Proceedings from the

# 26th Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 5-7, 2017

Sponsored by

## Tennessee Section of the American Water Resources Association

*In cooperation with the Planning Committee*

- Tom Allen, Neel-Schaffer, Inc.
- Paul Davis, P.E.
- David Duhl, TDEC, Division of Water Resources
- Michael Hunt, Nashville Metro Water Services
- Alfred Kalyanapu, Tennessee Tech University
- Deedee Kathman, Civil & Environmental Consultants, Inc.
- Rodney Knight, U.S. Geological Survey
- Tom Lawrence, Water Quality Matters!
- Ingrid Luffman, ETSU, Geosciences
- Patrick Massey, LDA Engineering
- Regan McGahen, TDEC, Division of Water Resources
- Patrick McMahon, S&ME, Inc.
- Daniel Saint, Tennessee Valley Authority
- Scott Schoefernacker, Center for Applied Earth Science and Engineering Research, University of Memphis
- Forbes Walker, University of Tennessee, Biosystems Engineering & Soil Sciences
- Sherry Wang, TDEC, Division of Water Resources
- Adrian Ward, Barge, Waggoner, Sumner & Cannon, Inc.
- Lori Weir, U.S. Geological Survey
- Mike Williams, Barge, Waggoner, Sumner & Cannon, Inc.

*Also Sponsored By*

- Amec Foster Wheeler Environment & Infrastructure, Inc.
- ARCADIS, Inc.
- Barge Waggoner Sumner & Cannon
- Buchart Horn, Inc.
- Center for the Management, Utilization & Protection of Water Resources
- Civil & Environmental Consultants, Inc.
- KCI Technologies
- Neel-Schaffer, Inc.
- OTT Hydromet
- Stevens Water Monitoring Systems, Inc.
- Tennessee American Society of Civil Engineers/Environmental & Water Resources Institute
- Tennessee Water Resources Research Center/ISSE
- Trutta Environmental Solutions

*Exhibitors*

- Amec Foster Wheeler Environment & Infrastructure, Inc.
- Ecosystem Planning and Restoration
- EnviroScience, Inc.
- Eureka Water Probes
- HydroTech ZS Consulting
- OTT Hydromet
- Ragan Smith Associates
- S&ME
- Stantec
- Stevens Water Monitoring Systems, Inc.
- Stream Mechanics
- TTU, Professional Science Master's
- Tennessee Water Resources Research Center/ISSE
- Trutta Environmental Solutions
- UTK, Student Chapter
- Xylem/YSI

Cover Design by Amy Hill, Center for the Management, Utilization & Protection of Water Resources,
Tennessee Technological University
with photo courtesy of Alan Cressler, U.S. Geological Survey

# PREFACE

Welcome to the 2017 TN-AWRA annual meeting. I think you will find the proceedings full of interesting presentations, and I trust you will agree there is a good variety of subject matter worthy of your consideration. Between the three (that's three!) pre-session talks and the final panel discussion, the planning committee has organized a meeting as diverse as our membership.

This year we have chosen planning for growth and protection of aquatic resources in Tennessee in a time of unprecedented growth as our theme. Our keynote speaker, Will Harman, will kick off the meeting by presenting his work on using a stream quantification tool for ecological uplift, thereby planting a seed in our minds as we listen to the technical talks. And we'll wrap it up with a panel discussion that will close the loop by asking panel members from agencies and NGOs what they see as the future of protecting aquatic resources in Tennessee in a time of unprecedented growth.

We will also hear from Barry Thacker, an engineer at Schnabel Engineering who will tell us about his activities helping water resources and so much more in the Lower Clinch River Watershed. I won't give too much away here, but it's safe to say that his talk will remind us of why we got in this profession in the first place and will cause us to double-down on our commitment to the people served by our efforts to improve water resources. Barry is a character, so come prepared for an entertaining and heart-felt talk during lunch on April 6.

I encourage you to take full advantage of the symposium: the talks, the vendor demonstrations, and the closing panel discussion. And please don't overlook the value of informal networking, especially in the evenings when new partnerships and collaborations are forged.

Thanks for being a part of the 2017 symposium.

David M. Duhl, Ph.D.
2017 President, TN-AWRA

**2016-2017 TN AWRA OFFICERS**

| | |
|---|---|
| President and Symposium Chair | David Duhl<br>TDEC, Division of Water Resources<br>312 Rosa L. Parks Avenue, 11th Floor<br>Nashville, TN 37243<br>Phone: (615) 532-0438<br>Email: david.duhl@tn.gov |
| President-Elect: | Alfred Kalyanapu<br>Tennessee Technological University<br>Prescott Hall 334, 1020 Stadium Drive<br>Box 5015<br>Cookeville, TN 38505<br>Phone: (931) 372-3561<br>Email: akalyanapu@tntech.edu |
| Past President: | Rodney Knight<br>U.S. Geological Survey<br>640 Grassmere Park, Suite 100<br>Nashville, TN 37211<br>Phone: (615) 837-4731<br>Email: rrknight@usgs.gov |
| Treasurer: | Tom Allen<br>Neel-Schaffer, Inc.<br>210 25th Ave N, Suite 800<br>Nashville, TN 37203<br>Phone: (615) 838-8420<br>Email: tom.allen@neel-schaffer.com |
| Secretary: | Regan McGahen<br>TDEC, Division of Water Resources<br>312 Rosa L. Parks Avenue, 11th Floor<br>Nashville, TN 37243<br>Phone: (615) 532-1175<br>Email: regan.mcgahen@tn.gov |
| Membership Chair: | Lori Weir<br>U.S. Geological Survey<br>640 Grassmere Park, Suite 100<br>Nashville, TN 37211<br>Phone: (615) 837-4720<br>E-mail: lrweir@usgs.gov |

***12:00 – 1:30 p.m.***
***Wednesday, April 5***
**Keynote Address** ***by*** **Will Harman,** PG, Stream Mechanics (wharman@stream-mechanics.com)

## QUANTIFYING FUNCTIONAL LIFT FROM STREAM RESTORATION ACTIVTIES

Stream restoration has many meanings. Some define restoration as a return to pre-disturbed conditions. Others take a broader approach and define restoration as the improvement of stream functions to a reference condition. The range of definitions for stream function is often based on the person's academic and professional background. For example, biologists think of functional improvements to biology and engineers often think of functional improvements to hydrology or hydraulics. These diverse viewpoints about restoration and function create significant challenges for developing stream restoration plans with realistic and quantifiable goals and objectives.

The Stream Functions Pyramid Framework was created to provide an organized thought process for developing stream restoration project goals, function-based assessments, restoration plans, and debit/credit determination methods for compensatory stream mitigation. The framework organizes stream functions into a pyramid-shaped hierarchy with higher-level functions supported by lower-level functions. Hydrology is at the base of the pyramid, followed by hydraulics, geomorphology, physicochemical, and biological functions. This implies that in order to have functioning biology, the lower-level functions must also be functioning.

This framework will be presented along with example applications on how to develop function-based goals and objectives and to evaluate functional lift at restoration projects. A new Stream Quantification Tool will be demonstrated that scores a project before and after restoration, yielding a functional lift score. The framework is evolving as agencies and private companies apply the principles in different climates and eco-regions. In Tennessee, the Department of Environment and Conservation is regionalizing the tool for use within the compensatory stream mitigation program.

***12:00 – 1:30 p.m.***
***Thursday, April 6***
**Lunch Presentation *by* Barry Thacker, Schnabel Engineering,**
**bthacker@schnabel0eng.com**

## RESTORING MORE THAN LAND AND WATER

*People before fish.* That was the message on protest signs carried by residents of Briceville when the Coal Creek Watershed Foundation proposed a plan to improve water quality in Coal Creek of the Clinch River in Anderson County.

Seventeen years later, the foundation has helped residents and local officials address flooding concerns, open a clinic to improve healthcare, extend public drinking water lines to remote areas, restore native fish species to Coal Creek, and embrace local history to attract tourist revenue. But its primary achievement is in development of the community's most valuable resource—its youth.

The foundation's Coal Creek Scholars program has helped 45 students from Briceville attend college. Scholars have completed degrees in engineering, science, teaching, nursing, and business, with one in law school and another in medical school. The only requirement for scholarship assistance is that Scholars must serve as mentors to current Briceville students.

Barry Thacker, PE, will tell this story as a living STEM-historian by portraying $19^{th}$-century mining engineer David R. Thomas. Coal Creek miners left a legacy—they fueled the Industrial Revolution after the Civil War and fought a war with the Tennessee National Guard to abolished convict leasing. Yet, hundreds of them perished in one of the state's worst disasters. The Coal Creek Saga is now part of Tennessee's social studies curriculum.

Barry will demonstrate that a career in STEM is not just a job, it's an adventure, especially when you venture into today's classrooms.

## SESSION 1A

## STREAM HEALTH: SCIENCE, CITIZENS AND REGULATIONS

*Freshwater Mussel Die-Off in the Upper Clinch River, Tennessee, Summer and Fall, 2016*
Greg C. Johnson and Tom Byl..…………..………..…………………........…………….1A-1

*Watershed Restoration Approaches in West Tennessee*
David Blackwood and Jeffrey Fore…..…….……………………..…….….......…......……1A-2

*Baseline Spring Hydrograph and Water Quality Monitoring at a Large Karst Spring, The Boils WMA, Jackson County, TN*
Evan A. Hart…………………………..………………………..…..……......…...…………1A-3

## NUTRIENTS AND AGRICULTURE

*The Great Lakes to Gulf Observatory—An Interactive Geospatial Application Focused on Nutrients in the Mississippi River and Its Tributaries*
Ted Kratschmer, Marcus Slavenas, John Sloan, Isaac Chapman, Jong Lee, William Kruidenier, and Richard Warner….…………………………………...……..……..........…………1A-4

*An Assesment of the Effectiveness of Winter Wheat Cover Crops for Nutrient Load Reduction in Two Tennessee Watersheds Dominated by Row Crop Agrigulture*
Shawn Hawkins and Hannah
McClellan……………………………………………………………………………..1A5

*Keeping Phosphorus Out of Our Waters: How Do Soil Phosphorus Levels Vary Across Tennessee?*
Forbes Walker and Debbie Joines....……..………..……………………………......….……….1A-6

## SESSION 1B

## STREAM RESTORATION

*Channelized: Is All Hope Lost for West Tennessee Streams?*
Heather Meadors.……………………………...…….……………….…..…...…….…….1B-1

*Characterizing TN Stream Morphology: Developing Statewide Regional Curves to Aid in Stream Restoration Design*
V. Jones………………………………………………………………………………..1B-2

*Stream Restoration to Address TMDLs*
Ken Barry and Patrick McMahon.……........…………..…………………………...…………1B-3

## STREAM RESTORATION AND BANK STABILIZATION

*Streambank Stabilization*
Andrew Simon, John Schwartz, and Patrick McMahon…......……....................……………1B-4

*Contrasting Approaches for Stream Bank Stabilization*
Ken Barry, Michael Pennell, Patrick McMahon, and Brent Wood...……..........……………1B-5

## SESSION 1C

## HYDROLOGICAL AND WATER SUPPLY MODELING

*Ecological Flows Analysis to Identify Thresholds of Water Withdrawal Scenarios and Stream Fish Community Responses*
Lucas Driver, Rodney Knight, and Jennifer Cartwright…………..…………....……………1C-1

*Moving Reservoir Water Supply Yield Analysis into the 21st Century*
Dave Campbell…………..…………………….……………….................……………….1C-2

*Quantifying the Evolution of Soil Surface Roughness as a Function of Rainfall Intensity*
Christos P. Giannopoulos, Benjamin K.B. Abban, A.N. (Thanos) Papanicolaou, Dimitrios C. Dermisis, Kenneth M. Wacha, Christopher G. Wilson, and Mohamed Elhakeem..…………1C-10

## GROUNDWATER HYDROLOGY

*Implications of Water Balance for Recharge of the Memphis Aquifer in a Small, Incised Urban Stream Valley*
W. Simco, D. Larsen, B. Waldron, S. Schoefernacker, and J. Eason…………..……………1C-11

*Statistical Evaluation of Landfill Leakages in Karst Areas*
Wanfang Zhou……………………………………………………………………..…………1C-12

*Estimating Groundwater Flow Using a Bail Test During Local Water Table Lowering*
Ingrid Luffman, Sydney Lawson, and Arpita Nandi……………..………..……..…………1C-13

## SESSION 2A

## ALGAE AND NUTRIENTS

*Structure of Algal Assemblages and Trophic State of Streams in Middle Tennessee: A Project Supported by the Tennessee Healthy Watershed Initiative*
Jefferson G. Lebkuecher, Molly R. Grimmett, Arianna L. Ackerman, and Tsvetan M. Tsokov……………………………………………………….................……………2A-1

*Efforts to Reduce Hypoxia in the Gulf of Mexico by Reducing Nutrient Losses from Tennessee*
Forbes Walker………………..………………………....……………………...…...………...2A-2

*A Simple Way of Calculating Site-Specific Threshold Nutrient Concentrations Based on a Targeted Chlorophyll_A*
Ming Shiao and Sherry Wang…..…..…………………………………………………….2A-3

## WATER USE AND AGRICULTURE

*Evaluating Water Supply Conflicts Between Urban and Agriculture Uses*
Brandy Manka...………………….....…………………..............……………….…..………….2A-4

*Conservation Management Practices for Agroecosystem Sustainability*
S. Jagadamma……………...………………….……………………………….....………….2A-5

*Water Budgets for Tennessee Dairy, Broiler, and Beef Cattle Farms*
Shawn Hawkins, Forbes Walker, and Chris Clark……………....……...……..…..………….2A-6

## DAM REMOVAL

*Water Quality Implications and Permit Requirements for Dam Removal in Tennessee*
Robert D. Baker…......……………………..……………………..…………...…..…..……….2A-7

*The Benefits and Issues Associated with Lowhead Dam Removal: A Case Study of the Removal of the Remnants of Brown's Mill Dam on the East Fork of the Stone's River*
Pandy English..……...…………………………………………………...….......…………2A-9

*Preparations for Dam Removal in Athens, Tennessee*
Forbes Walker, Andrea Ludwig, Mike Essington, Shawn Hawkins, Lena Beth Reynolds and Paul Ayers.……….…….…………..…………….………………...……...…..………….2A-10

## RESTORATION TO IMPROVE ECOLOGICAL CONDITIONS

*Regulatory Program Updates – U.S. Army Corps of Engineers, Nashville District, Regulatory Division*.…………………………….…………………………….…………………….2A-11

*Clinch Powell Clean Rivers Initiative—A Bi-State Watershed Coalition Restoring One of North America's Most Biodiverse River Systems*
Brad Kreps………..…..………..…………………………………………...…..………….2A-12

*May 26, 2016 Permittee-Responsible Mitigation Guidance: Implications for Prospective Applicants*
Brady McPherson……………………..…………………….........................…………2A-13

## SESSION 2B

### STORMWATER I

*Comparison of Roadway Runoff Quality Surrounding Repaving Events from Hot Lay Asphalt to Open Grade Friction Course Asphalt*
Kristen N. Wyckoff and Qiang He………………………………………………2B-1

*Changes in Residential Rain Garden Infiltration Capacity in Two Demonstration Gardens*
Andrea Ludwig, Wesley Wright, Mary Pleasant, Ruth Anne Hanahan, and Garrett Ferry……………………………………………………………2B-2

