on hydrologic predictability for Tennessee River Basin (TRB). With respect to these geophysical features, the components of total satellite rainfall error (hit, miss-rain, and false-rain biases) are characterized for three satellite rainfall products over the basin (3B42RT, CMORPH, and PERSIANN). The effect of these error components on streamflow simulation is analyzed through Variable Infiltration Capacity (VIC) hydrologic model. Whereas high flow regime (flooding) is highly undermined by miss-rain and negative hit bias, the low flow regime (drought) is significantly affected by the positive hit and false-rain bias. Therefore, these complementary effects of satellite rainfall uncertainty on streamflow simulation need to be understood before using satellite rainfall products for hydrologic model simulation. Detail performance of each satellite rainfall product is analyzed with respect to geographic proximity and season. Ultimately the study conveys helpful information for satellite product users about where, when, and which product to use for streamflow simulation within TRB.

Key words: satellite rainfall, streamflow, topography, LULC, and climate.

METHODOLOGY TO DETERMINE AQUIFER COMPARTMENTALIZATION AND ITS POTENTIAL EFFECTS ON GROUND-WATER FLOW AND QUALITY IN THE DAVIS WELL FIELD, MEMPHIS, TN

Darren Beal, Sarah Girdner, Dr. Ryan Csontos, and Dr. Brian Waldron

The Memphis aquifer in southwest Tennessee is the primary water supply for Shelby County. Historically water quality from this confined aquifer has been excellent, but studies conducted in the Memphis Light, Gas and Water (MLGW) Davis Well field in southwest Shelby County have indicated a progressive decline in quality since the well field was established owing to a localized absence of the confining unit separating the alluvial aquifer from the Memphis aquifer (Parks et al. 1995; Brown 1993). Numerical models used to simulate ground-water flow within the Memphis aquifer have simulated the aquifer as a homogeneous and isotropic sand body (Clark and Hart 2009; Brahana and Broshears 2001; Arthur and Taylor, 1998). However, the aquifer is known to have stratified clay bodies throughout the aquifer (Waldron et al. 2011). Using a powerful oil and gas industry software package called Petrel, geophysical logs obtained for the Davis well field were digitized and the log signals analyzed for the clay and sand components over the depth of the boreholes. In Petrel, a three-dimensional depiction of the well field was created based on 25 geophysical logs with the clay bodies identified and culled out for display. The geologic model clearly identifies numerous clay bodies within the Memphis aquifer with some bodies large enough to compartmentalize the aquifer into subunits. To illustrate the impact of the clay bodies on ground-water flow dynamics and possibly water quality, a conceptual model was developed within MODFLOW using GMS. The results indicate how a substantial clay body isolates ground-water flow to wells screened within the different compartments or subunits, thus providing an impetus for screening production wells deeper within the aquifer to gain improved water quality.

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MODELING NITRATE LEACHING IN THE RICHLAND CREEK WATERSHED

Jiahe Gu[1]*, Ravikanth Konjeti, and Schuyler Sanderson

ABSTRACT

Nitrous oxide is a greenhouse gas that significantly exacerbates global warming. Unlike carbon dioxide, which arises from many natural and anthropogenic sources, excess nitrous oxide is produced almost entirely by artificial processes, especially the widespread use of nitrogen based fertilizers. In 2008, nitrous oxide resulting from agricultural soil management contributed emissions equal to 215.9 $TgCO_2$. Although agricultural nitrous oxide emissions have been evaluated extensively, the levels of emission contributed by private fertilizer usage remain unclear. Here, we present a study of nitrous oxide emissions in the Richland Creek Watershed of Nashville, Tennessee.

Twenty lysimeters were installed at residential sites selected for various levels and methods of fertilizer application. Collected soil water from these instruments was analyzed for pH, electrical conductivity, and nitrate levels over the course of one year.

Results were analyzed in terms of spatial and temporal variability using multiple linear regression modeling based on soil chemical and physical properties, soil water chemistry, and the type and method of fertilizer application. The produced mathematical model predicts levels of nitrate leaching and, when combined with models of other nitrogen sinks, is useful in predicting levels of nitrous oxide emission.

Note: these are high school students at the School for Science and Math at Vanderbilt under the mentorship of Drs. Chris Vanags (Vanderbilt Center for Science Outreach) and Jim Fraser (Vanderbilt Department of Human and Organizational Development)

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REDUCING BIAS IN NUTRIENT LOAD ESTIMATES FOR SMALL STREAMS BY INCORPORATING ANTECEDENT DISCHARGE INFORMATION

Marquan D. Martin[1]

Accurate estimates of nutrient loads in streams are essential to understanding environmental effects associated with population growth, economic development, and land-use change. Such estimates are commonly used to develop nutrient-transport models that can influence numerous water-quality management and policy decisions. Estimates of seasonal and annual loads for streams are typically calculated from regression models based on a combination of daily discharge and periodic nutrient analyses. One commonly used load model developed by the U.S. Geological Survey ("LoadEst") is based on seven explanatory variables that capture attributes of daily discharge, season, and date. Though this model has been shown to produce uniformly distributed residuals in general, load estimates have been shown to be biased by as much as 75 percent for small basins. Review of the estimation bias for small basins suggests that some reduction in bias might be accomplished by including explanatory variables that represent prior flow conditions. The model is currently being adapted to test several variables that describe antecedent discharge. Revised load estimates will be evaluated to determine the effects on bias.

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SWAT MODEL CALIBRATION AND VALIDATION IN THE OOSTANAULA CREEK WATERSHED

Sean Nester, Hawkins, Williams, Layton, and Walker

Common causes of stream impairment in Tennessee are high *E. coli* concentrations, siltation, and high nutrient concentrations. The pollutants causing stream impairment are well established and provided to the public on the Tennessee 303(d) list. Although the 303(d) also lists pollutant sources, the method(s) used to identify pollutant sources are not rigorous and there is not prioritization for the installation of best management practices (BMPs) for streams impacted by non-point sources of pollutants. This presentation illustrates one method to redress these issues in the Oostanaula Creek watershed in East Tennessee using the Soil and Water Assessment Tool, a watershed model. In order to calibrate and validate the SWAT model we deployed an automated refrigerated sampler near the mouth of the stream adjacent to a USGS gauging station. The sampler draws daily composite water samples which are analyzed for phosphorus and nitrogen and sediment loadings. We also collect *E. coli* samples from several difference locations throughout the watershed every two weeks. Daily discharge data and the nutrient and sediment data provided by the sampler over the course of one and a half years were used to calibrate and validate a SWAT model for the Oostanaula Creek watershed. The calibrated model is presented along with preliminary attempts to identify major pollutant sources and prioritize BMP installations to control stream siltation.

SYNTHESIS OF NANO-ZERO VALENT IRON IN SAND MATRIX AND IMPACT ON MICROBIAL COMMUNITY

Victor Roland[1] and Kudjo Dzantor[2]
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ABSTRACT

Zero-valent iron has been used in various groundwater and soil remediation efforts such as arsenic, chlorinated solvent, and heavy metal removal. The objective of this project was to synthesize nano-sized zero valent iron (nZVI) particles in a sandy matrix to dechlorinate the organic solvent carbon tetrachloride (CCl_4) in the pore waters. The second objective of this experiment was to determine the affect of the synthesis reaction on microbial activity and diversity. Lab experiments were conducted on contaminated groundwater samples taken near an unlined landfill used to dispose of CCl_4, other organic solvents, and pesticides. Carbon tetrachloride concentrations in the groundwater ranged from 10-22 mg/L. Batch reactors were used to conduct kinetics studies to compare the CCl_4-dechlorination efficiency of pre-synthesized nZVI and in-situ synthesized nZVI scenarios. The batch reactors were sampled at increasing time intervals after the introduction of the chemicals or nZVI to asses the viability, diversity, and presence of iron-related, sulfur reducing, nitrifying, and pseudomonad bacteria. The in-situ synthesis of nZVI was succesful and effective in dechorinating CCl_4, with little ill effect on the microbial community. First-order reaction kinetics best fit most trials using the in-situ reaction approach. Adjusting the pH had little effect on the rate of nZVI induced dechlorination. The addition of sand into the batch reactors produced more complex reactions than in reactors without sand; therefore reaction rates were slower when sand was present. Post-reaction samples tested positive for iron-related bacteria, sulfate-reducing bacteria, Pseudomonad-slime producing bacteria, but negative for nitrifying bacteria. More investigation is needed to optimize this CCl_4 remediation method. Many questions remain about the fate of these nZVI particles and their transport in porous media such as sand. Column studies and additional kinetics studies will be used to address these questions. Long-term, field studies will be needed to optimize this method for site specific application.

INTRODUCTION

Zero-Valent Iron (ZVI) has been used in various environmental remediation scenarios ranging from remediation of heavy metals and inorganic salts to PCBs (1, 2, 3). Commonly used at a microscopic scale (mZVI), ZVI has been used in the construction of reactive barriers and as a slurry that may be injected into groundwater wells. The contaminated groundwater plume reacts with the zero-valent iron as it moves through the injection zone. This technology has evolved with the growing demand for greater removal efficiency and now includes nano-scale zero-valent iron materials (nZVI). The nZVI is more reactive than mZVI because it has a higher surface area

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per volume. nZVI can also be carried further into a porous media because of its small size. The main objective of this study focuses on the use of nZVI to remediate carbon tetrachloride (CT) contaminated groundwater. This study compares the removal efficacy of pre-synthesized nZVI versus nZVI particles synthesized in-situ using sodium borohydride ($NaBH_4$) reduction of ferrous and ferric iron. The $NaBH_4$ reduction occurs with dissolved ferrous (II) iron and precipitated ferric (III) iron, reducing them to an elemental iron species, Fe^0 (4). The current use of nZVI to dechlorinate CT requires that the nZVI be synthesized in a lab, kept in air-tight containers to prevent oxidation of the nZVI, transported to the site as a hazardous material, and pumped into the aquifer under elaborate safety conditions. The method we propose is to synthesize the nZVI in the aquifer and avoid the dangerous synthesis and costly transportation steps. These two approaches were evaluated based on their ability to dechlorinate CT through a process known as reductive dechlorination. Carbon tetrachloride (CCl_4) is a halogenated aliphatic hydrocarbon and may be dechlorinated through a series of reductive dechlorination reactions into harmless CH_4 and Cl^- (5). The first nZVI reaction converts CT to chloroform and several other degradation by-products in the presence of water (6). Subsequent reactions convert the chloroform to methane. The interest in this series of reactions is based on CT being used as a solvent for many years and then improperly disposed (7). Carbon tetrachloride is categorized as a persistent organic pollutant (POP) because it is so stable in the environment. It is also on the U.S. EPA's list of priority pollutants because it is widespread and is believed to cause cancer and birth defects in humans. Carbon tetrachloride has a low sorption capacity and migrates easily through areas of high hydraulic conductivity such as course sands and gravels (8). This property increases exposure risk by enabling contamination plumes to span vast areas.