*Storm Water Detention Pond Monitoring Program at CBU Soccer Field*
L. Yu Lin, Chee Chew, and James Simpson……………………………………2B-3

### STORMWATER II

*The Role of Trees in Bioretention Practices*
Andrew Tirpak and Whitney Lisenbee……………………………………………2B-8

*The Role of Cover Crops to Soil and Water Quality Under a Variable Climate*
Violet B. Freudenberg, A.N. Thanos Papanicolaou, Benjamin K.B. Abban, Christos Giannopoulos, Christopher G. Wilson, and Mohammad S. Ghaneeizad……………2B-9

*Exploring the Influence of Urban Watershed Characteristics and Antecedent Climate on In-Stream Pollutant Dynamics*
L.E. Christian, J.M. Hathaway, and T.H. Epps……………………………………2B-10

### STORMWATER QUALITY

*Area: Laboratory and Field Testing of Stormwater Treatment Devices: NJCAT, NJDEP, A Complete Explanation of Manufactured Treatment Devices Testing*
Gary Moody……………………………………………………………………2B-11

*The Importance of Particle Size Distribution When Defining 80% TSS Removal Efficiency*
Mark B. Miller…………………………………………………………………2B-12

*Investigating Design and Performance of Regenerative Stormwater Conveyances Through 3D Modeling*
Jessica M. Thompson, Jon M. Hathaway, and John S. Schwartz……………………2B-14

### FLOOD

*Seven Steps Closer to Flood Resilience*
Bradley Heilwagen………………………………………………………………2B-15

*PMP/PMF Automation Tool Overview*
Trevor Cropp……………….……….…………...………………..……...…..…….…...…2B-16

*Investigating Hydrologic Non Stationarity within the Obion River, TN Watershed*
Benjamin K.B. Abban, Mohammad S. Ghaneeizad, Angela Pelle, Christopher G. Wilson and A.N. (Thanos) Papanicolaou...……………………………………………………...……..2B-17

## SESSION 2C

### DROUGHT

*TVA Reservoir Operations and Drought*
Amanda K. Bowen...…………………………………………………………….…..…2C-1

*The 2016 Drought in the Tennessee Valley: A Look at the Statistics, the Response, and the Results and Impacts*
Daniel P. Saint..……….……………………………………………….…...………..……2C-2

*Droughts and Reservoir Yield: Decisions Informed by Tree Ring Data*
John Harrison…………….…………………………………………….………...……2C-3

### PUBLIC OUTREACH

*South Carolina's New Tools to Assess Surface Water Availability and Support Regional Water Planning*
John D. Boyer………………………………………………………....….………...……2C-4

*4-H Water Camp—Georgia vs. TN*
Lena Beth Reynolds…………..…...…………………………………...….......…….……2C-5

*Tennessee Valley Authority Water Resource Stewardship Efforts*
Shannon O'Quinn and Tyler Baker…………………………………..….…..………..……2C-6

### STREAM SURVEY

*Application of the High Definition Stream Survey on the Harpeth and Falling Water River*
Brett Connell.……………..……………...…………………...………...……………….……2C-7

*High Definition Stream Survey of the Lower Caney Fork River, TN: Assessing River Corridor Conditions and Trout Habitat at Multiple Discharge Rates*
James Parham……………………………………………………….................……..2C-8

*Assessing the Uncertainty of 100-Year Flood Extent in a Morphologically Active River—A Case Study in the Obion River*
MD NM Bhuyian and Alfred Kalyanapu………………….............................................……..2C-9

## WATER QUALITY

*Sulfur Isotope and Chemical Composition of Precipitation, Stream Water and Bedrock in Select Catchments in the Great Smoky Mountains National Park*
Adrian M. Gonzalez, John S. Schwartz, and Matt A. Kulp…………………..…...…....……2C-10

*Presence of Fecal Indicator Bacteria in Sand by Distance and Depth at a Freshwater Recreational Beach*
Megan A. Stallard, Lara K. Jarnagin, Jordan Jatko, and Frank C. Bailey..........………......……2C-11

*Experimental Studies on the Photocatalytic Degradation of Pharmaceutical Personal Care Products (PPCP) Using Rhodamine B Dye as a Surrogate*
Abibat Ahmed, Hassan Alsaud, Roger Painter, Lonnie Sharpe and Samuel Hargrove…...…2C-12

### SESSION 3A

## WATERSHED RESTORATION AND PLANNING

*Using Bioassessments to Track Changes in Stream Conditions in Response to Stream Restoration Projects*
Veronica Logue……………….……………………………...……………........………….3A-1

*A Monitoring and Assessment Framework to Evaluate Stream Restoration Needs in Urbanizing Watersheds*
John S. Schwartz, Sue L. Niezgoda, Tess M. Thompson, and Joanna Crowe Curran…..…….3A-2

*Visionary by Design: Contemplating a New Century of Innovation in the Tennessee River Valley*
Brad Collett….…………………………………………………………………………..….3A-3

## PLANNING FOR GROWTH AND AQUATIC RESOURCES IN TENNESSEE

*Speakers:* M. Hunt, Nashville Metro Water Services, Storm Water Division, NPDES Office; Robbie Karesh, TDEC Statewide Stormwater Coordinator, Division of Water Resources; Stephanie A. Durham, TDEC Assistant General Counsel; Andrea Ludwig, Associate Professor and Watershed Faculty Consortium Chair, UTK Department of Biosystems Engineering and Soil Science; Chris Granju, Knox County Stormwater Management Director; Shelby Ward, Counsel for Tennessee Clean Water Network (Abstracts Not Available)

### SESSION 3B

## MODELING

*Hydrological Model Calibration and 2D Hydraulic Analysis of Ralston Creek*
Jeffrey B. Shaver……………………….........................................................…..…………3B-1

*Supplemental Tools for Natural Channel Design*
Patrick McMahon and Ken Barry………….……………………..….........…..…...……….3B-3

*Advances in Hydrologic Assessment Techniques for Mixing Zone Modeling*
Brian Ham, Ginny Gray Davis, Shaun Winter…..…………………………..…...…...……….3B-4

## SESSION 3C

## TOOLS AND TECHNIQUES

*Creating an Application-Specific Tool for Loading Data into WQX*
Gerald A. Burnette…………………...………………………………..…………………....3C-1

*Identification of Potential Water Quality Trading Markets in Tennessee: A Spatial Analysis*
Ayuska Ojha and Christopher D. Clark…….………………………..........……………….3C-6

*Potential of Neutralized Bauxite Residual in the Removal of Aqueous Phosphorus*
Yongfeng Wang and Qiang He…....…………………………………..…...…………….3C-8

## STUDENT POSTERS

**Undergraduate**

*Groundwater Hydrology in a Karst Aquifer at Tennessee State University, Nashville, TN.*
Renas Barzanji, Lonnie Sharpe, Jr., acknowledgement Tom Byl………………………………P-1

*Monitoring Discharge and Hydrograph Response Times for a Large Karst Spring, The Boils, Jackson County, TN*
Bethany Boggs, Karaline Deaton, and Evan A. Hart…………....……………....…………….P-2

*Development of a Hydrologic Modeling System for the Dry Valley Catchment, Putnam County, Tennessee*
John Brackins, Alex J. Davis, Sarah E. Wilson, and Alfred J. Kalyanapu....…....…………….P-3

*Mapping the Extent of Coal Mining Damage in the Waterways of Wilder, Tennessee and Surrounding Areas, 2015-17*
Zachary Hodge………………………………...……….…………….....…………….P-4

*Effects of Water Hardness on Bacterial Attachment to Fine Sand*
Lara Jarnagin, Megan A. Stallard, and Frank C. Bailey……….……………....…………….P-5

*Determining the Presence of Traditional and Alternative Fecal Indicators in Murfreesboro, TN Storm Drain Biofilms*
Jordan Jatko, Megan A. Stallard, and Frank C. Bailey……….……………...….…………….P-6

*Stimulatioin of Plant Growth by Groundwater Naturally Rich in Sulfide and Calcium*
Dannelle Solomon……………………………………………………………………….P-7

**Graduate**
*Hydrology of an Urban Wetland at Tennessee State University, Nashville, TN*
JeTara Brown, Lonnie Sharp, Jr., acknowledgement Tom Byl………………………………..P-8

*Modeling Paleofloods in the Tennessee Valley: Associating Flood Deposits with Flows and Performing Frequency Fitting*
Hannah R. Kubas………………………………..…………....……………....…………….P-9

*Effects of Different Cover Crop Species on Soil and Water Quality*
Mingwei Chu, Sindhu Jagadamma, Michael Buschermohle, and Forbes Walker.…………...P-10

*Seasonal Variations and Statistical Analysis of the Physicochemical Characteristics in a Developing Wetland in Nashville, Tennessee, 2017*
Mark C. Okafor, De'etra Young, and Thomas D. Byl…………………..…………………....P-11

*Development of an eDNA Protocol to Detect and Quantify Streamside Salamanders* (Ambystoma barbouri) *in Low-Order Streams of Middle Tennessee*
Nicole Witzel, Ali Taheri, and William B. Sutton…...………………..……...………..……..P-13

**Doctoral**
*Critical Shear Stress Measurement of Cohesive Soils in Streams: Identifying Device-Dependent Variability Using an In-Situ Jet Test Device and Conduit Flume*
Badal Mahalder, John S. Schwartz, Angelica M. Palomino, and Athanasios N. Papanicolaou……………………………………………………………………………..…....P-14

*Influence of Environmental Characteristics on Fecal Indicator Measurements in Streams*
Lu Yang and Qiang He……………………………………………………………………..…....P-15

*Effect of Nutrient Addition During Phytoremediation on Lead Partitioning in Dredged Sediment*
Tianxue Yang, Qiang He, Chunguang He, Aixia Wang, and Lianxi Sheng...…………..…....P-16

## PROFESSIONAL POSTERS

*Assessing the Success of DRAINMOD and Reference Wetlands for the Prediction of Hydrology in Wetland Restoration Sites in North Carolina*
Eric Neuhaus, Kirsten Gimbert, Jeff Keaton, and John Hutton..…………………..………....P-17

*Estimated Use of Water in the Cumberland River Watershed in 2010 and Projections of Public-Supply Water Use to 2040*
John A. Robinson..……………………………………………………………..……..…....P-18

## SESSION 1A

## STREAM HEALTH: SCIENCE, CITIZENS AND REGULATIONS
**1:30 p.m. – 3:00 p.m.**

*Freshwater Mussel Die-Off in the Upper Clinch River, Tennessee, Summer and Fall, 2016*
Greg C. Johnson and Tom Byl

*Watershed Restoration Approaches in West Tennessee*
David Blackwood and Jeffrey Fore

*Baseline Spring Hydrograph and Water Quality Monitoring at a Large Karst Spring, The Boils WMA, Jackson County, TN*
Evan A. Hart

## NUTRIENTS AND AGRICULTURE
**3:30 p.m. – 5:00 p.m.**

*The Great Lakes to Gulf Observatory—An Interactive Geospatial Application Focused on Nutrients in the Mississippi River and Its Tributaries*
Ted Kratschmer, Marcus Slavenas, John Sloan, Isaac Chapman, Jong Lee, William Kruidenier, and Richard Warner

*An Assessment of the Effectiveness of Winter Wheat Cover Crops for Nutrient Load Reduction in Two Tennessee Watersheds Dominated by Row Crop Agriculture*
Shawn Hawkins and Hannah McClellan

*Keeping Phosphorus Out of Our Waters: How Do Soil Phosphorus Levels Vary Across Tennessee?*
Forbes Walker and Debbie Joines

# FRESHWATER MUSSEL DIE-OFF IN THE UPPER CLINCH RIVER, TENNESSEE, SUMMER AND FALL, 2016

Greg C. Johnson[1] and Tom Byl[2]

Mussel populations in several reaches of the Clinch River upstream of the Tennessee-Virginia boarder have experienced declines in species richness and density over the past 40 years. Downstream, on the Tennessee side of the upper Clinch River, mussel populations have remained fairly stable, with this section of the Clinch River supporting more threatened and endangered freshwater mussel species than any river in the country. Shoals on the Tennessee side of the Clinch River provide the broodstock for reintroduction and relocation efforts for numerous mussel species. During a reintroduction effort in July of 2016, biologists from Virginia Tech were looking for gravid female mussels at Kyles Ford, Tenn., and noted numerous dead and dying Pheasant-shell mussels (*Actinonaias pectorosa*) in the stream substrate and lying on top of the streambed. One of the best remaining mussel assemblages in the United States was experiencing a die-off.

Biologists from several agencies surveyed the die-off, and estimated tens of thousands of mussels died, primarily consisting of Pheasant-shell mussels, in the reach between Horton Ford and Swan Island, Tennessee. In response to the die-off, the Tennessee Department of Conservation and Virginia Department of Environmental Quality collected water-quality samples for analysis of major ions, metals and suspended algae to supplement their quarterly-sampling along about 100 miles of the Clinch River at three sites in Tennessee and six sites in Virginia. The U.S. Geological Survey (USGS) collected sediment, tissue and algae samples at six sites in Tennessee and Virginia, focused on a 40 mile reach bracketing the mussel die-off. Sediment samples were collected for metals and polycyclic aromatic hydrocarbon (PAH) analysis; mussel tissue was harvested at one site for analysis of pathogens, metals and PAHs; and algae and chlorophyll samples were also collected. The cause of the die-off is still undetermined. One possible contributing factor is that eastern Tennessee and southwest Virginia experienced a severe drought during the summer and fall of 2016, and drought conditions typically result in higher constituent concentrations in streams. In this presentation, data collected following the die-off will be compared to previously collected data and other possible explanations for the die-off will be discussed.

[1] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, 4700 Old Kingston Pike, Knoxville, TN 37919 gcjohnso@usgs.gov

[2] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Nashville, TN 37211 tdbyl@usgs.gov

# WATERSHED RESTORATION APPROACHES IN WEST TENNESSEE

David Blackwood[1] and Jeffrey Fore[2]

Watersheds and stream systems in West TN are highly altered from past channelization and landuse changes. These alterations often cause vertical and longitudinal channel instability, can increase flood risks, alter physical habitats for fish and wildlife, and ultimately contribute to widespread ecological degradation. Many of the most acute instream physical problems are caused by up-valley channel degradation that mobilizes large quantities of sediment and contributes to down-valley aggradation processes that fill valleys and alter stream and floodplain habitats. Addressing these problems is critical to the intended functioning of stream and floodplain restoration projects. We present a restoration framework commonly employed by the West Tennessee River Basin Authority that systematically addresses the common channel stability and restoration approaches used in West Tennessee stream systems. The approach generally relies on stabilizing active knickpoints throughout the watershed and appropriate siting and sizing of stream channel restoration. A conservation project completed in Pennycost Creek watershed will be used to demonstrate the approach.