The secondary objective of this study was to assess the impact of the proposed sodium borohydride induced nZVI synthesis method on indigenous microbial communities in the sands collected from the contaminated site. This is important because the final steps in attenuating the by-products of the nZVI reaction is largely done by anaerobic iron and sulfur-related bacteria. The CCl_4 reduction pathway is as follows; CCl_4 is degraded to chloroform ($CCl_4 + Fe^0 + H_2O \Leftrightarrow Fe^{2+} + CCl_3H + OH^- + Cl^-$), $CHCl_3$ is reduced to methylene chloride, CH_2Cl_2. The reduction by-products are present when dechlorination occurs; therefore it is necessary to maintain microbial communities for the long-term health of the ecosystem and final attenuation of the remaining contaminant residue (9).

APPROACH

This study used soil and CT-contaminated water collected from an unlined landfill were 100,00 to 300,000 barrels of industrial waste CT was buried in the late 1960 – early 1970's. CT contaminant plumes now extend for 1 to 2 miles from the landfill. The groundwater at the site flows through a sandy aquifer with alluvial clay lenses dispersed through out the shallow aquifer. The contamination plume has expanded to cover an area of approximately 3 mi^2, and concentrations range from 1 ug/L to 30 mg/L. Water samples and sediment samples were collected from the site for laboratory experiments. Initial batch experiments were conducted to observe trends between pH and nZVI slurry concentrations and reduction rates. A second set of batch experiments were conducted to assess the effectiveness of injecting varying concentrations of sodium borohydride into iron (II)-rich CT contaminated water in the presence of sand collected at the site. Background ferrous iron levels at the site ranged from 0.2 mg/L, Fe^{2+} to 66

mg/L, Fe^{2+}. Three concentrations of sodium borohydride were reacted with two concentrations of ferrous iron in the contaminated groundwater to determine if there were any correlations between ferrous iron concentration and sodium borohydride concentration; and if so, which conditions showed the greatest reduction rate.

Sand samples were taken at the completion of the borohydride reduction from the reaction chamber to analyze the diversity and viability of the microbial community. Biological Activity Reaction Test or (BART) provides identification of viable microbial communities, and based on lag time after inoculation they may provide a most probable number for microbial population data. Specifically, BART tests were conducted for pseudomonad slime-producing bacteria (SLYM), iron-related bacteria (IRB), and sulfur-reducing bacteria (SRB). The anaerobic IRB and SRB are key microbes because they are the largest contributors to the biological reductive dechlorination process. They also metabolize H_2, a major by-product of the nZVI reaction with water, and also formed during the synthesis process.

RESULTS AND DISCUSSION

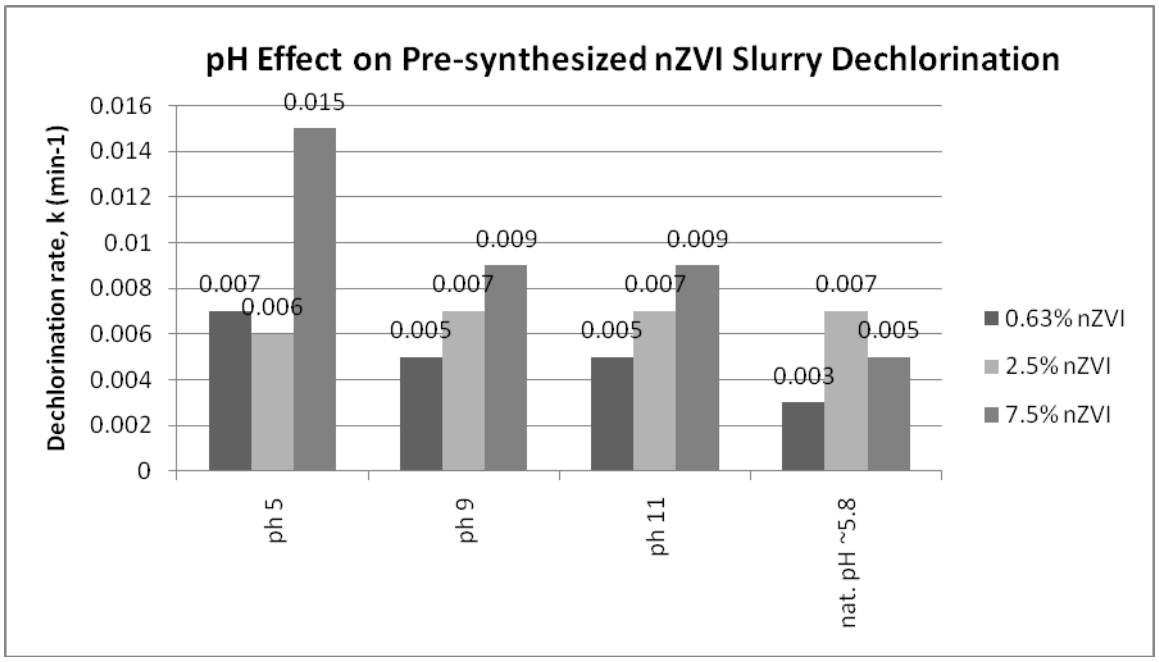

Figure 1: nZVI slurry batch experiment assessing effects of pH and nZVI concentration on dechlorination rate. Dechlorination rates were negatively affected by increases in pH.

Injecting pre-synthesized nZVI and synthesizing the nZVI in the sand were both effective methods for dechlorinating CT. The first study looked at the effect of pH on the reductive dechlorination rate since this was shown to have an effect in another study that looked at dechlorination of trichloroethylene. Under moderately acidic conditions, similar to the naturally occurring pH 5.8 at the site, reduction rates were similar despite increasing the concentration of nZVI ten fold (Figure 1).

The second experiment synthesized the nZVI in-situ using sodium borohydrate solution injections into the sand-water microcosms. This experiment was designed to determine optimum levels of ferrous iron and sodium borohydride to synthesize nZVI and achieve CT dechlorination. This would help determine if the reductive dechlorination reaction was mediated by the sodium borohydrate directly or if it was mediated by ferrous iron. It was noted in the first experiment, that if we increased the amount of pre-synthesized nZVI, we achieved a higher reduction rate (Figure 1). In experiment 2, when the $NaBH_4$ was increased, there was usually an increase in reduction rate (Figure 2). However, we found that doubling the dissolved iron concentration in the pore water prior to injecting the $NaBH_4$ more than doubled the rate of dechlorination. Those results suggest that, while the $NaBH_4$ may provide the reducing force (i.e., electron donor molecule), the nZVI is needed to transfer the electron to the CT and catalyze the reductive dechlorination reaction.

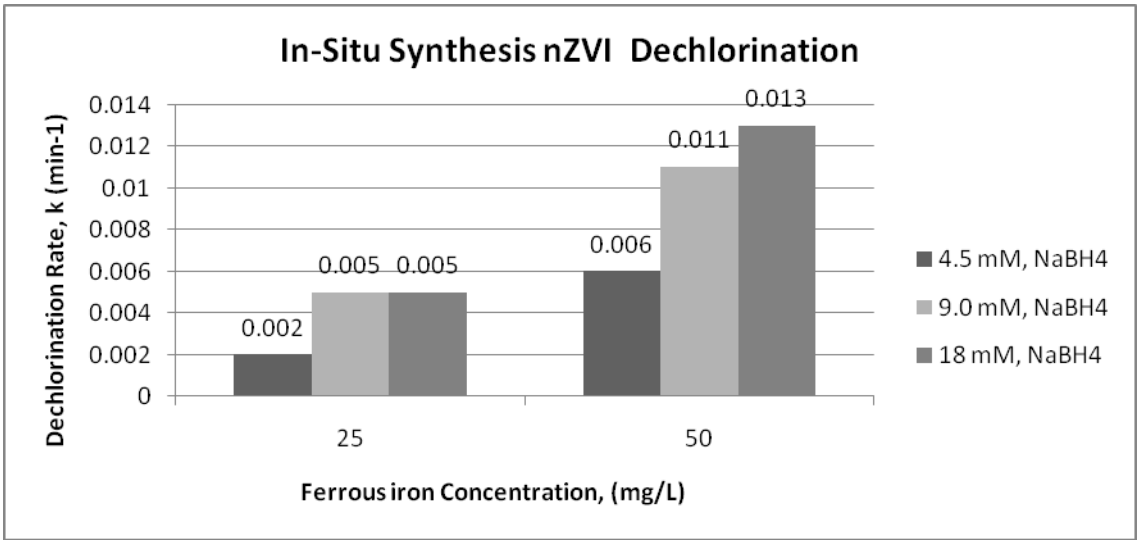

Figure 2: In-situ synthesis using $NaBH_4$ injection to convert Fe^{2+} into nZVI showed dechlorination rates more than doubled with increasing Fe^{2+} concentration.

The BART microbial tests are useful at determining if bacteria types are present and estimating their population based on growth responses. The aquifer soils used in this study were collected from the site. They were subjected to various treatments as discussed above. In the studies, we always had control microcosms where no treatment was added (no $NaBH_4$, Fe^{2+} or nZVI) to the soils. These no-treatment microcosms served as a reference for natural bacteria populations to be compared with the soils treated with $NaBH_4$, Fe^{2+}, or nZVI (Figures 3, 4, 5). In microcosms where $NaBH_4$ and Fe^{2+} were injected to synthesize nZVI in-situ, the reaction did not appear to adversely affect the microbial community in the sands as compared to the non-treated soils. The viable slime-producing bacteria remained consistent before and after the reaction as seen in Figure 3. Figure 5 shows a decrease in IRB possibly due to the conversion of Fe^{2+}, to Fe^0. The iron-related bacteria population slowly recovered as nZVI particles were oxidized (possibly by iron-oxidizing bacteria). Sulfur-reducing bacteria populations were stimulated by the addition of $NaBH_4$ and nZVI. It is known that sulfur-reducing bacteria like H_2 as an energy source. This is a by-product of $NaBH_4$ and nZVI reacting with water. Thus, we hypothesize that the hydrogen produced actually stimulated the sulfur-reducing bacteria until the H_2 was depleted.