[1] West Tennessee River Basin Authority
[2] The Nature Conservancy

# BASELINE SPRING HYDROGRAPH AND WATER QUALITY MONITORING AT A LARGE KARST SPRING, THE BOILS WMA, JACKSON COUNTY, TN

Evan A. Hart[1]*

The Boils spring is located on the Roaring River in Jackson County, TN and drains the collective watersheds of the Roaring River and Spring Creek. These watersheds are major tributaries of the Cumberland River above Gainesboro, TN. The land surrounding the Boils spring was designated as a state WMA in 2006 and both Spring Creek and Roaring River are designated as state scenic rivers. According to dye trace results, the main contributors to the Boils spring at baseflow are several large in-stream swallets located on Spring Creek, just below Waterloo Falls. Dye injected at these swallets traveled at least 9 km underground before emerging at the Boils, making this one of the longest dye traces in the state. Additional inputs at the Boils come from smaller swallets on Roaring River, below its confluence with Spring Creek. Average baseflow at the Boils during 2015-2016 was approximately 2.1 $m^3$/sec. During the drought in the fall of 2016, flow at the Boils bottomed out at 0.8 $m^3$/sec. Conductivity at the Boils ranged from 210-290 us and was highest during baseflow, with stormflow events being slightly lower. Spring water temperature ranged seasonally from 7 to 22 °C and also showed slight variation during storm events. The maximum discharge recorded at the Boils was approximately 14 $m^3$/sec. At higher flows, the Boils spills over into the main channel of Roaring River making discharge measurements impossible to attain. Future monitoring at the Boils continues as part of the Tennessee Karst Springs Initiative.

[1] Dept. of Earth Sciences, Tennessee Tech University, Cookeville, TN 38505 ehart@tntech.edu

# THE GREAT LAKES TO GULF OBSERVATORY – AN INTERACTIVE GEOSPATIAL APPLICATION FOCUSED ON NUTRIENTS IN THE MISSISSIPPI RIVER AND ITS TRIBUTARIES

Ted Kratschmer*, Marcus Slavenas, John Sloan, Isaac Chapman, Jong Lee,
William Kruidenier, and Richard Warner

The Great Lakes to Gulf Observatory (GLTG), www.greatlakestogulf.org, is an interactive geospatial application that integrates water quality data from multiple sources to better facilitate analysis and ultimately, knowledge of nutrient pollution, large river ecology and water quality conditions in the Mississippi River watershed. The GLTG's web-based application allows users to dynamically browse, search for and visualize water quality information on the Mississippi River and its tributaries. The application uses a combination of different respected data sources including long-term historical datasets and continuous real time sensors, providing the users with a better picture of water quality in the watershed.

Meant to add value to users of existing datasets and projects, the application's features, visualizations and design allow researchers, communities, and decision makers to better understand nutrient inputs and loads, transform data to knowledge and ultimately policy, enhance risk management decisions, empower watershed groups and inform long-term strategic planning. With the first phase of the project focused on nutrient pollution, the application and its infrastructure is relevant to state nutrient reduction strategies, watershed planning efforts and focused watershed initiatives.  Led by the National Great Rivers Research and Education Center, data integration and visualization occurs within a cyber-infrastructure framework constructed in collaboration with the National Center for Supercomputing Applications (NCSA) and the Illinois-Indiana Sea Grant Program (IISG) at the University of Illinois.

# AN ASSESSMENT OF THE EFFECTIVENESS OF WINTER WHEAT COVER CROPS FOR NUTRIENT LOAD REDUCTION IN TWO TENNESSEE WATERSHEDS DOMINATED BY ROW CROP AGRICULTURE

Shawn Hawkins and Hannah McClellan
[1]University of Tennessee, Department of Biosystems Engineering and Soil Science

Nutrient loss from agricultural fields contributes to a “dead zone” of low dissolved oxygen concentrations near the mouth of the Mississippi River in the Gulf of Mexico. In August 2015, this area reached 16,760 $km^2$, the largest area recorded since 2002. Efforts are underway in many states within the Mississippi River basin to reduce crop nutrient loss. In Tennessee, Soil and Water Assessment Tool (SWAT) water quality models have been developed to evaluate the nutrient load reduction for winter wheat cover crops on corn and soybean fields in the Red River and South Fork of the Obion River watersheds, which are dominated by agricultural landuse. SWAT is a physically based, watershed-scale, continuous time simulation model that links hydrology and nutrient cycling with crop growth. Model inputs included digital elevation data and United States Department of Agriculture crop satellite imagery (Croplands Data Layer) as well as a soils database. Rainfall inputs were from a Next Generation Radar database developed for Tennessee using data collected by the National Weather Service. River discharge data for calibration were collected by the Unites States Geologic Service gauging stations. Crop management schedules (planting, fertilizer applications, harvesting) were established in consultation with corn and soybean producers. Model results will be presented with a discussion of important field management parameters (USLE_P, USLE_C, and OV_N) which were changed to reflect the adoption of contour and no-till planting without the use of a cover crop. These are the dominant planting methods in the Tennessee watersheds that where studied. Flow calibration of the models is presented using the Sequential Uncertainty Fitting program along with a model parameter sensitivity analysis. Uncertainty model fits were good during both calibration and validation time periods, with p-values (representing the percentage of observed flows within the model uncertainty) between 0.5 and 0.7, and r-values (representing the relative width of uncertainty in the model flow prediction) well below 1. Incorporation of an unfertilized winter wheat cover crop throughout the entire watershed resulted in substantial load reduction in total nitrogen (30-50%) and total phosphorus (12-32%). The findings clearly indicate that incentivizing cover crop placement could be an important part of the Tennessee Nutrient Reduction Strategy in agricultural watersheds that will help control gulf hypoxia.

# KEEPING PHOSPHORUS OUT OF OUR WATERS: HOW DO SOIL PHOSPHORUS LEVELS VARY ACROSS TENNESSEE?

Forbes Walker and Debbie Joines
University of Tennessee

Across the Mississippi River basin non-point source phosphorus losses from the landscape contributes to water quality impairments. In response to concerns about the impact of nutrients (nitrogen and phosphorus) on water quality in the Basin and the Gulf of Mexico, each state has developed and is implementing strategies to reduce nutrient losses. Understanding the potential sources of phosphorus is an important step in developing successful implementation strategies.

In Tennessee soil phosphorus levels vary across Tennessee depending on geology, soil fertility management and land-use. In this presentation we will summarize the results of over 130,000 soil samples submitted to the University of Tennessee Soil, Plant and Pest Center by landowners, famers, and residences from all counties in Tennessee between 2008 and 2016. Soils testing highest for phosphorus tended to be in middle Tennessee due in part to the geology but also land-use.

## SESSION 1B

### STREAM RESTORATION
### 1:30 p.m. – 3:00 p.m.

*Channelized: Is All Hope Lost for West Tennessee Streams?*
Heather Meadors

*Characterizing TN Stream Morphology: Developing Statewide Regional Curves to Aid in Stream Restoration Design*
V. Jones

*Stream Restoration to Address TMDLs*
Ken Barry and Patrick McMahon

### STREAM RESTORATION AND BANK STABILIZATION
### 3:30 p.m. – 5:00 p.m.

*Streambank Stabilization*
Andrew Simon, John Schwartz, and Patrick McMahon

*Contrasting Approaches for Stream Bank Stabilization*
Ken Barry, Michael Pennell, Patrick McMahon, and Brent Wood

# CHANNELIZED: IS ALL HOPE LOST FOR WEST TENNESSEE STREAMS?

Heather Meadors

## ABSTRACT

The waterways of West Tennessee have long been described as straight ditches, devoid of habitat and filled with muddy water. These rivers and streams have had a history of negative impacts from human alterations, the worst being channelization. The effects of decades-old alterations are ongoing and include habitat degradation, increased erosion and sediment loading (Tennessee Department of Environment and Conservation, 2014). Additionally, many channels in urban areas have been concrete lined, causing permanent loss of habitat. Despite these challenges, all hope is not lost for stream quality in West Tennessee. The region still maintains functioning, diverse streams including the scenic Hatchie River and many of its tributaries. The Hatchie River, in combination with its large forested floodplan, provides habitat for a rich diversity of aquatic and terrestrial species (TN.gov, 2016). To improve altered streams, there are many current efforts, including projects conducted by the West Tennessee River Basin Authority (WTRBA) to restore or stabilize streams to functioning systems. In 2016, the Tennessee Department of Environment and Conservation Division of Water Resources and WTRBA began a new cooperative approach for stream restoration in these highly altered river basins and it is hoped that many successes for West Tennessee streams will come from this partnership.


Figure 1: Two streams in West Tennessee.

## REFERENCES

Tennessee Department of Environment and Conservation, 2014, The Status of Water Quality in Tennessee--The 2014 305(b) report: Nashville, Tennessee, Division of Water Resources, p. 67-69.

TN.gov, 2016, Hatchie Scenic River-- https://tn.gov/environment/article/na-sr-hatchie

# CHARACTERIZING TN STREAM MORPHOLOGY: DEVELOPING STATEWIDE REGIONAL CURVES TO AID IN STREAM RESTORATION DESIGN

Authors: Vena Jones, Tennessee Dept of Environment and Conservation
Greg Jennings, PhD P.E., Jennings Environmental, LLC
Jason Zink, PhD, Jennings Environmental, LLC

The TN Dept of Environment and Conservation has spent the last two years evaluating stream channel morphology on a Level III Ecoregion scale. TDEC has used this information to develop regional curves that relate bankfull channel dimensions (i.e., width, depth and cross-sectional area) and discharge to watershed drainage area. These curves, and their associated regression equations, were developed to assist practitioners in identifying the bankfull stage in ungaged watersheds and estimating the bankfull discharge and dimensions for river studies and natural channel designs. This tool can also be used as an aid in designing a pilot or low flow channel within flood control projects. This talk will cover the development of statewide regional curves, how to access the information, and how practioners may use them to develop stable stream rehabilitation projects across the state.

# STREAM RESTORATION TO ADDRESS TMDLS

Ken Barry, PE, D. WRE[1]; Patrick McMahon, PhD, PE[2]

Under the Clean Water Act, states are required to develop Total Maximum Daily Loads (TMDLs) for their pollutant impaired waters. Structural and Non-Structural Best Management Practices (BMPs) are frequently used to address non-point source TMDL pollutants of concern. These often include public education, ordinances/rules/regulations, street sweeping, bio retention, detention features, permeable pavement, etc. Stream restoration projects are, on the other hand, often undertaken to address compensatory mitigation requirements for impacts to jurisdictional waters. However, stream restoration projects have the potential to address TMDL pollutants of concerns such as sediment, nitrogen, phosphorus, and bacteria in a manner that is potentially more cost effective than some other traditional BMPs. This presentation will outline the relationship between TMDLs and stream restoration and will review the stream restoration crediting program being used in the Chesapeake Bay region to address sediment and nutrient reduction goals and the possible implications of its application for TMDL compliance in Tennessee.

# STREAMBANK STABILIZATION

Andrew Simon, John Schwartz, and Patrick McMahon

This session will include an audience/panel discussion.

## CONTRASTING APPROACHES FOR STREAM BANK STABILIZATION

Ken Barry, P.E., D. WRE; Michael Pannell, CPESC;
Patrick McMahon, Ph.D., P.E.; Brent Wood, P.E.

"Traditional" engineering approaches for stream bank stabilization have generally involved use of hard armor such as riprap or concrete. While these techniques certainly have their place, numerous bioengineering techniques for slope stabilization are now available to engineers and can provide greater habitat value and lower cost installations. Bioengineering techniques such as brush layering, live stakes, and live fascines can be used alone or in combination with more traditional approaches depending on the site constraints and project objectives. Three stream bank stabilization case studies are presented. For each case study we will discuss the site constraints, regulatory environment, design approaches, bank stabilization techniques utilized, and construction issues involved. Approaches to preserve existing, though potentially distressed, large trees in the stream bank will also be discussed.

## SESSION 1C

## HYDROLOGICAL AND WATER SUPPLY MODELING
**1:30 p.m. – 3:00 p.m.**

*Ecological Flows Analysis to Identify Thresholds of Water Withdrawal Scenarios and Stream Fish Community Responses*
Lucas Driver, Rodney Knight, and Jennifer Cartwright

*Moving Reservoir Water Supply Yield Analysis into the 21st Century*
Dave Campbell

*Quantifying the Evolution of Soil Surface Roughness as a Function of Rainfall Intensity*
Christos P. Giannopoulos, Benjamin K.B. Abban, A.N. (Thanos) Papanicolaou, Dimitrios C. Dermisis, Kenneth M. Wacha, Christopher G. Wilson, and Mohamed Elhakeem

## GROUNDWATER HYDROLOGY
**3:30 p.m. – 5:00 p.m.**

*Implications of Water Balance for Recharge of the Memphis Aquifer in a Small, Incised Urban Stream Valley*
W. Simco, D. Larsen, B. Waldron, S. Schoefernacker, and J. Eason

*Statistical Evaluation of Landfill Leakages in Karst Areas*
Wanfang Zhou

*Estimating Groundwater Flow Using a Bail Test During Local Water Table Lowering*
Ingrid Luffman, Sydney Lawson, and Arpita Nandi

# ECOLOGICAL FLOWS ANALYSIS TO IDENTIFY THRESHOLDS OF WATER WITHDRAWAL SCENARIOS AND STREAM FISH COMMUNITY RESPONSES

Lucas Driver, Rodney Knight, Jennifer Cartwright
USGS Lower Mississippi-Gulf Water Science Center

Water management and conservation efforts can benefit from scientifically-sound guidelines for the permitting of water withdrawals that maintain ecological health in streams while simultaneously maximizing water availability for industry, agriculture, drinking water, and waste treatment. Percent-of-flow (POF) standards are useful management tools because they are well-suited to preserving natural flow variability and are computationally and conceptually simple and thus relatively easy to communicate and implement.

We investigated the effects of incremental withdrawal scenarios on stream flow characteristics and fish communities in from 177 sites within the Tennessee and Cumberland River drainages. To discern ecological effects of hydrologic conditions under various withdrawal scenarios, suites of streamflow characteristics (SFCs) were calculated to summarize daily time-series streamflow data and statistically related to published ecological limit functions. Preliminary results indicate that ecological limit functions and simulated withdrawal scenarios can be successfully used to identify thresholds for the maximum streamflow that can be withdrawn before significant deterioration of fish community structure occurs.

This study fills a key gap between emerging ecological-flows research and implementation of water-management policy by predicting hydrologic and ecological responses to water withdrawal. Results from this study are directly applicable to management decisions related to the permitting of water withdrawals within the Tennessee and Cumberland River basins. Moreover, the approach developed for this study should be transferable to other areas within the eastern United States.

# MOVING RESERVOIR WATER SUPPLY YIELD ANALYSIS INTO THE 21ST CENTURY

Dave Campbell, P.E., D.WRE[1]*
Presented by John Harrison, Schnabel Engineering, LLC

## 1. INTRODUCTION

For water supply projects where projected unmet demand can't be supplied by wells or direct river diversions, water storage reservoirs are essential for providing a reasonable level of water supply reliability to validate a water utility's reliability (safe yield) during droughts. Safe yield analysis for water supply reservoirs in the Southeast United States, and most other states as well, rely upon basic procedures that were developed many decades ago. For a given set of facilities and processes at a given location, safe yield is commonly defined for as the rate at which water can be reliably delivered throughout the drought of record for a nearby reference stream.

Depending upon available site settings, water supply safe yield, mitigation and other considerations, water supply reservoirs tend to range in cost from about \$8 to \$12 million per million gallons per day (mgd) of safe yield. This ballpark cost is for the source of supply only. It does not include transmission, treatment or distribution. Therefore, a 10 mgd reservoir can be expected to cost about \$100 million. Given the significant costs involved, analyses for planning and permitting would derive value from applying the best approaches to data application and analysis techniques. Unfortunately, these considerations are not broadly understood by many utilities, and are not accepted by many regulators.