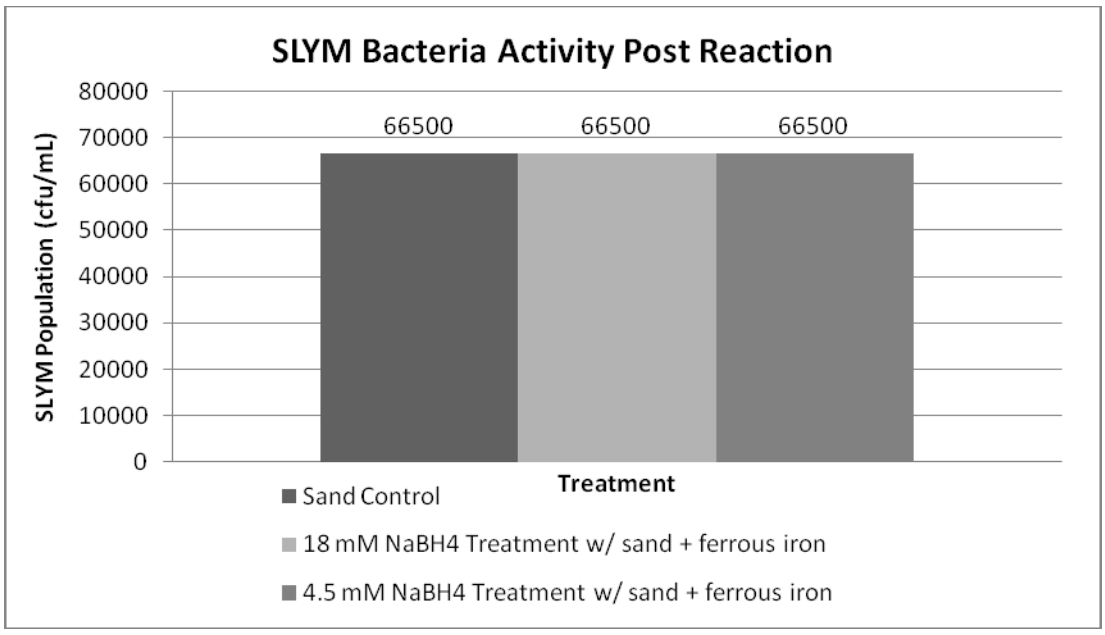

Figure 3: The slime-producing Pseudomonad bacteria were present before and after the injection, a good indicator that the nZVI synthesis reaction did not sterilize the soils.

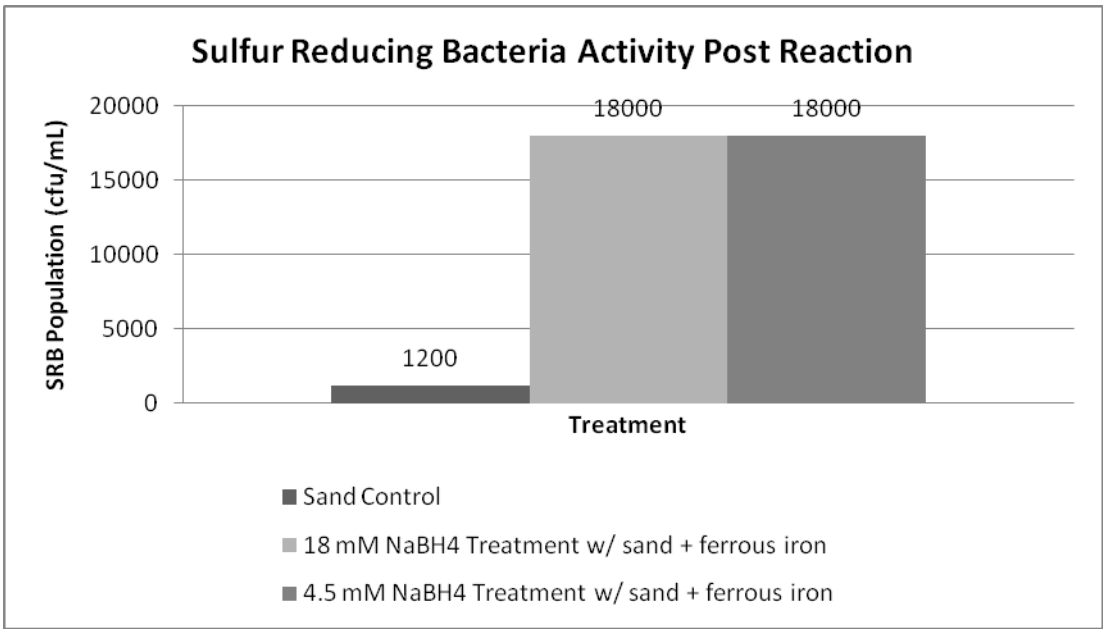

Figure 4: The sulfur-reducing bacteria population was small in the control soils, but increased after $NaBH_4$ was injected and nZVI + H_2 was synthesized.

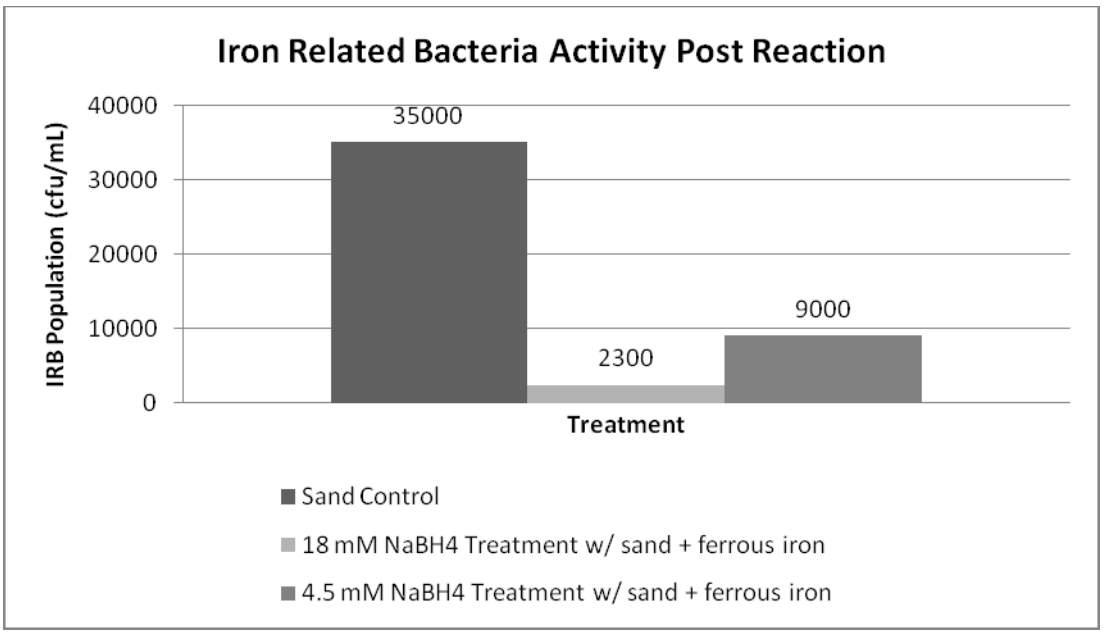

Figure 5: Iron-related bacteria were present before the reaction, but displayed a decrease in population size after the nZVI synthesis reaction. It is possible they were sensitive to changes in iron chemistry or some other by-product during the nZVI-synthesis reaction.

The study provided valuable information about factors that effect nZVI-induced dechlorination of CT. First, this study proves that nZVI can be synthesized in-situ, avoiding many of the pitfalls associated with synthesizing them in a reactor and transporting them to a site for injection. The pH plays a small role in the efficiency of the nZVI-synthesis reaction. Second, the study also shows that increasing the ferrous iron in the porewater increases efficiency of the reductive dechlorination reaction. Third, several important bacteria species, including Pseudomonads and sulfur-reducing bacteria, were not adversely effected by the in-situ treatment of $NaBH_4$ and nZVI. Future studies should determine the optimum conditions by which in-situ synthesis of nZVI could become a viable remediation technique.

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HYDROLOGIC, SEDIMENT, AND WATER QUALITY IMPACTS OF GROWING SWITCHGRASS IN TENNESSEE

Zachariah Seiden[1] and John Schwarts[1]

Renewable energy has become popularly discussed as of late. One major source for renewable energy is that of cellulosic ethanol. While considerable attention has been paid to the ethanol extraction process, there has been less research on the environmental impacts of these ethanol source crops. Due to the chemical nature of switchgrass, coupled with its biological tendencies, this crop is being greatly considered as a bio-ethanol source. Despite this, there is a need to evaluate the environmental impacts of growing switchgrass as opposed to other fuel crops. The purpose of this research is designed to evaluate how switchgrass affects the total suspended solid (TSS), total phosphorus (TP), and total nitrogen (TN) contents of groundwater runoff. Along with this, runoff flow rates, precipitation levels, and GIS data will be used to evaluate the hydrologic curve number (CN), soil erodibility factor (K), erosivity factor (R), crop-management factor (C), and the slope-length steepness factor (LS). This data will then be used to calibrate the Soil Water Assessment Tool (SWAT) model, which is used for runoff-based transport of nutrients (phosphorus and nitrogen) along with other agricultural chemicals. This will all be accomplished by sampling from eight different sites in Vonore, Tennessee. Four of these sites will measure runoff from plots of switchgrass, while the other four will measure the runoff from non-switchgrass plots. Along with this, two sites will be established to measure affects on the larger watershed scale. Site development and monitoring will continue through 2016. This presentation reports the status of the project and preliminary findings.

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CONTINUOUS MONITORING OF HORMONALLY ACTIVE COMPOUNDS IN EFFLUENTS FROM HALLSDALE-POWELL WASTEWATER TREATMENT FACILITY AT KNOXVILLE, TN – APPLICATION OF STANDARDIZED BIOLUMINESCENT YEAST-BASED HIGH THROUGHPUT BIOASSAY

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Endocrine disruptive chemicals (EDCs) have drawn great public concern due to their harmful health impact on both human beings and animals. Wastewater treatment process is the major barrier in preventing EDCs' release into aquatic environment. However, there is no established standard method for evaluating the performance of wastewater treatment in EDCs' removal. Traditional wastewater treatment uses concentrated microorganisms (activated sludge) for organic compounds removal and secondary clarification for water-solid separation. While an emerging technology called membrane bioreactor (MBR) uses filter for water-solid separation, allowing higher density of biomass and greater loading capacity. Hallsdale-Powell Utility District (HPUD) at Knoxville, TN recently adopted the state-of-the-art MBR, running paralleled with its traditional activated sludge process. This setup provides great opportunity for comparing the performance of MBR and conventional activated sludge in EDCs removal. In this study, we performed a six months continuous monitoring on the effluent from HPUD using high throughput yeast bioluminescent assay. Effluent from both traditional activated sludge and MBR in HPUD were sampled each week and extracted using established solid phase extraction method. Extraction extraction efficiency was evaluated using GC-MS. Standardized bioluminescent yeast-based bioassay was used to evaluate the estrogenic/androgenic equivalency of each sample. Our results showed that androgenic compounds are attenuated in HPUD to below-detection-limit level. Estrogenic compounds can be detected in effluents from both MBR and traditional activated sludge. Membrane bioreactor produced effluent with on average ~10 fold less estrogenic equivalency than that of the traditional activated sludge.

FATE OF CHEMICALS CARRIED FROM THE SURFACE INTO A CAVE

Ashley West[1], Rick Toomey[2], Tyesha Martin[1], Sean McMillian[1],
David Solomon[1], and Tom Byl[3,1]

ABSTRACT

Mammoth Cave, in south-central Kentucky, is the world's largest known cave system and is host to many unique and threatened species including the Kentucky Cave Shrimp. The National Park Service (NPS) operates Mammoth Cave National Park to encourage tourists while still protecting the unique and fragile ecosystem in the cave. The Park has identified parking-lots as potential sources of contaminants into the cave and have addressed this problem with storm-water filters. Currently, the NPS is considering the application of road deicers on primary roads through the Park. However, the NPS lacks some essential quantitative information with regards to contaminant transport from land surface into the cave ecosystem. The objective of this investigation was to characterize storm flow from potential source areas on the surface into the cave.

The preliminary results were achieved by monitoring water chemistry and bacteria near source areas, along the surface flowpaths, and along known flowpaths in the cave. A quantitative tracer study found it took one hour for dye to move from land surface, along the main flowpath, and into the cave. Constituents, such as quaternary ammonia compounds (QACs), chemical oxygen demand, ammonia, and diesel range aromatic ring compounds, decreased exponentially along the flowpath, to below detection levels in the cave. Zinc, copper, and nitrate decreased along the surface, but then held steady at low concentrations in the cave flowpath. Phosphate and sulfate decreased along the surface flowpath, but increased slightly in the cave. This is reasonable considering there are natural sources of sulfate and phosphate in the limestone at Mammoth Cave National Park. Bacteria were cultured and evaluated for resistance to the microbicides called quaternary ammonia compounds. Soil-water bacteria collected near the White Nose Disinfection Stations and RV Dump Station had a much greater resistance to QACs than bacteria collected in pristine areas, indicating they are devloping antibiotic resistance. Specific conductance in flowing cave waters ranged from 200-250 uS/cm. Storms had a temporary dilution effect on specific conductance in those same cave waters. An extreme storm that showered 2 inches in 24 hours caused the conductivity to drop to 40 uS/cm. A pool perched in Gratz Avenue (in the cave) had a stable specific conductance of 315-335 uS/cm regardless of storms. These preliminary results help us to understand the current conditions in the cave prior to road salt treatment and how various chemical concentrations adjust along the flowpath into the cave.

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IMPACT OF ARTIFICIAL RESERVOIR SIZE AND LAND USE LAND COVER ON PROBABLE MAXIMUM FLOOD

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The design of the dams usually considers available historical data for analysis of the flood frequency. The limitation of this approach is the stationarity assumption in flood frequency behavior, and thus, potential shifts in flood frequency due to physically plausible factors cannot be considered during design or operations. For example, future flood extremes that may change due to strong local atmospheric feedback from the reservoir and surrounding land use and land cover (LULC) are not considered in conventional dam design approach. A recent study using a regional atmospheric model has shown that LULC change can physically impact the probable maximum precipitation (PMP). Probable Maximum Flood (PMF), which is the key design parameter for hydraulic features of a dam, is estimated from PMP and the hydrology of the basin. Given the non-linearity of the rainfall-runoff process, a key question that needs to be answered is "*How do reservoir size and/or LULC modify extreme flood patterns, specifically probable maximum flood?*" This study applied the distributed Variable Infiltration Capacity (VIC) model to simulate the PMF from the atmospheric feedbacks simulated for various reservoir sizes and LULC conditions (*Pre-dam*, *Current Scenario, Reservoir-double*, and *Non-irrigation*). The atmospheric feedbacks were simulated as PMP using the model Regional Atmospheric Modeling System (RAMS). The RAMS-generated PMP scenarios were propagated through the VIC model to simulate the PMFs prior to downstream routing through a dam's spillway. Comparison of PMF results for *Pre-dam* and *Current Scenario* conditions for the specific dam showed that PMF peak flow can decrease. On the other hand, the reservoir size had virtually no detectable impact on PMF results. The study also overcame several logistic and conceptual hurdles to generating the basin's natural response to PMF given the extensive nature of upstream impoundment on various tributaries in ARW. The premise that modern dam design and operations should consider future extreme precipitation variation due to the reservoir and LULC change is well supported by our study.

Keywords: dams, probable maximum precipitation (PMP), probable maximum flood (PMF), land use, land cover

ADAPTATION OF A GOOGLE-EARTH BASED EDUCATION TOOL FOR PLACE-BASED LEARNING OF HYDROLOGIC CONCEPTS USING A CAMPUS WATERSHED AND WI-FI CONNECTIVITY AT TENNESSEE TECHNOLOGICAL UNIVERSITY

W.Y. Yigzaw[1], F. Hossain[1], and E. Habib[2]

It is important that students perfectly visualize the subject matter they are learning in class. For some engineering subjects, for example, Engineering Hydrology, creating a real-world understanding can be challenging. Hydrology often involves a larger-than-classroom watershed involving topics such as rainfall-runoff transformation, land use/land cover, terrain features and complex instrumentation that are difficult to be replicated in a smaller laboratory. The conventional approach to incorporating "hands-on" learning concepts for such a course has therefore been to organize field trips at faraway places which are time consuming. Adaptation of a Google Earth-based Hydrology education tool for place-based and hands-on learning on hydrology concepts using a campus watershed can bridge the gap between field trips and classroom instruction. A tool, called HydroVIZ, first developed by researchers at the University of Louisiana at Lafayette, is a Google Earth-based tool, which allows student-driven active learning of hydrology concepts on site. By leveraging a campus watershed located very close to the classroom at Tennessee Technological University (TTU), HydroViz adaptation allowed for a hands-on and place-based learning experience for students without the need for time-consuming field trips. By using Wi-Fi internet connectivity, students applied the adapted tool while located inside the campus watershed to pose key hydrology questions and seek answers in a hands-on manner that would otherwise not be possible in the classroom. In essence, the adapted tool was successful in fulfilling the notion that – *when you cannot bring the watershed to the classroom, bring the classroom to the watershed.*

Keywords: Hydrology, Google Earth, Place-based Learning, Wi-Fi, Hands-on Learning.

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SPECIAL SESSION: PRESENTATIONS FROM CHINA

Qiang He
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University of Tennessee

Study on Development and Utilization of Water Resource in Northwest of China
Huang Qiang, Bai Tao, Bai Xia, and Chang Jianxia

Experimental Study on Gas-Liquid Two-Phase Flows in a Cylindrical Aeration Tank by PTV Method
Wang Meng and Cheng Wen

Monitoring and Characteristic Analysis of Snowstorm Runoff Pollution in Xi'an City
Li Huai-en, Qin Yao-min, and Du Guang-fei

Sediment Transport Characteristics Under Low Temperature Flow and Its Consequences in Inner Mongolian Reach
Qin Yi, Li Ziwen, Wan Jun, and Cao Ru-xuan

Establishing and Application on Single Parameter Model of Soil Water Diffusivity in Nanxiaohegou Basin
Xiaoyu Song and Huaiyou Li

Optimization of Water Resources Utilization by PSO-GA
Chang Jian-xia

Changes Induced by Soil and Water Conservation in Runoff and Sediment Yield in Typical Watersheds on the Loess Plateau
Li Peng, Zhangxiang, and Li Zhanbin

Parameter Calibration of the Xinanjiang Rainfall-Runoff Model Using Differential Evolution Algorithm
Jungang Luo and Jiancang Xie

Characteristic of Runoff and Nutrient Transport on Slope Land in Northern Shaanxi
Wenjuan Shi, Quanjiu Wang, Juan Wang, Peng Bai, and Xiaoyu Song

Eco-Environmental Risks Identification on the Cascade Development in the Upper Reaches of the Yellow River
De-Xiu Hu

Research on Dynamic Ecological Requirements and Its Application to the Main Reach of the Weihe River
Ni Wang, Jiancang Xie, Jungang Luo, and Jiwei Zhu

Modeling Chloride Transport in an Aggregated Soils with Three Models
Zhou Beibei, Li Yun, Wang Quanjiu, Jiang Yanli, and Shao Ming'an

Development and Application of X-WSR-Z System Methodology in Water Resources Management
Jiwei Zhu, Jiancang Xie, and Ni Wang

Interval Two-Stage Stochastic Integer Programming for Urban Water Resources Management Under Uncertainties
ShuHong Mo, HaiNi Duan, and Bing Shen

Study on Comprehensive Development Model and Effects of Regional Water and Land Resources in Urbanization
Zhu Jiwei, Xie Jiancang, Zhao Yuewang, Wang Ni, and Huang Yinbing

STUDY ON DEVELOPMENT AND UTILIZATION OF WATER RESOURCE IN NORTHWEST OF CHINA

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ABSTRACT

Including Xinjiang, Gansu, Ningxia, Qinghai and Shaanxi five provinces, Northwest area is 3.093 million km^2, account for 32.2% of China, and the population is 96.6 million which is 7.21% of total population. China is being on Western Development and northwest area is one of the key development areas. Although extensive in territory and abundant in light, heat, mineral and other resources, northwest area of China belongs to arid and semi-arid region. As China's energy base and exporting land, due to its special geographical location and climate features, some problems have arisen in this area, such as less rainfall, mal-distributed water resource in space and time and severe water shortages. On the base of introducing the distribution and characteristics of water resource, this paper analyzed the status of water resource development and its problems. Meanwhile, it showcased the distinctive hydraulic engineering in northwest and introduced the breakthrough and development in the process of development and utilization of water resource in northwest of China. At last, according to problems of water resource in northwest of China, the paper put forward suggestions and solutions, which will provide reference for a sustainable utilization of water resource in northwest of china.

Key words：water resource; development and utilization; northwest area

西北地区水资源开发利用研究

摘要：中国西北地区包括新疆、甘肃、宁夏、青海和陕西5个省区，面积309.3万km^2,占中国国土面积的32.2%，人口 0.966
亿，占全国总人口的7.21%。中国正在进行西部大开发，其中，西北地区是重点开发区域之一。中国西北地区属于干旱、半干旱地区，土地辽阔，光、热、矿等资源丰富，是中国的能源基地和输出地，其特殊的地理位置和气候导致了降雨少、水资源时空分布极不均匀，水资源严重短缺。本文在介绍西北地区水资源分布及其特点的基础上，分析了西北地区水资源开发利用现状及其存在的问题，列举了西北地区具有代表性的特色水利工程，介绍了西北地区水资源在开发利用过程中的突破和发展。针对西北地区水资源存在的问题提出了相应对策和建议，旨在为西北地区水资源可持续利用提供参考。
关键词： 水资源；开发利用；西北地区

EXPERIMENTAL STUDY ON GAS-LIQUID TWO-PHASE FLOWS IN A CYLINDRICAL AERATION TANK BY PTV METHOD

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Aeration is a very important step in the production chain of aerobic bacteria biochemical wasted water treatment, can ensure the supply of dissolved oxygen needed by the biochemical action during treatment, and simultaneity enhance the circulation of liquid in the tank. Aeration processing is a complex two-phase flow that likes the bubble plume, which is various and random in forms able to make a great important impact on the fluid structure and movement behavior. The research on the image measurement of bubble plume velocity field distribution gives a great help on the aeration efficiency improvement. Wasted water treatment is one of the high energy-consuming industries, enhance the aeration efficiency is effective to improve the efficiency of wasted water treatment, and reduce the operation costs. Consequently, this study will provide essential theoretic meaning as well as application value to the aeration and wastewater treatment.