## 2. OVERVIEW OF PLANNING CONSIDERATIONS

To contain an already lengthy paper, this document will confine itself to major factors affecting source water demand and supply to illustrate practice and areas of concern. For water supply reservoirs, it is common practice to project the level of water supply need fifty years out. An extended timeframe is definitely merited, given that it is not unusual for planning, permitting, detailed surveys, geotechnical site investigations, design, bidding, project construction, and reservoir filling to take twenty or more years. About half of the total project development time usually involves permitting activities.

Over the past two to three decades, there has been significant change in water supply planning regulatory processes. Over time, permitting for reservoirs has required the applicant to perform more analyses and the level of detail of those analyses have become much more rigorous. Twenty years ago, there was limited scrutiny of population projections, per capita demand estimates, yield analysis parameters, water system operations and drought contingencies.

Some additional scrutiny from two decades ago may have had merited to cull out those that might have biased the process. However, engineering parameters and analysis processes are now thoroughly dissected and questioned on an individual basis. Each consideration now has to withstand distinct scrutiny and stand alone. Individual considerations are critiqued and

[1] Schnabel Engineering, 1380 Wilmington Pike, Suite 100, West Chester, PA 19382 davec@schnabel-eng.com

questioned in a manner that tends to minimize the magnitude of the required solution. A set of pre-minimized individual considerations are then merged into an overall analysis framework to derive an outcome. This process is both flawed and biased, and regulators are well aware that the integration of a set of pre-minimized elements provides for a minimal solution – one with a marginally small probability of meeting the unmet need being addressed.

Many regulators have continued to claim climate change to be "speculative", despite all major federal agencies involved with climate and/or water resources having policies that require consideration of climate change (Example statements below).

> "*It is the **policy of USACE** to **integrate climate change preparedness and resilience planning and actions in all activities** for the purpose of **enhancing the resilience of our built and natural water-resource infrastructure** and the effectiveness of our military support mission, and to **reduce the potential vulnerabilities of that infrastructure and those missions to the effects of climate change and variability**.*" [1]– United States Army Corps of Engineers (2014) (Author emphasis)

> "***In the face of a changing climate**, **resilient and adaptable drinking water**, wastewater and stormwater utilities (water sector) ensure clean and safe water to protect the nation's public health and environment by ma**king smart investment decisions to improve the sustainability of their infrastructure** and operations and the communities they serve …*" [2] - United States Environmental Protection Agency (2016) (Author emphasis)

## 3. CONVENTIONAL DEMAND SIDE CONSIDERATIONS

In planning for a new or expanded reservoir water supply, a fifty year population projection, and projection of industrial use are the primary bases for assessing total demand. Projected population is translated to water demand based on a projected per capita potable water use. Per capita use either incorporates drought reductions or reservoir storage is used to trigger demand reductions for significant reservoir drawdowns. It is common for residential and commercial uses to be aggregated, but each is occasionally computed separately [Ex., 250,000 population X 120 gallons per capita per day (gpcpd) = 30 mgd]. Projected industrial use is added to aggregated residential and commercial water usage to arrive at total system demand. This total demand is then reduced by the safe yield of current supplies (less any loss of yield over time) to define what is commonly termed unmet demand. The unmet demand is the target safe yield value for additional water supply needed to meet growing demands throughout the planning period.

Demand side analysis appears to be a very straight-forward and logical approach to defining unmet demand. If the values applied to the process were robust and accurate, the findings would be logical. However, projecting population 50 years into the future is extraordinarily challenging and rife with uncertainties. Setting a per capita demand value for residential and commercial use 50 years into the future is also quite challenging. Projecting industrial water

[1] http://www.corpsclimate.us/docs/USACE_Adaptation_Plan_Policy_2014Jun27_highres.pdf
[2] https://www.epa.gov/sites/production/files/2016-04/documents/final_2016_nwp_climate_workplan.pdf

demand 50 year out requires a crystal ball. None of these critical inputs are more than guesses, backed by some calculations to make them appear to have rigor.

## 4. DEMAND SIDE SHORTCOMINGS

Current application of 50-year population projections will be used illustrate the failings of current common demand side practice. Other issues related to demand projections (e.g., per capita consumption and industrial demand projections) are also problematic in some jurisdictions. To assess the effectiveness of using long-range, deterministic population projections, Bureau of the Census Document P25-1130[1], published in February 1996, was selected to allow both backward and forward looks at population. This document provides historic population statistics through 1995 and projections from 1995 to 2050. Page 29 of the referenced report defines population estimates as follows:

> "*The* ***history of population projections*** *has shown that unfo****reseen events can rapidly modify the demographic environment****. The actual future population is never identical to the projected population. Although attention has been paid to problems of estimating the forecast accuracy of past population projections and the confidence intervals of future populations,* ***many problems remain before a method can be developed for placing reliable confidence intervals around population projections****. There is considerable controversy over the means of handling improvements in methods, changing variability in population growth rates, and other complicating factors. Given these difficulties, the hig****hest and lowest series in this report were not chosen on the basis of a formal analysis of error ranges****, but rather on the basis of the long-standing approach of projecting a 'reasonable high' and a 'reasonable low.'*" (Author emphasis)

This document provides United States population growth projections for Low, Middle and High categories to reasonably envelop United States population growth. In P25-1130, the Bureau of the Census presents the following 55-year United States population growth findings:

- Reasonable Low – 7%
- Middle Range – 50%
- Reasonable High – 97%

"Reasonable" 2050 population projections (between the high and low bands) for the United States as a whole are bounded by a range from a reasonable low of 107% to a reasonable high of 197% of the Year 1995 basis values. Using the range from reasonable low to reasonable high, these values create estimated 2050 United States populations from 283 million (20 million more than Year 1995 population) to 519 million, a 1995 to 2050 population growth of 256 million. Year 2050 population within the "reasonable range" can vary by 236,000,000 people. If they are a part of the population, they will need to have 23,600 mgd (or 26.8 million acre-feet per year).

To convert national population growth to present a more simplified picture, 0.1% of national population is used to characterize more typical water utility service population. This simplified example translates the population growth discussed in the previous section; reasonable low

[1] http://www.census.gov/prod/1/pop/p25-1130.pdf

projection of 20 million through the Year 2050, and reasonable high projection of 256 million through the Year 2050; to a utility growth range between 20 thousand and 256 thousand. Also for simplicity, 100 gpcpd has been assumed and includes only residential demand for projections. Note that high demand growth is nearly 13 times the low demand growth.

Assuming all other factors are off the table, the commonly applied rules would define the best that the applicant could hope for is a mid-range population growth value of 131 thousand (at 1% of national population growth). If the project moves ahead based on the mid-range population estimate considered as a fixed value, the water utility could develop facilities to deliver about 11 mgd of excess source water for the planning period, could short itself by 12.5 mgd in source water (and likely run out of water 20 years prior to the end of the planning period, OR likely end up somewhere in between. With about $50 to $200 million in new source water capital costs on the line, updated and more refined approaches to reservoir source water projects are sorely needed.

Additionally, projections for smaller geographies, by definition, engender higher and higher levels of uncertainty.

> "Smaller geographies – even counties – historically experience broader growth trend fluctuations than regional or state forecasts. Bigger areas benefit from larger numbers that tend to smooth out local variations that are hard to predict or near impossible to expect."[1]

This and a number of other demand based issues, that go beyond the scope of this paper, deserve more thoughtful attention to arrive at solutions that better validate water resources allocations and protect water utilities from wasteful over- or underspending. It is also interesting to note that from 1995 until about 2005, actual United States population exceeded the "reasonable high" of the Census Bureau estimates. Year 2016 actual population was just below the "reasonable high and exceeded the "reasonable low" for Year 2050 by 15%.

Demand Side Givens:

- National 55-year population projections from mid-level values to "reasonable high" or "reasonable low" estimates for projections were assessed by the Bureau of the Census to indicate a 45% +/- variation,
- *Actual population for the first two decades* of the cited projections were found to either be above or closely approximate the "reasonable high" projection values, and
- Projections for smaller geographies further increase projection uncertainties. Assuming similar levels of technical rigor, Tennessee population estimates are, by definition, less accurate (on a percentage basis) than National estimates for the same projection period.

Therefore:

Given the facts presented above, the common practice of locking in on a single calculated population projection or a mid-range population projection poorly serves:

- A process highly deserving of much better than biased and/or antiquated project considerations,

[1] http://www.oregonmetro.gov/sites/default/files/2014UGR-Appendix-1b-forecast-FAQ-Final.pdf, Appendix 1b, page 7 of 12

- Opportunities for water utilities to achieve prudent and rational facilities planning and capital investments, and
- The critical need for stewardship in administering reasoned and justifiable allocation of water resources.

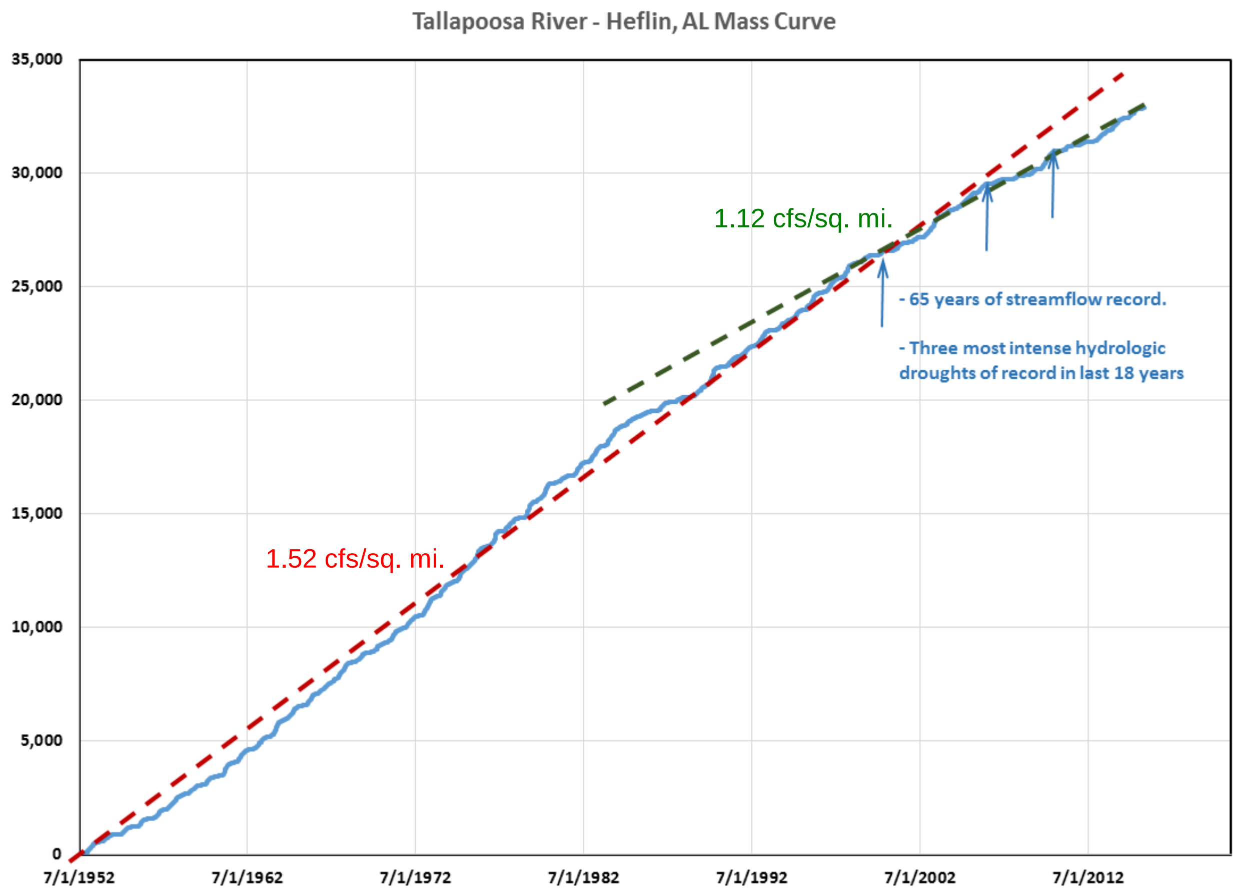
## 5. CONVENTIONAL SUPPLY SIDE CONSIDERATIONS

Conventional reservoir planning/permitting activities focus first on defining unmet demand, which in many jurisdictions is interpreted as a fixed demand added to existing sources of supply (also fixed values) to serve a total demand achieved at the end of the planning period. For a given set of facilities and processes at a given location, safe yield is commonly defined for as the rate at which water can be reliably delivered throughout the drought of record for a nearby reference stream.

Supply side considerations are assessed through water balance analyses. The process begins with the reservoir full and the net of all inputs and outputs are used to adjust the reservoir storage, with full design storage as a maximum. Inputs include natural runoff into the reservoir, pumped diversion into the reservoir (if so equipped), rainfall onto or evaporation off of the reservoir surface (seasonally varied), water supply withdrawals, environmental flow releases to the stream below the dam, and spillway discharges. Through daily water balances, reservoir storage is computed. The water supply withdrawal rate that maintains storage at or above a defined minimum value (such as 25% of full storage) is defined as the safe yield. It is typical for diversion projects, where pumping from a river delivers water to a reservoir on a small tributary stream, to assess combinations of pumping capacity and reservoir storage to balance diversion stream habitat, cost, and project resilience.

## 6. SUPPLY SIDE SHORTCOMINGS

While a number of considerations affect the availability of withdrawals sufficient to validate projected demand, the discussion will focus on streamflows as a dominant consideration and one that is too often currently applied without appropriate considerations. In assessing streamflows, several decades ago, there was near certainty that historical records captured the highs, lows, means and variations of streamflow to be expected in the future. This is known as stationarity. Much has been learned about climate since that time. The mass curve below of the Tallapoosa River near Heflin, Alabama shows a clear break at the end of the 1990s. The red line represents average flow volume per square mile to 1999, with the green line representing average flow volume per square mile from 1999 to the present. The three most intense droughts for this 65 years of record have occurred in the last 18 years.



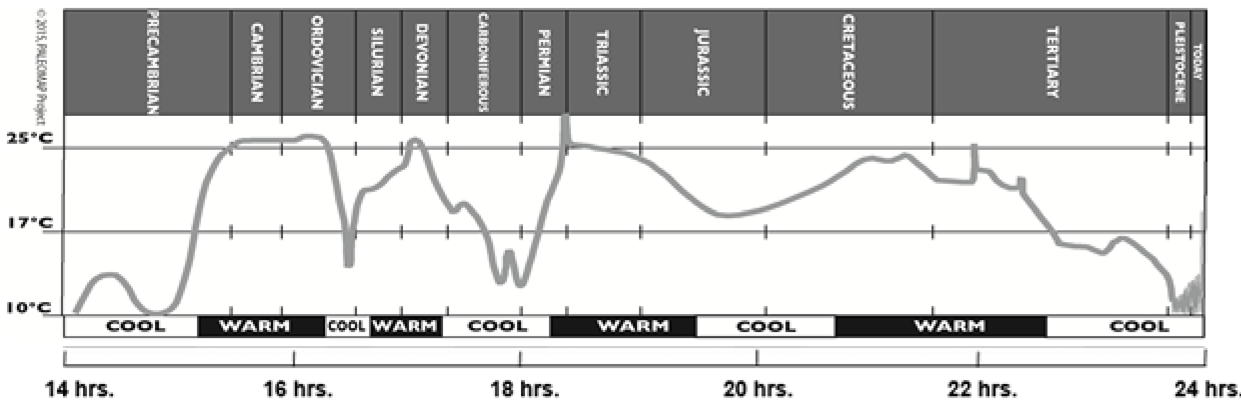

In some cases, projects located near one another, but residing in different watersheds, will be tested against droughts of much different severity (different reference gages selected due to watershed). While floods are analyzed based on a regionalized rainfall basis, droughts are most commonly tied to a single stream gage, and adjacent gages can reveal significantly differing drought severities. Many jurisdictions also retain yield values developed when a water supply reservoir is first permitted and developed, even though these sites have been subjected to much more severe drought flows at later dates.