In this study, the experiments operate in a cylindrical tank that has 250 mm in diameter and 700 mm in height. In the study of Cheng, et al [1] using a thin rectangular aeration tank to obtain the bubble plume behavior, only 40 mm in horizontal depth. Therefore, the results are difficult to describe or portray realistically fluid structure and movement behavior in the real aeration step, but in this study we improved this. In order to study the velocity distribution of bubble plume, 36 test cases of experiments have been performed, which consists of changes three impact factors of aeration rate, aeration header distribution and aspect ratio of the container. A CCD camera was used to record the bubble plume behavior with the speed 500 frame/s. This study aims to get the velocity distribution of bubble plume via PTV methods in laboratory experiments. To ensure the accuracy of the treatment, firstly treat the original image with band pass to filter noise. After pre-processing is imposed on the visualized images of bubble plume

with image binary [2], the position of the bubble is figured out by Particle Masked Correlation according to cross correlation efficiency as well as the velocity vector field is obtained by Triple Pattern Matching, a kind of PTV method, and remove the pseudo vector.

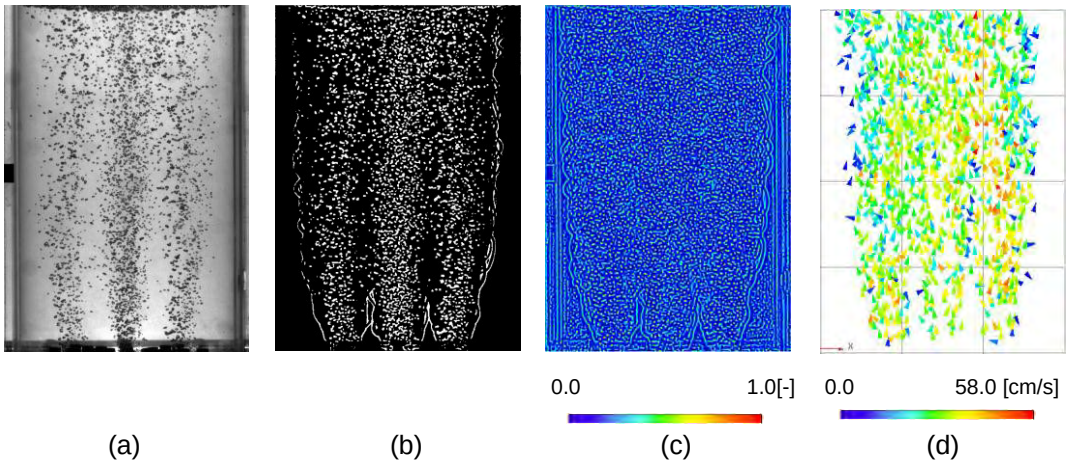

Figure.1 (a) original image (b) binary image (c) cross correlation efficiency (d) time-dependent bubble velocity in the aspect ratio of 1.5,75 L/h

Through the calculation and analysis, our conclusions are obtained as below. When in aspect ratio of 1.0, the time-serial of bubble plume is evenly distributed in both sides of the bubble plume. The bubble plume rises along the centerline in the aspect ratio of 1.0. When in aspect ratio of 1.5, the time-serial of bubble plume is also evenly distributed. When in aspect ratio of 2.0, the movement of bubble plume is bent and snake-like, the top of the bubbles are easy to overflow the device, which makes an impact on the motion of bubble plume. And we managed to obtain the optimum aeration header distribution, which give an equal liquid circulation to the flow distribution; the gas velocity is about 29 cm/s.

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圆柱形曝气容器中气泡羽流速度场的PTV分析与研究

曝气是污水好氧生化处理系统中的一个重要工艺环节，指将空气中的氧强制向液体中转移的过程，可以保证微生物生化作用所需的溶解氧，同时曝气还可以提高池内水流湍动程度，提高氧传质效果。曝气过程属于气泡羽流流动，其多样且随机的流动结构及运动规律对曝气作用的影响至关重要，研究气泡羽流在曝气池中的速度场分布的图像测量有助于提高曝气的效率。污水处理是高能耗行业之一，提高曝气效率可以有效提高污水处理能效，降低处理运行成本，因此本研究具有非常重要的理论和应用前景。

在本研究中，使用圆柱形仿曝气容器进行气泡羽流实验，在 Cheng, et al的研究中[1]使用厚度为4mm的矩形仿曝气容器获得了一系列气泡羽流的流场结果，但未能很好的描述真实曝气情况下，曝气池中的气泡羽流流动结构与速度场的分布，本次实验进行了改进。实验中使用高速摄影机，以500帧/秒的速度获得了分辨率为640*480，3种不同工况下的气泡羽流数据，3种不同工况分别为曝气量，纵横比以及曝气头的分布位置。本研究旨在阐明如何通过图像处理技术获得的气泡羽流的流动结构及运动规律。在预处理中，为了保证数据在后续处理中的准确，对原始图像进行了带通滤波以消除噪声，并对图像进行了二值化处理来增强气泡羽流图像的可视化效果。采用Particle Masked Correlation法，通过查找相关性来确定气泡的位置坐标，最后利用Triple Pattern Matching
法得到不同工况下气泡羽流流场中气相的瞬时速度场及时均速度场，并消除伪矢量。

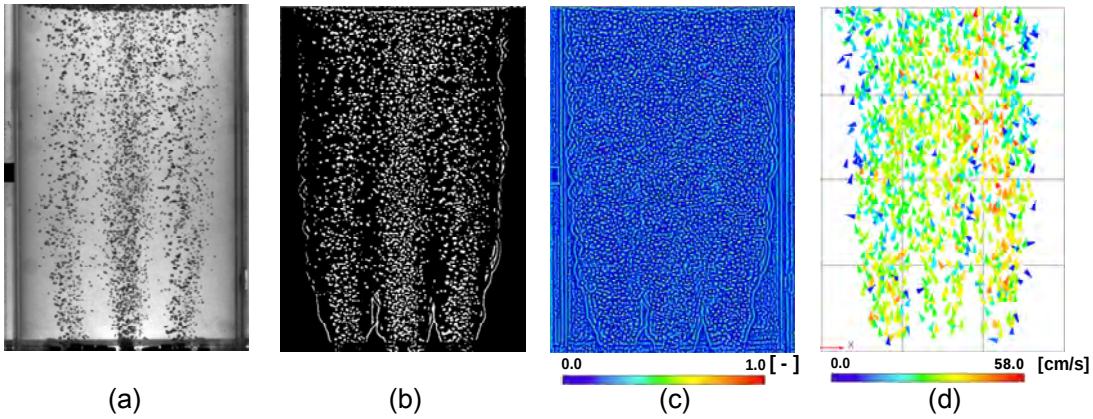

Figure 1 (a) original image (b) binary image (c) cross correlation efficiency (d) time-dependent bubble velocity in the aspect ratio of 1.5,75 L/h

实验结果发现，不同工况对气泡羽流的运动形态及速度场分布有着不同的影响。当纵横比为1.0时，气泡羽流的流线分布出现稳定的漩涡结构并保持较长时间。当纵横比增加到1.5和2.0时，气泡羽流中上部的结构和形式开始显现出不稳定。当曝气头分布较为集中时，曝气池中气泡的速度场分布较为均匀，有利于曝气池中活性污泥等的均匀流化，气相速度约为29cm/s；当曝气头分布过于集中时，则会导致曝气池中部的气相速度过高，破坏气泡羽流稳定的循环结构；当曝气头分布过于分散时，则会导致曝气池中气相速度分布过于松散，不利于液相的循环，影响氧传质效率。

MONITORING AND CHARACTERISTIC ANALYSIS OF SNOWSTORM RUNOFF POLLUTION IN XI'AN CITY

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Based on the monitoring of snowstorm and rainfall runoff pollution in Xi'an city, Shaanxi province in China, characteristics of snowstorm runoff pollution were analyzed and compared with rainfall runoff pollution, and the water quality of snowstorm runoff were evaluated. The main results obtained are as follows: 1) the pollution of snowmelt runoff has first flush effect obviously, the concentrations of pollutants such as SS, COD and TN in the initial stage were higher than the later in a snowmelt runoff process; 2) the original snowmelt-water quality is better, its concentrations of main indexes were lower than that of snowmelt runoff from various types of land uses; 3) there are great differences of quality of snowmelt runoff between different land uses; 4) the results of comparison between snowmelt runoff pollution and rainfall runoff pollution showed that the pollutant concentrations of the former are usually lower than that of the later except TP and Zn, at the same sites; and 5) the snowmelt runoff concentration of TP for school playground, roof and residential, as well as the COD for school road, is higher than the limit values of the fifth class surface water quality standard.

Keyword：snowstorm runoff; monitoring; characteristic analysis; urban; non-point source pollution.

西安市暴雪径流污染监测与特性分析*

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摘要：在对西安市区两场融雪径流污染进行监测的基础上，对融雪径流污染特性进行了分析；同时，将相同地点的融雪径流污染与降雨径流污染进行了对比，并对融雪径流进行了水质评价。结果表明：总体看来，两场融雪的监测结果比较接近；融雪径流水质具有明显的初期效应，主要污染物SS、COD、总氮初期融雪径流的浓度明显高于后期融雪径流的浓度；原雪水的水质较好，主要指标的浓度均低于各种土地利用类型的融雪径流；不同土地利用类型融雪径流的水质差异较大。通过对比，发现除总磷和Zn外，相同地点融雪径流的污染物浓度低于降雨径流的污染物浓度。学校操场、屋顶、家属区的总磷和学校道路的COD等指标超出地表水V类水质标准。

关键词：暴雪径流；监测；特性分析；城市；非点源污染

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SEDIMENT TRANSPORT CHARACTERISTICS UNDER LOW TEMPERATURE FLOW AND ITS CONSEQUENCES IN INNER MONGOLIAN REACH

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ABSTRACT

Observation data analysis showed that sediment transport in ice-jam flood is characterized by larger transport capacity, ever bigger size particles suspending and strong scouring ability comparing with summer flood. Co-influence of hydrodynamic and thermodynamic factors is the root of those phenomena. Based on the discussion of the mechanism of the phenomena formation, the consequences of the characteristic of sediment transportation in low temperature flow were recognized in ice flood control and river deformation. The study results showed two things: one is that winter reservoir operation rule for Inner Mongolian Reach ice flood control enlarged the probability of the river siltation, and two is that ice-flood with high sediment concentration makes river cross section be shallow. On other side of the hand, larger scouring power keeps the downstream channel of Inner Mongolian Reach being in equilibrium, although other part of the river is shrinkage lot.