Through reconstruction of prerecorded climate over hundreds of years to billions of years timeframes, and the many active climate models that have been developed or are being enhanced, it is clear that for longer periods of time, stationarity has never existed, and now, even for moderate periods of time, stationarity is dead and memorial services are long overdue.

We are immersed in media coverage and concerns related to global warming, climate change and climate variability, which represent a range of perspectives, time scales, and word choices.
It needs to be understood that a broad range of perspectives are still active with regard to the origins and impacts of climate change. Not everyone (including this author) is bought into the dominant thesis that it's dominantly manmade. Climate change has attained cultural momentum

and become a major pop culture theme. While the concept has become popular, we're not dealing with a popularity contest.

If one takes the long view of the situation – say around 4.5 billion years - the purported age of our planet – it is easy to see that change has been with us from the very beginning, and there is no reason for us to believe that things have somehow settled out. Recognizing that the Earth was thermally unstable until the molten rock solidified and the planet cooled enough to support liquid water. Everything had settled out prior to the last two billion years, except for cyclic trends between hot-house and ice-house conditions (illustrated in the graphic below[1]).




If the age of the earth is shrunken to represent a single day, there appear to have developed fairly regular two-hour supercycles of fluctuating greenhouse and icehouse conditions, each carrying shorter term variations to add a touch of complexity. Continuing the 24 hour earth history analogy, the last ice age ended 0.2 seconds ago - and a Medieval Warm Period occurred about 0.02 seconds ago. Also notice that today's temperatures are only modestly higher than the ice age minimums so, practically speaking, there's nowhere to go but up. How do the effects of fossil fuel emissions compare to natural cycles that have created a long-term 17° C (30° F) swing in average annual global temperature over the past two billion years or more, with periodic accents by volcanic eruptions, periods of intense solar flares and other natural phenomena?

I consider myself a global warming agnostic. I can't dispute that the activities of man have an effect on the environment, but it's more difficult to define globally, and even more difficult to separate man's activities from a plethora of naturally occurring conditions related to global temperature. A portion of my skepticism regarding the magnitude of human influence comes from cases of cooking the books, and emotional pushback to those I have come to know as 'global warming enthusiasts' – those that for a range of personal reasons find the idea of man-induced climate change suited to their purposes and, therefore, deem to make it so.

Jennifer Marohasy, a highly-regarded Australian biologist, made this poignant observation:

[1] http://scotese.com/climate.htm, PALEOMAP PROJECT

"A consensus of 60 or 60,000 scientists is not science. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means he or she has results that are verifiable with reference to the real world. There is a need to take environmentalism out of science. This is going to be even harder than moving beyond politics, because religion can be even harder than politics to deal with."

Recognition of the dynamic nature of our planet's climate becomes a brilliant statement of the obvious. Therefore, as I see it, the debate relates primarily to the extent to which man's activities have influenced a powerful natural engine of thermal dynamics, both internal and external to our earth, that has continued unabated for more than 2 billion years.

Supply Side Givens:

- Streamflow stationarity is dead. Too many practitioners and regulators involved with reservoir yield, and likely other climate related issues, haven't gotten or don't want to get the message.
- Temperatures are rising. The direction is upward because the current global temperature is about $4^{0}$C higher than the minimums over the past two billion years. Rising temperatures will increase atmospheric energy, and the conclusions of the experts that both more intense storms and longer and more intense droughts will occur seem to be rational.
- Analyzing droughts based on a single streamflow gaging station, many times with the records having to be transposed to the project site, inherently opens the door to far greater variability than if regional analyses were used as a basis. The 2007 drought in Georgia was far more intense in West Georgia than in the Atlanta Metro Area (about 50 miles away), but only by chance.

Therefore:
Given the facts presented above, consensus techniques need to be developed to:

- Fill the gap with simplified interim procedures to be used while bigger changes are developed and agreed upon,
- Assess project droughts (intensity and duration) on a regional basis, and
- Using the best of the climate models, calibrate historic streamflows to reflect best estimates of drought period streamflow reductions and increases in drought durations.

As overall project guidance applicable to all parties:

- Evaluate Risk Analysis as a tool for characterizing inputs as either fixed value, Monte Carlo based probabilities or other meaningful bases; and defining water supply failures in terms of probabilities and consequences (dollars and lives).
- There is a critical need for collaborative stewardship in administering reasoned and justifiable allocation of water resources. Given the inherent uncertainties, unknowns and, sometimes, unknowable's, pinning fixed numbers to represent reality 50 years into the future is futile and wasteful to all parties and interests. It is far better to undertake rigorous analyses to get it as right as we can, and then to build contingencies into the project design and/or operations to accommodate supplemental actions if the project demand is not being utilized or if demand growth exceeds expectations.

# QUANTIFYING THE EVOLUTION OF SOIL SURFACE ROUGHNESS AS A FUNCTION OF RAINFALL INTENSITY

Christos P. Giannopoulos, Benjamin K.B. Abban, A.N. (Thanos) Papanicolaou, Dimitrios C. Dermisis, Kenneth M. Wacha, Christopher G. Wilson, and Mohamed Elhakeem

This study examines the evolution of soil surface roughness as function of rainfall intensity starting from a smoothened bare soil in agricultural landscapes. These conditions have not been examined in the literature as most studies have focused on an initially disturbed surface with initial length scales greater than 2 mm and varying between 5 – 50 mm. Three representative rainfall intensities, namely 30 mm/h, 60 mm/h and 75 mm/h, from a rainfall simulator were applied over a smoothened bed surface in a field plot. Soil surface elevations were measured before and after each applied intensity with a microtopographical surface-profile laser scanner (resolution <0.5 mm). Two indices were used to quantify soil surface microroughness, which were the Random Roughness index and the crossover length. Findings show a consistent increase in roughness under the action of rainfall for initial microroughness length scales of 2 mm. Analysis shows that on average the Random Roughness index and the crossover length increased by multiples of 3.15 and 1.9, respectively. This contradicts existing literature where a monotonic decay of roughness of soil surfaces with rainfall is recorded for disturbed surfaces. Results of this research reveal the existence of a characteristic scale of roughness in the magnitude of 2 mm that distinguishes smooth from disturbed surfaces.

# IMPLICATIONS OF WATER BALANCE FOR RECHARGE OF THE MEMPHIS AQUIFER IN A SMALL, INCISED URBAN STREAM VALLEY

W. Simco, D. Larsen, B. Waldron, S. Schoefernacker, J. Eason

The Memphis aquifer is the most important source for groundwater in western Tennessee; however, recharge processes to the aquifer are poorly understood. Previous studies have shown that in rural areas recharge occurs more efficiently in stream gullies with sand bottoms than in upland terraces. The same is expected in urban streams where the Memphis Sand is exposed. Water balance research of Sandy Creek in Jackson, Tennessee, provides information regarding infiltration and potential recharge to the Memphis aquifer that may be typical urban stream valleys where in the aquifer is exposed.

The West Tennessee River Basin Authority has completed several stream restoration projects in western Tennessee; however, their work has not included quantifying the hydrologic impact. In the present study, pre-stream restoration hydrologic data from the Sandy Creek has been collected since February 2016. The hydrologic analyses include grain-size analysis of soil and sediment, soil-water analysis by tensiometer, lysimeter and neutron-probe moisture measurements, discharge estimates using stage-discharge relationships, as well as weather data from an on-site weather station. Preliminary data show that the upper reach of Sandy Creek is ephemeral. Discharge is present only during storm events and stream flow rapidly dissipates following precipitation events, presumably due to infiltration into the stream bed. Soil moisture data indicate a seasonal shift in water retained in the soil column, with peak soil water storage during winter to early spring and steady drying through the late fall. Effective moisture (P - ET) is consistent with soil moisture observations with positive values for all months of the year except October and November. Recharge will be estimated by considering daily water balance (P – ET – R) integrated over the drainage basin.

**NOT AVAILABLE**

# ESTIMATING GROUNDWATER FLOW USING A BAIL TEST DURING LOCAL WATER TABLE LOWERING

Ingrid Luffman[1]*, Sydney Lawson[1], and Arpita Nandi[1]

## INTRODUCTION AND BACKGROUND

The ease with which groundwater moves through porous media is quantified by hydraulic conductivity (K), and may be measured through both lab and field methods. Lab methods may include empirical grain size distribution methods and permeameter tests, while in the field, auger hole tests and well tests are common methods for estimating K. With a well test, water is removed from the well (or introduced into the well), and recovery drawdown is measured, yielding parameters which are later used to estimate K. Estimating K for an aquifer provides information about the movement of groundwater in the subsurface, and is an important component of Darcy flow and transmissivity estimates which themselves are important for water resources management.

This research presents the results of a well bail test performed at the Outdoor Soil and Water Laboratory on the East Tennessee State University Valleybrook Campus in Washington County, TN. The age of the well is unknown; it is the well previously used to water livestock on the farm that once occupied the property. No well records exist, and little is known about the aquifer other than it is unconfined. The well has an inner diameter of 79 mm and a depth of 8.25 m, measured using a plumb line, and the screened length is unknown but assumed to fully penetrate the well below the water table.

## METHODS

The Hvorslev bail test method was selected because it is an appropriate method to calculate K using a single well in an unconfined aquifer of unknown thickness, under the assumption that the material surrounding the well is representative of the aquifer material (Fetter, 2001). Depth to water was recorded using a Solinist 101 #366 water level meter. Next, two slugs of water (6.6 L total) were bailed successively, and depth to water was measured immediately and at timed intervals during a sixteen-week recovery period. Initially the measurement interval was 30 seconds, which was lengthened as the well's recharge rate slowed.

Drawdown was calculated as $h_t - h_{static}$, where $h_t$ is depth to water at time t and $h_{static}$ is initial depth to water prior to bailing. Recovery was calculated for each time step using $\Delta h_t = (h_t - h_{static})/(h_0 - h_{static})$, where $h_0$ is depth to water at time $t=0$ immediately after bailing. Recovery data versus log(time) were plotted and $t_{37,}$ the time at which $\Delta h_t = 1/e = 0.368$ (where $e=2.718$ is the mathematical constant Euler's number), was calculated and employed in the Hvorslev equation (Hvorslev, 1951) to estimate K,

[1] Department of Geosciences, East Tennessee State University, 325 Treasure Lane, Johnson City, TN 37614
luffman@etsu.edu

$$K = \frac{r^2}{2Lt_{37}} \ln\left(\frac{L}{R}\right)$$

where $r$ = radius of the well casing, $R$ = radius of the well screen, and $L$ = length of the well screen. This equation is applicable for wells with a length more than 8 times the radius of the well and it was assumed that the well was screened along its saturated depth, measured from the static level to the base of the well.

## RESULTS AND DISCUSSION

The well recovered as expected for 22 hours, after which depth to water began to increase, likely related to pumping of monitoring wells at a nearby landfill (Figure 1). To account for this, the local water table trend was modeled using linear regression on the late drawdown data and the slope of the regression line was used to detrend all drawdown data. Subsequently, $\Delta h_t$ was calculated using the detrended drawdown data, and modeled using linear and exponential models.

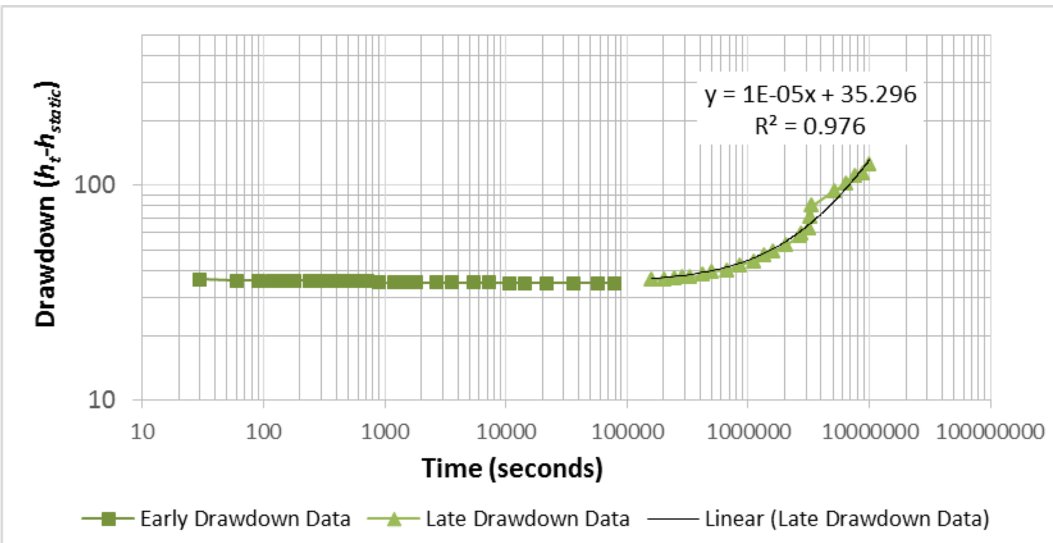



**Figure 1.** For the first 22 hours ($1x10^5$ seconds) of recovery, depth to water decreased, after which it began to increase as the local water table dropped.

A short period of acceleration in the water table drop occurred 38 days ($3x10^6$ seconds) into the observation period, which partitioned the $\Delta h_t$ dataset into two groups (Figure 2). Both groups were modeled using linear and exponential trend lines (equations displayed on Figure 2) producing four estimates for $t_{37}$ and four K values ranging from $1.78 \times 10^{-10}$ to $4.58 \times 10^{-10}$ m/s (Table 1). The small range suggests that the K estimate is not sensitive to the choice of trend model, and the detrending method used here is appropriate for removal of local variations in the water table outside of a well's area of influence. K estimates calculated in this study are smaller than USDA reported K values for shallow soils at this site.