低温输沙特性及在内蒙古河段产生的后果

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摘要：观测数据的分析结果表明：冰凌洪水输沙与夏洪输沙相比，具有更强大的输移能力和冲刷能力,所能悬移的泥沙粒径更大。引起这些现象的根本原因是水力要素和热力要素的共同作用。通过研究这些现象的形成原理，发现低温输沙的特性会对冰期河流的防洪问题和河床演变产生重要影响。根据研究成果，可以看到黄河内蒙古河段上游水库的防凌调度运行方式将增加河道发生淤积的可能性；含沙量高的冰期洪水也会引起河道横断面的形态变宽浅。与此同时，尽管大部分河段近20年来淤积萎缩严重，但冰凌洪水的巨大冲刷能力却保持了黄河内蒙古以下河段处于相对稳定的平衡状态。

ESTABLISHING AND APPLICATION ON SINGLE PARAMETER MODEL OF SOIL WATER DIFFUSIVITY IN NANXIAOHEGOU BASIN

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ABSTRACT

Selection and identification of soil hydraulic properties parameters are the base of soil water movement and prediction of pollutants transport. Unsaturated soil hydraulic properties are important physical parameters for modeling water flow and solutes transport, in which soil water diffusivity is one of the most important parameters. However, because these parameters have a strong spatial variability, making a direct determination of them in a larger region is often not feasible, and by the spatial structure of soil variability in the determination of the existence of large errors. To overcome these shortcomings, many researchers tried to soil structure and hydraulic parameters of the function must establish in order to find a determination of soil moisture characteristics of the more simple and effective method. In this paper, the infiltrating method by horizontal soil column was applied to characterize soil water diffusivity with the different landform condition and different land-use types on the loess hilly areas in Nanxiaohegou basin of Gansu province. And the experimental results sampled from 18 land use types were analyzed by single-logarithm model and double-logarithm model of soil water diffusivity. The result showed that between parameters of single-logarithm model has significant linear correlativity, so single-logarithm model with a parameter could be established to describe soil water diffusivity of the different landform condition and different land-use types in Nanxiaohegou basin. Further analyzed relationship between parameter A and B of single-logarithm model, it showed that all of them in the different landform types and whole basin were the linear relationship. So, it can be established the single logarithmic model to characterize the soil water diffusivity of the Nanxiaohegou basin. It indicated by analyzing the statistical characteristic of parameter B that it had certain change characteristic along with the landform type change, which may take the soil moisture diffusivity space variation. Therefore, it can use parameter B to take the reflection landform type the target applying to estimate in the region soil moisture diffusivity.

Key words soil water diffusivity, single parameter model, landform types, Nanxiaohegou basin

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南小河沟流域土壤水分扩散率单一参数模型的建立及应用

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2 黄委会西峰水土保持科学试验站，西峰 745000）

摘要：非饱和土壤的水力性质是进行土壤中水分与污染物运移模拟的物理参数，其中土壤水分扩散率是定量模拟土壤水分流动和溶质运移的最重要的参数之一。通过对甘肃省南小河沟流域不同地貌、不同土地利用方式的土壤分层取样，采用水平土柱吸渗法测定各地类的非饱和土壤水分扩散率；运用土壤水分扩散率的单对数模型和双对数模型对试验结果进行分析。结果表明：单对数模型参数具有明显的线性相关，可以建立表征描述南小河沟各地类的土壤水分扩散率的单一参数的单对数模型；进一步从全流域及划分地类后得到的模型参数B与A的关系分析表明它们具有较好的线性关系，可对模型进一步简化为单一参数模型。分析单一参数模型B的统计特征表明：参数B随着地貌类型的变化具有一定的变化特征，

可作为土壤水分扩散率空间变异的变异系数。因此，可以用参数B作为反映地貌类型的指标，应用于区域土壤水分扩散率的估计中。

关键词： 土壤水分扩散率；单一参数模型；地貌类型； 南小河沟流域

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OPTIMIZATION OF WATER RESOURCES UTILIZATION BY PSO-GA

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ABSTRACT

The objective of this paper is to present an optimal model to address the water resources utilization of the Tao River basin in China. The Tao River water diversion project has been proposed to alleviate problems of water shortage in Gansu Province in China. A multi reservoir system with multi objective such as water diversion, irrigation, hydropower generation, industrial requirement, and domestic purpose in the Tao River basin is considered. As water resources become more fully utilized, it is necessary to operate the system efficiently by using optimal operating model. A multi objective, multi reservoir operation model for minimization of water shortage and maximization of hydro-power production is proposed. A adjustable PSO-GA hybrid algorithm is proposed, which combines the strengths of PSO and GA to realize the balance between natural selection and good knowledge sharing to provide robust and efficient search of the solution space. The effectiveness and applicability of the proposed methodology is examined by applying it to the Tao River water resources utilization in China.

基于PSO-GA算法的水资源优化利用模型

论文提出了洮河流域水资源合理利用的优化模型。引洮供水工程是为改善甘肃省中部地区极度缺水现状而实施的跨流域调水工程，同时还具有灌溉、发电、城镇工农业供水等任务。文中以缺水量最小和梯级发电量最大为目标，提出了多目标、多水库优化调度模型，并提出了PSO-GA混合算法。该算法能充分发挥PSO快速局部最优搜索能力和GA全局搜索的优点，保证了算法的快速和有效性。将模型算法应用于洮河流域，其优化结果也证明了模型的可行性。

CHANGES INDUCED BY SOIL AND WATER CONSERVATION IN RUNOFF AND SEDIMENT YIELD IN TYPICAL WATERSHEDS ON THE LOESS PLATEAU

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ABSTRACT

Aiming at the serious soil and water loss in the loess region, large-scale soil and water conservation activities are conducted, and has formed the comprehensive system including warping dam, terrace and vegetation. How to recognize and evaluate the function and efficient of these measures is becoming a new challenge people have to face. In this study, based on long term observation data in paired watersheds, double-accumulative curve method and time series contrasting method are adopted to analyze the changes induced by soil and water conservation in runoff and sediment yield in Jiuyuangou and Peijiamao watershed. From the development of soil and water conservation management, 1962 yr and 1967 yr were determined as two key turning points for the function of soil and water conservation measures, and the function process of these measures can be divided into 4 stages. Runoff and sediment yield from the paired watershed indicated that soil and water conservation measures have significant effect on runoff and sediment reduction. Compared to the paired Peijiamao watershed, which were almost no soil and water conservation measures, changes in runoff and sediment yield induced by soil and water conservation can be determined, among which runoff and sediment in Jiuyuangou Watershed decreased 41.5% and 53.8% respectively. Results from this study, together with other studies, are helpful to determine functions and efficient of soil and water conservation.

Key words: soil and water conservation; changes in runoff and sediment;

黄丘区水土流失综合治理对流域水沙变化作用研究

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摘要：

针对严重的水土流失问题，黄土高原地区开展大量的水土保持治理工作，初步形成了以淤地坝、梯田以及林草措施等综合治理体系，科学分析这些治理措施的作用与功效是目前黄土高原地区水土保持工作面临的重要命题与挑战。本研究应用双累积曲线法和不同流域对比法对韭园沟和裴家峁1954-
1976年径流泥沙测验资料进行分析，结合流域治理资料演变分析，确定了水土保持治理措施发挥重要作用的转折点，划分了水土保持措施作用的四个阶段；结合对比流域分析了韭园沟水土保持措施后的减水减沙作用，结果表明韭园沟流域库坝等工程措施为主的的水土保持措施对洪水总量和输沙总量都有显著的减少效果，其作用分别为41.5%和53.8%。对比未治理流域裴家峁，韭园沟流域侵蚀模数减少52.5%。这一研究结果，对于开展进一步治理水土流失，指导水土保持工作，提供了理论依据。

关键词：水土保持措施；水沙关系；流域减蚀效果

PARAMETER CALIBRATION OF THE XINANJIANG RAINFALL-RUNOFF MODEL USING DIFFERENTIAL EVOLUTION ALGORITHM

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ABSTRACT

In this paper, a novel optimal parameter estimation method for the Xinanjiang rainfall-runoff model is proposed. In the proposed method, a new approach based on penalty terms is imposed in the numerical solution of the model in order to prevent negativity of outflows and storages. The proposed algorithm is very fast and using few control parameters. The performance of the method is compared with reported techniques given in the literature through two applications. The results obtained for two applications demonstrate that the proposed algorithm is capable of finding a global optimum and conceptually realistic parameter set for the Xinanjiang model and can confidently be applied to estimate optimal parameter values of the Xinanjiang model.

Keywords: Differential Evolution; Rainfall–Runoff Model; Parameter Calibration; Global Optimum

摘要：提出了一种新的新安江模型参数优化估计方法，该方法具有求解速度快，控制参数少等特点。在该方法中引入惩罚项，以防止出现负的出流量。通过两个实例应用对该方法的性能与已有的方法进行了比较，结果表明：本文提出的新安江模型参数优化估计方法能够找到全局最优的参数集合，可以很好的解决新安江模型参数估计问题。

CHARACTERISTIC OF RUNOFF AND NUTRIENT TRANSPORT ON SLOPE LAND IN NORTHERN SHAANXI

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ABSTRACT

Jujube is the main economic trees planted in Northern Shaanxi in China. Using it to replace the traditional trees during restoring the reclaimed land to forestry can not only reduce water and soil loss but also increase the peasants' income. However water and nutrition loss are still serious in the bare soil surface in Jujube slope land, especially in rainstorm season. In order to find an effective method to control water and nutrition loss in Jujube slope land, using Br- as tracer, characteristics of water and nutrition transport were studied in the conditions of three different slope gradient (16°, 21°, 26°), slope length (5m, 10m, 15m), and four different underlying surface (including barren land, legume intercropping, PAM land and straw mulch land). The results show that accumulative runoff yield slight decreases with the increase of slope length and it increases with the increase of slope gradient, however, the effect of the slope length on runoff yield reduce when the slope length is more than 10m under the same rainfall intensity. And nutrient loss with runoff becomes more serious with increasing of slope length and slope gradient. The order of runoff yield for different coverage measures is: bare soil surface > legume intercropping > PAM>straw mulch, but the order of nutrient loss with runoff is: legume intercropping > bare soil surface > straw mulch > PAM. Soil water content is largest for treatment with straw mulch and is lowest for treatment with legume intercropping. The Br^- concentration in the soil decreased with the increase of soil depth. Power function is proved to be more suitable to describe the process of solute transport in loess area.