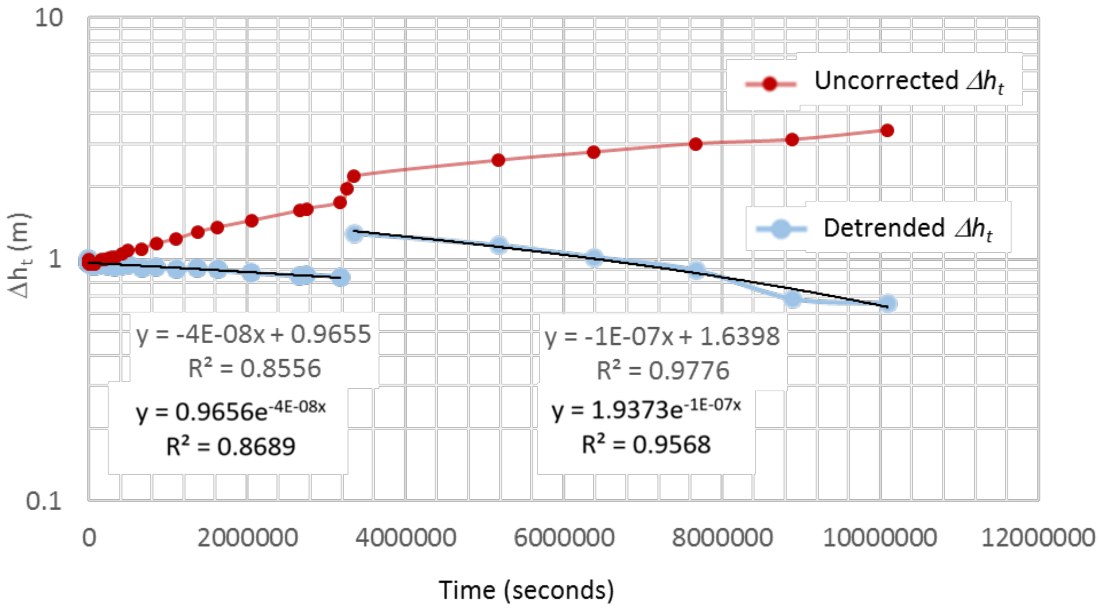



**Figure 2.** Exponential and linear regression models were fit to two partitions of the detrended recovery. Raw (uncorrected) data are shown for comparison.

**Table 1.** Recovery time $t_{37}$ and calculated hydraulic conductivity (K).

| | | $T_{37}$ (s) | K (m/s) |
|---|---|---|---|
| Partition 1 | Linear model | 14,937,500 | $2.88 \times 10^{-10}$ |
| | Exponential model | 24,115,000 | $4.58 \times 10^{-10}$ |
| Partition 2 | Linear model | 12,718,000 | $1.78 \times 10^{-10}$ |
| | Exponential model | 16,609,000 | $3.51 \times 10^{-10}$ |

## CONCLUSION

Hydraulic conductivity was measured for a well in an unconfined aquifer of unknown thickness using the Hvorslev bail test method. A drop in the local water table during recovery was modeled using regression, and drawdown data were detrended. Hydraulic conductivity values calculated using various best-fit models were consistent, ranging between $1.78 \times 10^{-10}$ and $4.58 \times 10^{-10}$ m/s, which is smaller than the USDA reported K values for soils at this site.

## REFERENCES


Fetter, C.W., 2001. *Applied hydrogeology,* 4th Edition. Upper Saddle River, NJ: Prentice Hall.

Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.

## SESSION 2A

### ALGAE AND NUTRIENTS
### 8:30 a.m. – 10:00 a.m.

*Structure of Algal Assemblages and Trophic State of Streams in Middle Tennessee: A Project Supported by the Tennessee Healthy Watershed Initiative*
Jefferson G. Lebkuecher, Molly R. Grimmett, Arianna L. Ackerman, and Tsvetan M. Tsokov

*Efforts to Reduce Hypoxia in the Gulf of Mexico by Reducing Nutrient Losses from Tennessee*
Forbes Walker

*A Simple Way of Calculating Site-Specific Threshold Nutrient Concentrations Based on a Targeted Chlorophyll_A*
Ming Shiao and Sherry Wang

### WATER USE AND AGRICULTURE
### 10:30 a.m. – 12:00 p.m.

*Evaluating Water Supply Conflicts Between Urban and Agriculture Uses*
Brandy Manka

*Conservation Management Practices for Agroecosystem Sustainability*
S. Jagadamma

*Water Budgets for Tennessee Dairy, Broiler, and Beef Cattle Farms*
Shawn Hawkins, Forbes Walker, and Chris Clark

### DAM REMOVAL
### 1:30 p.m. – 3:00 p.m.

*Water Quality Implications and Permit Requirements for Dam Removal in Tennessee*
Robert D. Baker

*The Benefits and Issues Associated with Lowhead Dam Removal: A Case Study of the Removal of the Remnants of Brown's Mill Dam on the East Fork of the Stone's River*
Pandy English

*Preparations for Dam Removal in Athens, Tennessee*
Forbes Walker, Andrea Ludwig, Mike Essington, Shawn Hawkins, Lena Beth Reynolds and Paul Ayers

## RESTORATION TO IMPROVE ECOLOGICAL CONDITIONS
## 3:30 p.m. – 5:00 p.m.

*Regulatory Program Updates – U.S. Army Corps of Engineers, Nashville District, Regulatory Division*

*Clinch Powell Clean Rivers Initiative—A Bi-State Watershed Coalition Restoring One of North America's Most Biodiverse River Systems*
Brad Kreps

*May 26, 2016 Permittee-Responsible Mitigation Guidance: Implications for Prospective Applicants*
Brady McPherson

# STRUCTURE OF ALGAL ASSEMBLAGES AND TROPHIC STATE OF STREAMS IN MIDDLE TENNESSEE: A PROJECT SUPPORTED BY THE TENNESSEE HEALTHY WATERSHED INITIATIVE

Jefferson G. Lebkuecher[1], Molly R. Grimmett, Arianna L. Ackerman, and Tsvetan M. Tsokov

The Tennessee Healthy Watershed Initiative (THWI) is a partnership among the Tennessee Department of Environment and Conservation, Tennessee Valley Authority, Tennessee Chapter of The Nature Conservancy, and West Tennessee River Basin Authority. Funding by the THWI to determine the structure of algal assemblages in Middle Tennessee streams provided base-line data needed to monitor changes of water quality. The composition and biomass of photoautotrophic periphyton and concentration of total phosphorous of benthic organics at 10 stream sites in 8 watersheds were utilized to: (1) document the diversity and structure of algae assemblages, (2) evaluate the trophic state of the stream sites, and (3) calculate algae trophic indices. Over 200 algae taxa, 99 of which were not recorded previously in Middle Tennessee, were identified and percent composition recorded. The concentration of total phosphorous of benthic organics is a more accurate indicator of trophic state relative to water concentrations of soluble reactive phosphorous, $NO_2 + NO_3$ nitrogen, and total nitrogen as demonstrated by correlation analyses to benthic concentrations of chlorophyll *a*, ash-free dry mass of benthic organics, and values for algae trophic indices. Changes in habitat quality of the stream sites can be easily monitored in the future using either periphyton biomass, concentrations of chlorophyll *a*, diatom composition, soft-algae composition, or algae trophic indices given all of these analyses were used to determine biotic integrity by this study.

[1] Department of Biology, Austin Peay State University, Clarksville, TN 37044, LebkuecherJ@apsu.edu

# EFFORTS TO REDUCE HYPOXIA IN THE GULF OF MEXICO BY REDUCING NUTRIENT LOSSES FROM TENNESSEE

Forbes Walker
University of Tennessee

The hypoxic or dead zone in the Gulf of Mexico has been observed and documented since the early 1970s. Hypoxia is a natural phenomenon whereby the concentration of dissolved oxygen falls below 2 ppm and fish and other aquatic species cannot be supported. It has been hypothesized that the size of the hypoxic zone has been increasing as a result of human activities in the Mississippi river basin, including the loss of nutrients (nitrogen and phosphorus) from the landscape.

Since the 1990s the states in the Mississippi river basin have worked to develop strategies to reduce the size of the hypoxia zone through the Hypoxia task Force. In recent years, each state has developed and adopted strategies to reduce the loss of nutrients from agriculture and other stakeholders. This work is being supported by a multi-state effort by the Land Grant Universities and other partners representing each state within the Basin. This presentation will provide an overview of efforts being conducted by the University of Tennessee, the Tennessee Department of Agriculture, the Tennessee Department of Environment and Conservation and others in Tennessee to meet these goals.

# A SIMPLE WAY OF CALCULATING SITE-SPECIFIC THRESHOLD NUTRIENT CONCENTRATIONS BASED ON A TARGETED CHLOROPHYLL_A

Ming Shiao[1] and Sherry Wang[2]

The traditional method of determining site-specific numeric nutrient criteria is through using a process-based water quality model such as QUAL2K. The model is first calibrated with field measurements collected from the waterbody. Instream nutrients input to the model are then systematically reduced until modeled Chlorophyll_*a* concentration meets a pre-determined Chlorophyll_*a* target. The final instream nutrient concentrations (TP and TN) are treated as the numeric nutrient limits for the waterbody. This modeling method can be time consuming and requires significant resources for data collection. In this presentation, we introduce a quick spreadsheet calculation (nutrient-algae calculator) as an alternative to the resource intensive modeling approach.

The nutrient-algae calculator produces the amount of nutrients that yield the target Chlorophyll_*a* (or algal biomass) concentration, which is usually determined based on designated uses of the waterbody. Since the calculator is site-specific, it can be applied to a small (reference) stream as well as a large river (or lake/reservoir) with different designated uses in different portions of the waterbody. Another application of the calculator is to evaluate the limiting nutrient of a waterbody when it is difficult to determine by field data alone. It can also be used to evaluate whether a target Chlorophyll_*a* concentration is over- or under-protective of its designated uses. Examples of applying the calculator to waterbodies with different characteristics will be discussed.

The nutrient-algae calculator is science based and is transparent to all users. The intended use is to assist in regulatory decision making while also serving as an educational tool for nutrient-algae related studies.

[1] TDEC, Div. of Water Resources. Ph.D. ming.chen.shiao@tn.gov
[2] TDEC, Div. of Water Resources. Ph.D. sherry.wang@tn.gov

# EVALUATING WATER SUPPLY CONFLICTS BETWEEN URBAN AND AGRICULTURE USES

Brandy Manka
University of Tennessee

Growing population in large urban centers and climate change have the potential to influence future agricultural production in the eastern United States. The conflict between urban users and agriculture producers, particularly in terms of water supply, could arise in the Tennessee Valley and other areas in the southeast. To assess this potential conflict, the water demand for all users, particularly usage for agricultural purposes, must be quantified. In contrast to western states, Tennessee is considered a riparian law state; where landowners have rights to surface water passing through or by their property. Agricultural water withdrawals are exempt from registration and reporting requirements if the pumping station is portable, increasing the difficulty of estimating irrigation withdrawals. Alternative solutions must be developed to quantify irrigation and to manage water resources efficiently in the Tennessee Valley. Hydrological models need to be adequately calibrated with accurate information on usage and key input parameters, such as evapotranspiration and soil moisture. Supporting the hydrological modeling effort, the combination of remote sensing techniques and ground-truth data will produce a method for the estimation of these parameters. The ground-truth data includes in situ generated soil moisture and voluntary information from landowners regarding irrigation techniques, frequency, and amount. Site selection was based on farms practicing surface water irrigation in the Duck River basin in middle Tennessee that represent varying soil and crop types. Results of the advances in remote sensing techniques and hydrological simulations, which uniquely utilize the Tennessee Valley Authority's river forecast and modeling system, will be presented.

# CONSERVATION MANAGEMENT PRACTICES FOR AGROECOSYSTEM SUSTAINABILITY

S. Jagadamma

As farmland area is shrinking and food demand is growing, food production has to be increased with the support of external nutrient and crop protection inputs. Though increasing food production is a major priority, this poses a serious risk of deterioration of soil, water and environmental quality. Conservation management practices such as cover cropping, judicious application of inorganic fertilizers, reduced tillage and crop rotations play a crucial role in increasing or maintaining agronomic productivity and enhancing soil quality with attendant decrease in water quality impairments. Therefore I examined how long-term tillage, crop rotation, cover cropping and nitrogen fertilization managements influence crop productivity and soil quality for the different cropping systems of US. Results confirmed the need for wider application of location- or crop-specific conservation management practices for sustainable crop production systems.

# WATER BUDGETS FOR TENNESSEE DAIRY, BROILER, AND BEEF CATTLE FARMS

Shawn Hawkins, Forbes Walker and Chris Clark[1]

Water budgets have been developed for Tennessee beef cow, broiler, and dairy farms as part of a USDA project that emphasizes preparedness for climate change and a potentially drier climate in the southeast United States. Water consumption for a pastured beef cattle herd has been monitored at the University of Tennessee Middle Tennessee Research and Experiment Station (MTREC) for nearly two years. Weekly herd statistics and dates for calving, breeding, and weaning are recorded continuously, with consumption normalized to the number of cows/cow-calf pairs. Pastured beef cattle consume 15±7 gallons/day/cow calf pair, with total consumption varying seasonally as calves are born, nursed, and eventually weaned. Tennessee beef cattle consume approximately 15 million gallons per day, or 5.5 billion gallons/year. Likewise, water required to produce broiler chickens (i.e. directed consumed by the birds from drinker lines) varies seasonally and with the duration of the grow-out or size of finished bird. In 2013, Tennessee produced 182,500,000 broilers. At approximately 2 gallons/bird produced, the corresponding water consumption in Tennessee is estimated to be 1 million gallons per day, or approximately 365 million gallons/year. Another important water use by broiler farms, evaporative cooling of production houses during summer, is purely consumptive and peaks during the July-August growouts at approximately 1.5 gallons per bird produced. Dairy farm water consumption is being monitored at the University of Tennessee East Tennessee REC. The fresh water parlor flush typically accounts for 50% of water use, but can be economized by using the influent flush water for milk cooling. Water consumed by the free stall barn misters, which is used to cool the cows in the heat of summer, is a substantial source of water use affected by mister orifice size.

[1] The University of Tennessee, 2506 E. J. Chapman Drive, Knoxville, TN 37996 shawkins@utk.edu

# WATER QUALITY IMPLICATIONS AND PERMIT REQUIREMENTS FOR DAM REOVAL IN TENNESSEE

Robert D. Baker[1]

## INTRODUCTION

Dam removal is gaining credibility as a viable management option for dams that have either deteriorated physically or are seen as a barrier to the life cycle movements of aquatic life. There are social, chemical, hydrological, and biological benefits from dam removal. However, negative impacts, primarily short term, can occur with the removal of a dam.

Permits are required for dam removal by the U. S. Army Corps of Engineers and the Division of Water Resources under the *Clean Water Act*. These permits seek to address any negative impacts and develop monitoring to improve our scientific knowledge of the effects of dam removal based on case study.

## DISCUSSION

The impoundment of flowing waters results in physical and chemical changes to the quality of those waters. Thermal changes can be expected because of greater exposure to sunlight. Thermal changes induce changes in dissolved oxygen and density properties. In relatively deeper impoundments with greater residency time, the thermal density changes will result in stratification; which allow reduction–oxidation reactions at the soil-water interface in the hypolimnion.

The impoundment of flowing waters eliminates habitat for rheophilic fishes and benthos. Fish collection data[2] at the Roaring River in Jackson County show the elimination of cool water, lithophillic spawners such as smallmouth bass and darters in the impounded segment of river upstream of the fish barrier dam constructed in 1973. The dam was constructed to block the movement of what were then considered trash fish from the federally managed Cordell Hull Reservoir into free-flowing areas of the river.

The impoundment structures are a barrier to the life cycle movements of aquatic life. A similar barrier was removed from Upper Citico Creek in Tennessee's Cherokee National Forest. The U.S. Forest Service constructed that dam in 1966 to keep warmer-water species like bream, sunfish and chub in Indian Boundary Reservoir from migrating into the trout-supporting waters of Citico Creek. The barrier proved to be unnecessary, as the warm-water species could not survive in the cold flow segment of the creek. Instead, the dam only served to separate members of the same species, creating inbreeding and less healthy fish.