KEY WORDS: Loess plateau slope land, runoff, solute transport, underlying conditions

陕北枣树坡地径流和养分的迁移特性

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摘要：枣树作为陕北地区主要的经济林种，代替传统的退耕还林树种不仅有效的减小了当地坡地水土流失，而且增加了农民的收入，因此得以大面积种植。然而枣树坡地中裸露的地面水土和养分的流失仍然很严重，尤其在暴雨季节更是如此。为了寻求控制枣树坡地水土和养分流失的有效方法，以Br^-
作为示踪剂，研究了不同地形和下垫面条件下（PAM、无覆盖、秸秆覆盖、间作豆科作物）水分和养分的迁移特性。研究结果表明，随坡长的增加，累积径流量有所减小，但当坡长大于10m后，累计径流量随坡长的变化不是很明显。坡度增加，累积径流量增大，通过径流流失的养分也随之增加。不同下垫面产生径流量的大小顺序为：裸地>豆科间作>秸秆覆盖>PAM地；而养分随径流流失的大小顺序为：豆科间作>裸地>秸秆覆盖>PAM地，豆科间作地的养分流失量较大的原因在于间作使得土表较为疏松，从而产生的侵蚀量和养分流失较大。秸秆覆盖的保墒效果最好，豆科间作因蒸腾耗水保墒效果最差。土壤含水量土壤中Br^-的含量随土层深度的增加而增加，且其迁移规律更符合幂函数关系。

ECO- ENVIRONMENTAL RISKS IDENTIFICATION ON THE CASCADE DEVELOPMENT IN THE UPPER REACHES OF THE YELLOW RIVER

De-Xiu Hu

ABSTRACT

The basic water resources characteristics of the upper reaches of the Yellow River is introduced in the article. The current water resources issues in the utilization, development and management of the Yellow River are summarized. Based on the comprehensive analysis of the current stage and planning of the cascade hydro-electric engineering development in the upper-stream of the Yellow River, the possible eco-environmental impacts are systematically discriminated, and the accumulated effectiveness of the related risks are also analyzed. The results lay a foundation for evaluating eco-environmental risks and taking measures to reduce the risks in the cascades development of the Yellow River watershed.

KEY WORDS: risks identification, eco-environment risk, cascades development, watershed, the Yellow River

黄河上游流域梯级开发的生态环境风险辨识

中文摘要：本文分析了黄河上游水资源的基本特点，总结了黄河水资源开发利用与管理中的存在问题，并对黄河上游水电工程梯级开发的现状与发展趋势进行综合分析，在此基础上，分析了黄河流域梯级开发可能带来的生态与环境影响，进而对黄河上游流域梯级开发的生态与环境风险进行了系统的辨识，并对相关风险影响的累积效应进行了综合分析。相关研究成果可为黄河流域梯级开发的生态与环境风险评估、风险减缓措施制定等奠定基础。

关键词：风险辨识，生态环境风险，梯级开发，流域，黄河

RESEARCH ON DYNAMIC ECOLOGICAL WATER REQUIREMENTS AND ITS APPLICATION TO THE MAIN REACH OF THE WEIHE RIVER

Ni Wang, Jiancang Xie, Jungang Luo, and Jiwei Zhu

The Weihe River, the biggest branch of The Yellow River, is suffered with more and more severe water shortage, pollution, and high sediment problems according with the intensive and improper utilization of water resources. For example, ecological water is embezzled by water consumption for production and domestic so that ecological water use can not be satisfied especially in the Middle and Lower River, which lead to the disquieting decline of river ecological system. After analyzing the advantages and disadvantages of existing instream ecological flow calculation method, a dynamic method is put forward in the paper to improve the practicality mainly. In the dynamic method, ecological flow is divided into three parts of sediment transport, diluting and self-cleaning and fundamental ecological flow, and main stream of the Weihe River in Shaanxi province is divided into 7 zones in accordance with location of hydrologic station, administrative zone and object water quality by water function regionalization. Moreover, the dynamic method takes annual variation and seasonal change of ecological flow into account to meet the hydrologic characteristics.

Ecological water requirements calculated from the method above indicate great annual and seasonal variation, and which have general tendency of increasing from the upper zone to the lower one with the maximum value of $4.57\times10^{9}m^{3}$. Ecological water requirement shows great relationship with runoff, discharge capacity and sediment erosion and deposition status. The method used herein could work to calculate dynamic ecological water demand on the river with serious annual and seasonal hydrologic variation or with great changing of development and utilization level along the river. The dynamic ecological water demand calculated is easy to be used in the practice and could be used to instruct water allocation and management.

Key word: ecological water requirements; dynamic; sediment transport water demand; diluting and self-cleaning; main stream of Weihe River

河流生态环境需水量的动态计算与实例分析

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摘要：随着渭河流域水资源开发利用强度的增大，生产、生活用水严重挤占生态水量，导致缺水、水质污染和泥沙淤积等问题日渐突出，河流生态系统健康状况令人担忧。本文针对现有生态需水量计算方法在指导性和实用性方面存在的问题，按照水功能区要求的目标水质，结合水文站点的位置以及各行政区边界对河流进行分区，以输沙需水量、河流稀释自净需水量和基本生态环境需水量三个分项对生态需水量进行分解，建立了考虑年际、年内及空间变化的动态计算方法，将陕西省境内渭河干流分为7段分别计算生态环境需水量。结果表明渭河干流生态需水量有明显的年际、年内变化，各分段生态环境需水量整体呈逐渐增大的趋势，平水年最大值达45.7亿m^{3}，需水量与沿程流量、排污和泥沙冲淤的变化关系密切。该方法适用于水量年内分配不均，自然条件及河流沿程开发利用变化程度较大的河流。计算出的生态需水量具有动态可操作性，可用于指导渭河干流水量分配与水资源管理。

关键词：生态环境需水量；动态；输沙水量；稀释自净；渭河干流

MODELING CHLORIDE TRANSPORT IN AN AGGREGATED SOILS WITH THREE MODELS

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ABSTRACT

Breakthrough curves (BTC's) of chloride displaced through columns of different aggregate sizes of a Loessial soil were measured under water-saturated steady flow conditions. The data were simulated using three conceptual models. In model I, all soil water was assumed to be mobile with a physical equilibrium existing in the system. For model II, soil water was partitioned into mobile and immobile regions. Convective diffusive solute transport was limited to the mobile water region. Transfer of the chloride between the two soil water regions was assumed to occur at a rate proportional to the difference in tracer concentration between the two regions. In model III, soil water was also divided into two regions based on their flow velocities but none of the regions have a non-zero flow rate. Two unknown parameters in Model I and four parameters in model II and model III were estimated by fitting model predictions to the experimental data. Though the three models could describe all the BTC's obtained from columns packed with all the aggregates sizes at a small pore water velocity (0.68cm/h) well, however, the values of fitted parameters varied greatly. The peclect number derived from two-region model and two-flow region model showed the same changing tendency with the aggregate size and increased with the increase of aggregate size. The peclect number values derived from CDE are about two orders of magnitude smaller than those obtained by the two-region model and two-flow region model. The mobile water fraction obtained with the two-flow region model decreased with the increase of aggregate sizes while the mass transfer coefficient ω decreased with the increase of pore water velocity due to the short resident time of chloride transport through the soil columns.

Key words: CDE, two-region mode, two-flow region model, aggregate size, pore water velocity

利用三种模型对团聚体土壤中的氯离子迁移过程进行模拟

摘要：本文通过室内扰动土柱研究一维饱和条件下氯离子在不同粒径的团聚体土壤中的迁移过程，同时利用三种模型分别对其迁移过程和参数进行拟合。模型一中，我们假设所有土壤水均为可动水，模型二中将土壤水分为可动水与不可动水，可动区的溶质运移主要包括对流和弥散两种过程，不可动区的溶质仅以扩散形式与可动区发生质量交换,
且扩散速率取决于可动区和不可动区的浓度差；而两流区模型同样将土壤水化为两个区域，且两个区域的水流速均不为灵，但根据其流速快慢将其划分为快区和慢区，两区之间可以发生溶质交换。当孔隙水流速为0.68cm/h时，三种模型均可以较好模拟氯离子的迁移过程，但其拟合参数结果相差较大。两区模型和两流区模型拟合所得的Pe值随团聚体粒径的增大而增大，而CDE拟合所得Pe值较前两者拟合结果小了两个数量级。两流区模型拟合所得的快区水含量随团聚体粒径的增大而减小，同时由于氯离子在土柱内滞留时间的缩短，质量交换系数随孔隙水流速的增加而减小。
关键词：CDE;两区模型；两流区模型；团聚体粒径；孔隙水流速

DEVELOPMENT AND APPLICATION OF X-WSR-Z SYSTEM METHODOLOGY IN WATER RESOURCES MANAGEMENT

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ABSTRACT

Complex problems, such as water resource management, are synthesis problems which are mostly related to demography, society, economy, resource and environment. This type of problems is mostly embodied as the nonlinearity of structure, the diversity of behavior and incompleteness of information, of which the theoretical method to solve the problem mainly includes reductionism and holism. Hereinto, the West mainly uses reductionism, emphasizing the subdivision and quantification of substances, advocating quantification and modeling to solve the problem; while the East stresses the connection and integrity of things, laying more emphasis on qualitative analysis. This paper targeted at traditional quantitative analysis and model calculations to solve problems of deficiency in decision-making management, started from systems science, introduced group behavior of humans, individual psychological factors and dialectical thinking, proposed to establish Systems Methodology of Psychology (Xinli) - Physics (Wuli) - Logic (Shili) – Ethics (Renli) - Philosophy (Zheli) while emphasizing technology, engineering, logistics, optimization and other measures at the same time. The paper described the basic content of X-WSR-Z Systems Methodology, established a 0-1-0 relational model, clarified the basic principles and working process of Systems Methodology, and explained the relationship of Systems Methodology, comprehensive methodology, modern science and technology system and the world's cultural origin and development. At last, the paper applies X-WSR-Z System Methodology to realize the solution and management of urban water conservation problem by seven steps of interpreting the intention, investigating and analyzing, determining the target, building the model, formulating schemes, coordinating relations and realizing the conceptualization. It has been proved that X-WSR-Z System Methodology can be used as the solution for the problems in the area of water resource management and other more complicated problems.

Key words: X-WSR-Z; System; Methodology; complexity; water resources management;

基于X-WSR-Z方法论的水资源管理研究

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摘要：复杂问题，譬如水资源管理问题，大多是涉及人口、社会、经济、资源与环境的综合问题。这一类问题多呈现为结构的非线性、行为的多样性和信息的不完备性，解决这一类问题的思想方法主要包括还原论和整体论。其中，西方以还原论为主，强调物质的细分和量化，主张定量化和模型化来分析解决；东方则强调事物的联系和整体，多注重定性化分析。本文针对传统定量分析和模型计算在解决这一类问题决策管理中的不足，从系统科学出发，在强调技术、工程、运筹、优化等措施同时，引入人的群体行为和个体心理因素，以及辩证思维，提出建立了心理（Xinli）-物理（Wuli）-事理（Shili）-人理（Renli）-哲理（Zheli）系统方法论。论文介绍了X-WSR-Z系统方法论的基本内容，并建立了0-1-0关系模型，明确了系统方法论的基本原则和工作流程，并阐述了系统方法论与现代科技体系、世界文化源流的关系。最后，论文针对城市节水问题，应X-WSR-Z系统方法论通过理解意图、调查分析、确定目标、建立模型、制定方案、协调关系等步骤来实现求解和管理。实践证明，X-WSR-Z方法论可以较好的用于水资源管理的其他领域或者更多复杂问题的决策或求解中。

关键词：X-WSR-Z;系统;方法论;复杂;水资源管理

INTERVAL TWO-STAGE STOCHASTIC INTEGER PROGRAMMING FOR URBAN WATER RESOURCES MANAGEMENT UNDER UNCERTAINTIES

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ABSTRACT

How to deal with the uncertain factors in urban water resources system is important for water management, stochastic programming model and the mathematical methods used for describing the uncertain problems were combined in a general optimization framework to established a interval two-stage stochastic integer programming model(ITSIP). In the first stage, the decisions for water supply targets of each water sources are determined based on pre-judging the uncertain events in the future. In the second stage, the compensation for pre-decision is adopted when the promised amounts are not delivered to get the minimized economic losses based on dealing with the uncertain events rationally. ITSIP is applied to the water supplying planning system for Baoji city in the northwest, solutions from it provide kinds of water allocation patterns in interval under different scenarios. The results indicate that the model is valuable to solve the variables in water allocation system, and a number of decision alternatives could be generated under various levels of stream flows.

Keywords: Water resources management, Two-stage, Uncertainty

基于不确定性的区间两阶段随机整数城市水资源配置研究

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摘要： 有效地处理城市水资源配置系统中的不确定性问题是水资源管理研究的重要方向，本文将不确定数学方法和随机规划模型相结合建立了区间两阶段随机整数规划模型。用随机规划思想处理系统不确定性，其中第一阶段决策是对规划年不确定事件预先判断，确定各供水源的供水目标，第二阶段决策通过对未来不确定性的合理处理，对预先决策给予补偿，使得经济损失最小。用概率分布和区间数来处理模型参数的不确定性。将模型应用于西北地区城市宝鸡市区多水源多用户水资源配置系统，并给出了不同的情境下区间形式的决策方案。研究结果表明该模型能有效处理城市水资源配置系统中的不确定性。

关键词： 水资源管理，两阶段，不确定性

STUDY ON COMPREHENSIVE DEVELOPMENT MODEL AND EFFECTS OF REGIONAL WATER AND LAND RESOURCES IN URBANIZATION

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ABSTRACT

Water and land resources is the basic factor in the urban ecosystem and the two respond and restraint with each other. Urbanization promotes the rapid development and comprehensive use of regional water resources and land resources and also changes the structures of regional water and land resources, utilization efficiency and the ecological environment patterns. Based on the coupling relationship between regional water and land resources and the game analysis on development and utilization of them, the comprehensive development model of regional water and land resources was constructed. The information entropy and equilibrium of land use structure dynamic change in Xi'an Chanba ecological zone (Shaanxi, China) from 2001 to 2011, were analyzed. GDP, the level of urbanization, the ecological service value were selected as the evaluation index to calculate the comprehensive effect index after complex development. The gray system theory had been used to calculate and analysis the correlation between different land use structure and the combined effect. The research results showed that the information entropy rose from 1.5 in 2004 to 1.795 3 in 2011, and the balance degree of land structure (J) rose to 0.788 2 in 2011, namely, the land use structure has changed greatly and tends to rationalization. The combined effect index of land use from 0.207 8 in 2004 up to 0.835 7 in 2011, and the gray correlation between different land use structure and the combined effect is: r11> r9> r2> r5> r7> r3> r4> r6> r8> r1> r10, which showed that the combined effect of water and land resources is improved significantly after complex development, and its main driving factors are the entropy and water use. In the future, it should be the case that the construction of urban water ecosystem will drive regional water and land resources and comprehensive development of ecological environment.

Key words: urbanization; water and land resources; comprehensive development; model; effect; information entropy

城市化进程中区域水土资源复合开发模式及效应研究

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摘
要：水资源和土地资源是城市生态系统中的基础要素，二者相互响应、相互制约。城市化推进了区域水资源与土地资源的迅速开发和综合利用，同时改变了区域水土资源结构、利用效率及生态环境格局。基于区域水土资源耦合关系及其开发利用的博弈分析，本文构建了城市水土资源开发的复合模式。以西安浐灞生态区为对象，对区内2001-
2011年土地利用结构动态变化信息熵和均衡度进行分析，选取地均国内生产总值、城镇化水平、生态服务价值作为评价指标，并计算了复合开发后的综合效应指数，应用灰色系统理论计算分析了不同土地利用结构与综合效应之间的关联度。结果表明：动态变化信息熵由2004年前的1.5上升至2011年的1.795 3，土地结构均衡度J上升至0.788 2，土地利用结构变化显著；土地利用综合效应指数值由2004年的0.207 8上升到2011年的0.835
7，土地利用结构与综合效应灰色关联度排序为：r11> r9 >r2 > r5 > r7 > r3 > r4 > r6 > r8 > r1 >
r10，表明复合开发后水土资源综合效应明显提高，其主要驱动因子为信息熵和水域利用。今后，应实现城市水生态建设带动区域水土资源以及生态环境的综合开发。

关键字：城市化；水土资源；复合开发；模式；效应；信息熵

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The Tennessee Water Resources Research Center (TNWRRC) and the Southeastern Water Resources Institute (SWRI) are the formal water resources research entities under the Institute for a Secure and Sustainable Environment (ISSE) at The University of Tennessee. The two organizations work synergistically together to address water resources research needs to the broad regional community.

The TNWRRC is a federally designated research institute headquartered at the University of Tennessee, Knoxville. The Center was established in 1964 by Governor Clement following the enactment of the Water Resources Research Act of 1964 (PL 88-379) by Congress. TNWRRC's missions include: (1) to assist and support all academic institutions of the state, public and private, in pursuing water resources research programs that address problem areas of concern to the state; (2) to promote education in fields related to water resources and to provide training opportunities for students and professionals in water resources related fields; and (3) to provide information dissemination and technology transfer services to state and local governments, academic institutions, professional groups, businesses and industries, environmental organizations, and others that have an interest in solving water resources problems.

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The institute represents a restructuring and expansion of the Waste Management Research and Education Institute—a state Center of Excellence established in 1985—to focus more broadly on environmental challenges. The institute will include programs previously found in two other long-standing organizations housed at the university and devoted to environmental research: the Joint Institute for Energy and Environment and the Energy, Environment and Resources Center. The consolidation of environmental research activities will enhance collaboration, facilitate more efficient administration, and build on existing strengths and on-going research efforts.

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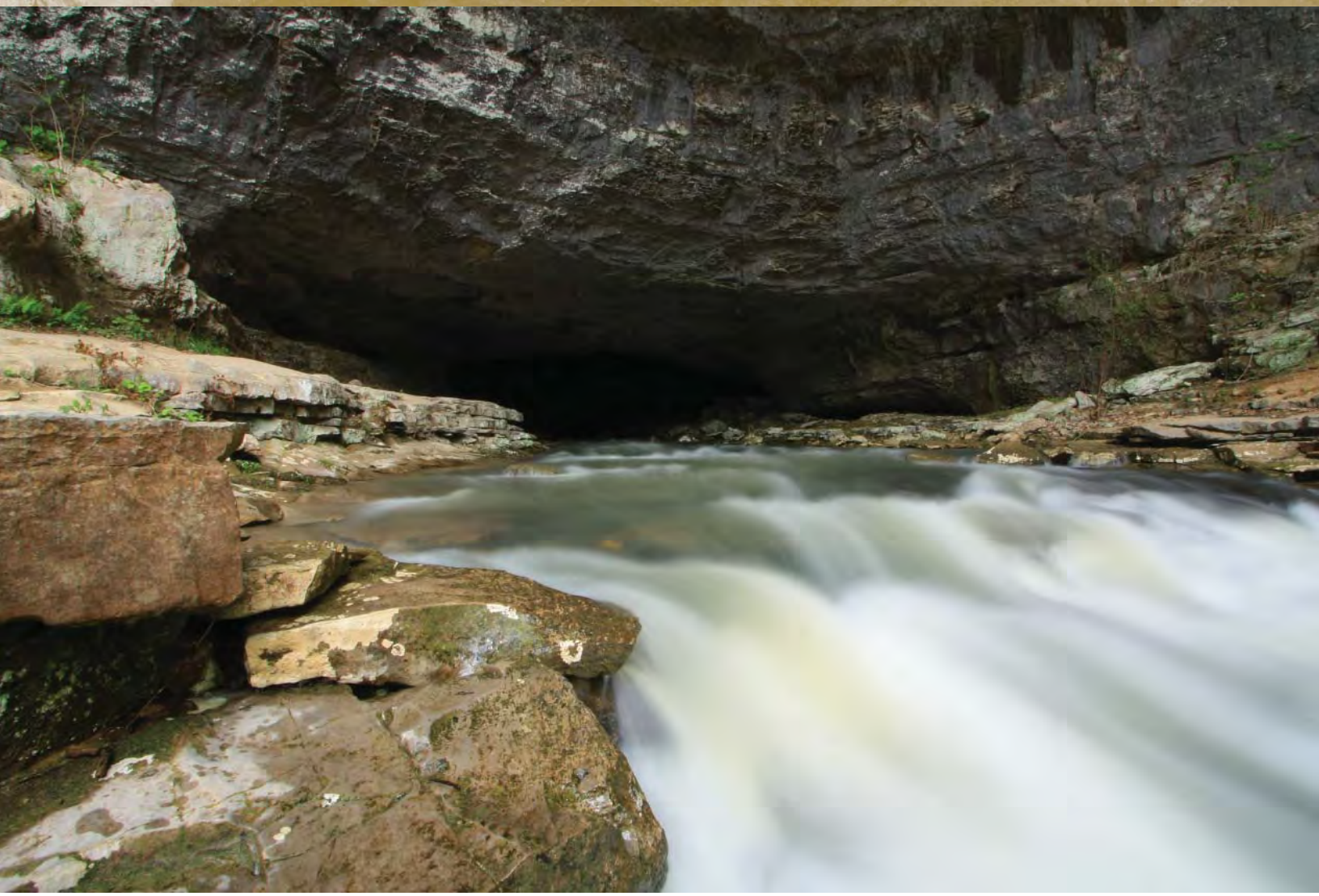

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