Several dams have been removed in Tennessee. Most have been lowhead dams.  They include a lowhead dams on Richland Creek and Sevenmile Creek in Davidson County, the Harpeth River

---

[1] Division of Water Resources, 312 Rosa L. Parks Avenue, 11th Floor, Nashville, Tennessee  37243-1102
[2] Tennessee Aquatic Database System, Tennessee Wildlife Resources Agency (unpublished)

in Williamson County, and Citico Creek in Monroe County. The lowhead dam on the Roaring River in Jackson County has been permitted for removal.

Lowhead dams represent a significant public safety hazard. They are often referred to as "drowning machines". The combination of reversed currents, large hydraulic forces, low buoyancy, dangerous rotating submerged objects, hard surfaces, potential hypothermia and disorientation create this dangerous environment. Lowhead dams are also smaller and easier to access and demolish than storage reservoir dams. Subsequently, these dams are targeted for removal because of these features.

Both the federal *Clean Water Act* and the *Tennessee Water Quality Control Act* require permits for the activities associated with the physical removal of a dam. Section 404 of the *Clean Water Act* requires a permit from the U. S. Army Corps of Engineers for the discharge of dredged or fill material. While the removal of material from waters of the U. S. does not require a permit, typically the removal of a dam will require some discharge of fill material in association with its removal. For instance, work pads, side-casting, demolition debris, are likely to be considered discharges by the Corps.

Section 401 of the *Clean Water Act* requires the state to certify that the activities conducted under the Corps' §404 permit meet Tennessee's water quality standards. Also, the *Tennessee Water Quality Control Act* requires a permit for any alteration of the properties of waters of the state. The changes in water quality during the active construction phase of dam removal as well as the long term (positive) changes to water quality that occur from restoration of the flowing hydrology requires an Aquatic Resource Alteration Permit.

Adverse impact to water quality can occur during the deconstruction or demolition and removal phase. These impacts are typically related to the active release of sediment from instream equipment work. During low flows typically associated with dam removal strategy, sediment released into the water column can readily settle and smother substrate downstream of the work site.

Best management practices for the equipment access and operation must be presented with a permit application. Handling and disposal of the demolished material must be shown with the application.

Dams typically trap sediment and bedload in the slackwaters upstream of the dam. When the dam is removed, this sediment and bedload will invariably evacuate to a profile commensurate with the pre-existing stream grade. The disposition of the trapped sediment must be decided before dam removal.

Depending on the nature of the material trapped, a decision must be made as to whether or not to allow the material to naturally redistribute downstream as bedload or to excavate and remove the material. Physical and chemical characterization of the material must be performed. A determination must be made as to whether or not there is a reason to believe the trapped sediment may be contaminated. In the case there is a reason to believe, sediment sampling and chemical analysis must be performed.

## THE BENEFITS AND ISSUES ASSOCIATED WITH LOWHEAD DAM REMOVAL: A CASE STUDY OF THE REMOVAL OF THE REMNANTS OF BROWN'S MILL DAM ON THE EAST FORK OF THE STONE'S RIVER

Pandy English

In 1829, a log dam was built at Brown's Mill on the East Fork of the Stone's River to power the flour grist mill on site. In the 1940's and 50's, concrete and metal were used to reinforce the dam. The City of Murfreesboro purchased the site in 1981 for an emergency water supply. In 1991, during a historical restoration, the Brown's Mill millhouse fell into the river causing its removal from the National Register of Historical Places. Over the years, the dam became more dangerous with exposed rebar and jagged concrete endangering paddlers. The river's water quality suffered especially in the summer due to the stagnant water upstream of the dam. Most important ecologically, is that the dam blocked the natural connectivity of the river.

The Environmental Services Division of the Tennessee Wildlife Resources Agency partnering with the Tennessee Chapter of the Nature Conservancy received a grant from the Tennessee Healthy Watershed Initiative to remove Brown's Mill lowhead dam. The remnants of the dam were removed on September 19, 2014.

The East Fork of the Stone's River is a high priority stream in both the Tennessee State Wildlife Action Plan and the Nature Conservancy Stone's River Watershed Assessment. Historically, 21 Species of Greatest Conservation Need (GCN) have been found in the section of river near this dam site.

Mussels, fish, and macroinvertebrates were surveyed before and after the dam removal. Water quality was and continues to be monitored. Cross-sectional surveys, instream flow studies and pebble counts were all conducted immediately above and below the dam as well as upstream and downstream of the dam site before and after the dam was removed.

The cross-sectional surveys show a changing geomorphology of the river. Macroinvertebrate diversity has increased with an EPT (Ephemeroptera, Plecoptera, Tricoptera) score increasing from 13 to 30. Mussel diversity remains the same but with more individuals of the same species, predominantly Painted Creekshell (*Villosa taeniata*). The pre-dam fish IBI surveys in 2013 detected 35 species. The 2016 post-dam fish surveys detected 32 species. During the 2013 IBI sample, five species (whitetail shiner, bedrock shiner, green sunfish, largemouth bass and speckled darter) were detected that were not detected during the 2016 IBI sample. During the 2016 IBI sample three species, (bigeye chub, smallmouth bass and spotted bass) were detected that were not found during the 2013 survey. These results of the Brown's Mill dam removal surveys and more data on the ecological effects of the removal of lowhead dams will be discussed.

# PREPARATIONS FOR DAM REMOVAL IN ATHENS, TENNESSEE

Forbes Walker, Andrea Ludwig, Mike Essington, Shawn Hawkins,
Lena Beth Reynolds, and Paul Ayers
University of Tennessee

There are over 1,200 dams in Tennessee (greater than 20 feet tall) that were designed for drinking water supplies, flood control and the generation of hydroelectric power. Many were built decades ago, and are no longer functioning as originally designed, due to sedimentation and lack of maintenance. There are potentially many hundreds if not thousands more dams in Tennessee that are less than 20 feet tall. In many cases, these obsolete dams have an impact on natural stream processes by reducing the connectivity of rivers, altering environmental flow regimes (including sediment transport), and restricting the ability of fish and other aquatic species to access the upper reaches of a watershed.

In the Oostanaula watershed in McMinn County, two dams have been identified as potentially causing more harm than benefit, including a large low-head dam in the city of Athens. Plans are being developed to remove this dam in Athens while still maintaining its primary use as a secondary water source for the city. Prior to removal and the development of a removal plan, the amount sediment, presence of legacy pollutants contained in the sediment as well as potential for harmful impacts of sediment released downstream will be characterized. This presentation will summarize the challenges that will be faced in removing this dam and progress made to develop a removal strategy that will benefit water quality and aquatic habitat in the Oostanaula watershed.

## REGULATORY PROGRAM UPDATES – U.S. ARMY CORPS OF ENGINEERS, NASHVILLE DISTRICT, REGULATORY DIVISION

The U.S. Army Corps of Engineers (Corps) is reissuing 50 existing nationwide permits (NWPs), general conditions, and definitions, with some modifications. The Corps is also issuing two new NWPs and one new general condition. Concurrent with the review of the NWPs, Nashville Regulatory Division proposed regional conditions specific to Tennessee and solicited public comments through public notice procedures. The Nashville Regulatory Division developed the final regional conditions based on comments received from the Memphis District Corps, federal and state resource agencies, and the public. The effective date for the new and reissued NWPs and regional conditions is March 19, 2017, and they will remain valid until March 18, 2022. The NWPs are intended to streamline the authorization process for activities that will result in no more than minimal individual and cumulative adverse environmental effects, thereby reducing the amount of time necessary to obtain the required authorization. Additionally, the regional conditions developed for Tennessee are an important mechanism to ensure that the adverse environmental effects of activities authorized by the NWPs are no more than minimal, both individually and cumulatively.

NWPs provide an incentive for project proponents to minimize their impacts to jurisdictional waters and wetlands to qualify for the more readily obtained NWP authorization. By encouraging avoidance and minimization by offering a streamlined permitting process for project proposals with minimal impacts, NWPs are an important tool in protecting the environment. In addition, NWPs allow Corps districts to focus limited resources on those regulated activities that have the potential for substantial adverse environmental effects and require the more rigorous review process required by individual permits.

## CLINCH POWELL CLEAN RIVERS INITIATIVE—A BI-STATE WATERSHED COALITION RESTORING ONE OF NORTH AMERICA'S MOST BIODIVERSE RIVER SYSTEMS

Brad Kreps, The Nature Conservancy, Clinch Valley Program Director, Chair of the CPCRI Steering Committee

The Clinch-Powell River System in Virginia and Tennessee harbors one of the highest concentrations of rare freshwater species in North America. However, one of its leading indicators of environmental health- endangered freshwater mussels, are showing signs of serious decline. Reasons for this decline are complex and have historically been a point of strong contention between Tennessee and Virginia. In response to this challenge and pursuant to a Memorandum of Understanding between the states and the U.S. Environmental Protection Agency, the Clinch Powell Clean Rivers Initiative (CPCRI) formed in 2008. http://cpcri.net/

Since its formation, CPCRI has operated effectively as a diverse collection of state and federal agencies, universities, industry leaders, and non-governmental organizations. Partners have been implementing a shared science plan to collect and analyze a range of physical, chemical, and biological data to better understand the underlying causes for rare mussel decline. There have also been collaborative efforts to complete a Healthy Watersheds Assessment and to strategically implement watershed restoration project across the river system.

CPCRI is supported by facilitation from The Nature Conservancy. The presentation will focus on the results of CPCRI since the signing of the MOU and provide examples of how conflict between two states can be transformed into an effective watershed collaboration based on science and contructive patnerships.

# MAY 26, 2016 PERMITTEE-RESPONSIBLE MITIGATION GUIDANCE: IMPLICATIONS FOR PROSPECTIVE APPLICANTS

Brady McPherson[1]

## INTRODUCTION

In an effort to improve the efficiency and compliance of compensatory mitigation implemented within Tennessee, guidance was created that outlines the compensatory mitigation content needed to satisfy the requirements set forth in 33 C.F.R. PARTS 325 and 332, otherwise known as the “2008 Mitigation Rule”. The most significant changes contained within the new compensatory mitigation guidance require documentation of functions lost and replaced as a result of the permitted activities. Documentation is satisfied by performing function-based rapid assessments that provide a means to document and evaluate departure between existing and proposed conditions in a repeatable manner. Although mitigation banks and in lieu fee mitigation sponsors may be more familiar with the concepts and methods used to satisfy these new requirements, permittee-responsible mitigation applicants may not be. In some cases the new assessment methodology could be considered a burden on the applicant. In other cases it can be utilized to optimize site development and reduce mitigation burden. As the use of permittee-responsible mitigation increases in Tennessee, familiarity with the new assessment methodologies and understanding how they could impact the applicant will likely be a critical factor in appropriately representing loss and replacement of aquatic function and facilitating the timely approval of mitigation plans. Some of the implications of following the (DRAFT) May 26, 2016 Permittee-Responsible Mitigation Guidance will be discussed as part of this presentation.

## DISCUSSION

Reach delineation can be a difficult task when using the stream function-based assessment methods. Variations in valley type, landscape position and stream type are some of the likely triggers for starting a new assessment reach. Transitions from confined to more broad and open valleys will often require multiple assessment reaches in order to characterize the changes in geomorphic character. In small or unstable channels, changes in geomorphic character can easily impact credit production estimates and mitigation responsibilities. For example, in unstable and incised channels there can be depositional features with varying elevations that exhibit the bankfull elevation. Likewise, facet measurements in small channels can be very sensitive to error and can easily cause a shift in the perceived functional condition. These assessments may also be used to establish a baseline from which the implemented mitigation will be evaluated meaning that small discrepancies can result in a base-level shift with long-term repercussions.

With the advent of the new function-based assessments and potential function-based crediting mechanisms, applicants will have the means necessary to characterize the condition of the

[1] Stantec Consulting Services Inc., 10509 Timberwood Circle, Suite 100, Louisville, KY 40223, Brady.mcpherson@stantec.com

resource they propose to alter or improve and determine the credit value. In the interim it is possible that an applicant may advocate that when impacting a very poorly functioning stream less mitigation may be warranted than what the current guidelines state. This idea is not new and has been discussed before when applicants have proposed modifications to armored channels that exhibited very little habitat. The significance of the function-based assessments is that a more detailed analysis can be completed to support the case. The level of effort necessary to collect this information may not be preferable to all client's and would likely increase the review time, permitting schedules and costs, however, it may be warranted in some cases. This is a reasonable expectation when understanding that the resources proposed for offsetting that impact may be evaluated in the same manner. This understanding also suggests that if an applicant proposes to impact a resource of relatively high functional value that they can expect to incur the maximum mitigation responsibility if the impact is approved.

The stream function-based assessments can also be used to optimize site selection and site design. Many companies have needs that are specific to their success and not all properties can meet those needs, although, it is not uncommon for a company or organization to evaluate multiple properties as part of their site selection process. As the focus of mitigation shifts to the more deliberate practice of function-based assessments, it may warrant that companies incorporate greater resources into planning and site reconnaissance. Greater allocation of resources to address market level shifts is not a new concept, even if it is new in Tennessee. In some cases it may prove beneficial to the client to invest in more detailed inventories of onsite aquatic resources using these new assessment methodologies to account for this shift. This information can then be used to prioritize sites based on environmental impact, optimize site design, avoid high functioning resources, and ultimately minimize burdensome long-term mitigation responsibilities. The (DRAFT) May 26, 2016 Permittee-Responsible Mitigation Guidance introduced compliance with the long-term management stipulations in the 2008 mitigation rule, and is perhaps the greatest long-term implication for prospective permittee-responsible applicants. Financial assurances for perpetual invasive species maintenance and other forms of site maintenance have not routinely been required for mitigation in Tennessee. These perpetual responsibilities can increase project budgets significantly, and at times may not be practical.

The (DRAFT) May 26, 2016 Permittee-Responsible Mitigation Guidance was developed in an effort to increase compliance with the 2008 Mitigation Rule. Although, additional effort is required to meet the requirements of the guidance it can reward an applicant who implements advance planning, deliberate decision making, and sound science. Proper application of the guidance and its assessments can help avoid costly permitting delays, develop defensible mitigation plans, reduce long-term mitigation responsibility, and positively affect the applicant and regulatory relationship.

*About the Speaker:* Brady McPherson is a senior environmental scientist for Stantec Consulting Services Inc. Brady has a broad range of experience in stream and wetland mitigation including site identification and development, permitting, assessment, design, monitoring, and long-term management in both Tennessee and Kentucky. Brady holds a Bachelor's of Science in Soil Science from Middle Tennessee State University and a Master's of Science in Biosystems Engineering Technology from the University of Tennessee.

## SESSION 2B

## STORMWATER I
## 8:30 a.m. – 10:00 a.m.

*Comparison of Roadway Runoff Quality Surrounding Repaving Events from Hot Lay Asphalt to Open Grade Friction Course Asphalt*
Kristen N. Wyckoff and Qiang He

*Changes in Residential Rain Garden Infiltration Capacity in Two Demonstration Gardens*
Andrea Ludwig, Wesley Wright, Mary Pleasant, Ruth Anne Hanahan, and Garrett Ferry

*Storm Water Detention Pond Monitoring Program at CBU Soccer Field*
L. Yu Lin, Chee Chew, and James Simpson

## STORMWATER II
## 10:30 a.m. – 12:00 p.m.

*The Role of Trees in Bioretention Practices*
Andrew Tirpak and Whitney Lisenbee

*The Role of Cover Crops to Soil and Water Quality Under a Variable Climate*
Violet B. Freudenberg, A.N. Thanos Papanicolaou, Benjamin K.B. Abban, Christos Giannopoulos, Christopher G. Wilson, and Mohammad S. Ghaneeizad

*Exploring the Influence of Urban Watershed Characteristics and Antecedent Climate on In-Stream Pollutant Dynamics*
L.E. Christian, J.M. Hathaway, and T.H. Epps

## STORMWATER QUALITY
## 1:30 p.m. – 3:00 p.m.

*Area: Laboratory and Field Testing of Stormwater Treatment Devices: NJCAT, NJDEP, A Complete Explanation of Manufactured Treatment Devices Testing*
Gary Moody

*The Importance of Particle Size Distribution When Defining 80% TSS Removal Efficiency*
Mark B. Miller

*Investigating Design and Performance of Regenerative Stormwater Conveyances Through 3D Modeling*
Jessica M. Thompson, Jon M. Hathaway, and John S. Schwartz

**FLOOD**
**3:30 p.m. – 5:00 p.m.**

*Seven Steps Closer to Flood Resilience*
Bradley Heilwagen

*PMP/PMF Automation Tool Overview*
Trevor Cropp

*Investigating Hydrologic Non Stationarity within the Obion River, TN Watershed*
Benjamin K.B. Abban, Mohammad S. Ghaneeizad, Angela Pelle, Christopher G. Wilson and A.N. (Thanos) Papanicolaou

# COMPARISON OF ROADWAY RUNOFF QUALITY SURROUNDING REPAVING EVENTS FROM HOT LAY ASPHALT TO OPEN GRADE FRICTION COURSE ASPHALT

Kristen N. Wyckoff[1] and Qiang He[1,2]

A highly trafficked roadway was selected for repaving to an open grade friction course (OGFC) asphalt. OGFC is frequently used for paving surfaces due to the ability of the pavement to reduce the spray back from the roadway in wet conditions, increasing driver safety. While OGFC paved roadways are known to create safer driving conditions, less is known about how the pavement impacts stormwater runoff quality from the roadway surface. OGFC asphalt is more porous than other standard asphalt lays used for roadway surfaces. The increased surface area has the potential to decrease pollutant loading from the roadway surface to surrounding water collection bodies.

Runoff samples were collected from four points along the major roadway, two from the north-bound direction, and two from the south-bound direction. Samples were collected for two months prior to repaving, and following the end of repaving, with no collection during construction. Samples were collected using first flush vortox samplers. Storm events were selected using Environmental Protection Agency (EPA) recommendations of a dry period greater than 72 hours with greater than 0.1 inches of rainfall.

Runoff quality from the roadway surfaces was measured and analyzed following standard methods and multivariate statistical analysis. Primary contaminants of interest included *Escherichia coli*, suspended solids, and nutrients. Data analysis suggests that the OGFC is superior to hot lay asphalt for certain contaminants. It may be advantageous to continue repaving roadways with OGFC asphalt in order to reduce contaminant loading and improve safety during wet conditions.

[1] The University of Tennessee, Department of Civil Engineering, Environmental Engineering, Knoxville, Tennessee, USA
[2] Institute for a Secure and Sustainable Environment, The University of Tennessee, Knoxville, TN, USA

# CHANGES IN RESIDENTIAL RAIN GARDEN INFILTRATION CAPACITY IN TWO DEMONSTRATION GARDENS

Andrea Ludwig[1], Wesley Wright[2], Mary Pleasant[3], Ruth Anne Hanahan[4], and Garrett Ferry[5]

Rain gardens have become more common in residential landscapes as we recognize the need for more sustainable urban runoff management solutions. The University of Tennessee now has three campus rain gardens as well as a slue of other green infrastructure practices, including a newly green Volunteer Boulevard. Faculty have also worked with community partners to optimize the design of a large scale, sub-basin rain garden in a North Knox County subdivision. The overarching goal of these rain garden applications is to showcase to the public the function and benefits of residential rain gardens, aiming to facilitate adoption among homeowners in urban watersheds. These practices also provide an opportunity to gather field-scale data on the capacity of these practices to meet runoff reduction goals. To gain an understanding of infiltration capacity, shallow wells were installed in two of the demonstration practices and continuous water level was monitored over multiple seasons. This presentation will describe the rain garden applications, review preliminary infiltration data, and share lessons learned.

[1] Associate Professor, Biosystems Engineering & Soil Science Department, University of Tennessee
[2] Research Associate, Biosystems Engineering & Soil Science Department, University of Tennessee
[3] Stormwater Engineer, Knox County Stormwater
[4] Senior Research Associate, Tennessee Water Resources Research Center, University of Tennessee
[5] Stormwater Coordinator, University of Tennessee Facility Services

# STORM WATER DETENTION POND MONITORING PROGRAM AT CBU SOCCER FIELD

L. Yu Lin[1], Chee Chew[2], and James Simpson[2]

## ABSTRACT

The Lick Creek Drainage Watershed in the City of Memphis consists of six bayous: Lenox, Arlington, Lick Creek, Idlewild, Overton, and Royster. Because the watershed has experienced flooding, the City of Memphis decided to build several detention ponds in the basin to reduce the flooding. A soccer field of Christian Brothers University on the Lenox Basin was designed and built in 2011. During extreme storms, the CBU soccer field will act as a detention pond to route 46.6 ac-ft. of runoff. However, the pond was based on the outlet control. The downstream area still experienced minor floods after the pond was built. A five-year monitoring program was conducted. The objectives of the project are to: (1) develop a storm water monitor system for the detention basin located on CBU's soccer field; (2) monitor storm water quantity for the drainage basin; and (3) provide the information to improve the detention pond facility. Three gages, including one rain gauge, one stage gage, and one discharge gage were installed for this monitoring program. This paper will present the results of this monitoring program. Overall, the facility provides sufficient storage routing to reduce the flooding after the improvement. During heavy rainfall event, such as the Spring of 2011 and the Summer of 2013, no any floods were recorded in the study area.

## INTRODUCTION

Christian Brothers University is located on the upstream of the Lenox Bayou Watershed, which receives storm water runoff from two adjacent sub-areas with a total area of 61.5 acres. The basic watershed characteristics are composed of the time of concentration of 23.5 minutes, the average of slope of 2.8%, and the average peak discharge of approximately 100 cfs according to the 25-year frequency design storm. Because of frequent flooding in the watershed, the City of Memphis decided to use CBU's soccer field as a detention basin in order to attenuate the peak flow (discharge) and to prevent flooding in the downstream watershed on Lick Creek Watershed. In 2011, the City of Memphis completed the construction phase of the detention facility and granted this monitoring program. The original objectives of this project were to: (1) develop a storm water monitor system for the detention basin located on CBU's soccer field; (2) monitor the storm water quantity for the drainage basin; (3) determine the storm water quality of those storms; and (4) provide results and information to the City for future improvement.

The designed drainage system at CBU's soccer field as shown in Figure 1 consists of one 54-inch diameter RCP sewer pipe, one 72-inch diameter RCP sewer pipe, one 5' (height) x 4' (width) box culvert, a 164'-long concrete board-crest weir, four 8-inch PVC French drainage

[1] Department of Civil and Environmental Engineering, Christian Brothers University, Memphis
[2] Civil Design Division, City of Memphis, Memphis

pipes, one 42-inch diameter RCP sewer pipe, and an inlet/outlet control manhole. During extreme storms, the CBU soccer field has the capacity to hold a maximum of 16.9 ac-ft. of runoff.

This monitor system consists of three devices: one rain gauge, one stage flowmeter, and one discharge flow meter. The rain gauge is a typical rainfall recorder made by RainWise. The meter can indicate up to 9.99 inches of rainfall for a single rainfall event. The top of the meter can record the rainfall using a data log. Sutron's Stage-Discharge Recorder (SDR-0001)[3] is a stage flowmeter that is a device that can be easily programmed to record water levels (stage). The meter was also used to measure the outflow from the open weir to the soccer field. A discharge meter made by the Greyline DFM 5.0 is suitable for stormwater recording. The Greyline DFM 5.0 meter includes a new digital signal processor to filter background noise and interference and a flow sensor to measure flow rates accurately in liquids containing gas bubbles or solids particles. The meter was installed in the 42-inch outlet pipe for the discharge measurement.

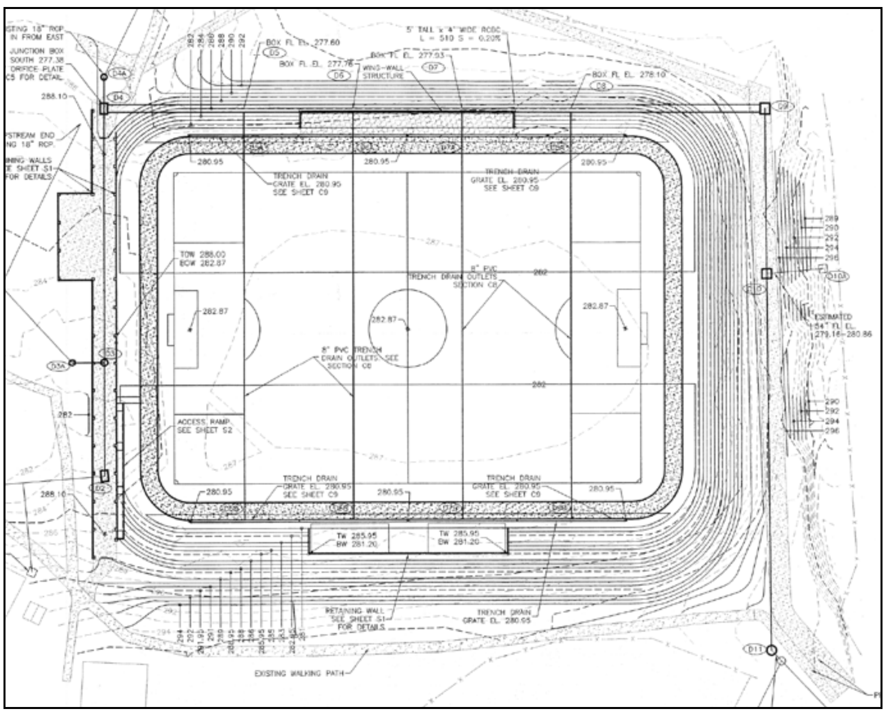


Figure 1: Drainage System on CBU's Soccer Field

## RESULTS AND DISCUSSION

Between January 1 and December 20, 2016, there were one hundred and eighteen rainfall events recorded on the CBU campus according to RainWise readings. The magnitude of the rainfall ranged from 0.01 to 4.16 inches per day. Figure 2 shows the daily rainfall events and their magnitudes. In term of precipitation, 2016 was a normal rainfall year with the annual average of 50.7 inches of rainfall. The highest rainfall event which occurred on March 9, 2016 was 4.16 inches per day. In 2016 the rainfall in the Memphis area followed the wet/dry season pattern. In the Spring time of 2016, the wet season started in early March and continued to the end of May. In the Fall, the wet season started almost at the end of November. Fewer rainfall events were recorded until the beginning of December of 2016. Very mild thunderstorms were recorded this year during the summer time as well. Only five rainfall events were above one inch per day. The highest rainfall in the summer of 2016 was only 1.25 inches per day.

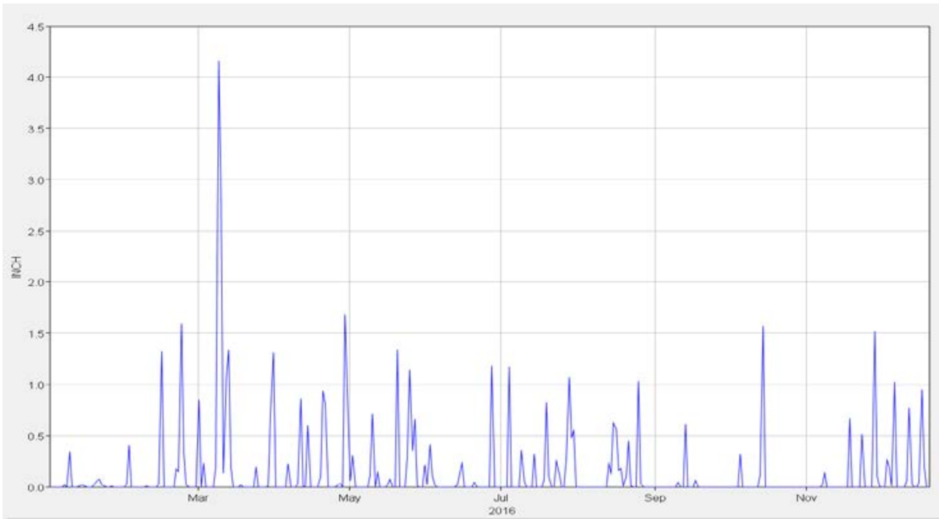


Figure 2: Rainfall Data in 2016

The highest flow data collected from Greyline's DFM 5.0 flow meter in the 42-inch diameter pipe are listed in Figure 3. On 3/9/2016- 3/14/2016 event, the peak flows in the outlet pipe was approximately 98 cfs. The flows were consistent with the rainfall gauge data recorded on CBU's campus.

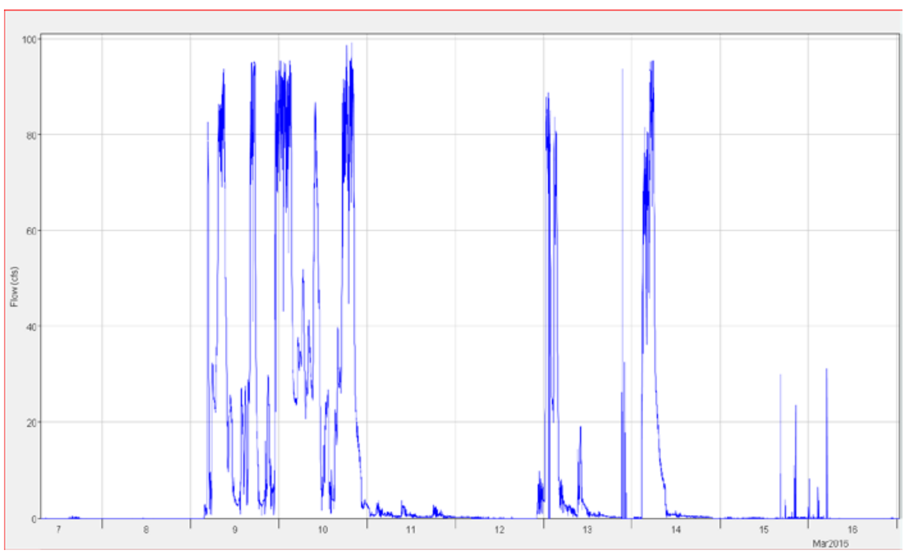


Figure 3: Flow Hydrograph on 3/9/2016 – 3/14/2016

Twelve rainfall events routed the direct runoff into CBU's soccer field in 2016. With all data combined with previous years' data, the rainfall data vs. water depth in the soccer field and the discharge flows vs. water depth on the soccer field are shown in Figures 4 and 5. Figure 4 shows the water depths vs. rainfall were exponentially increased as the rainfall increased. The formula can be expressed as:

$$Depth = 0.637 * EXP (0.4433 * Rainfall)$$

This data will provide an expectation of water depth in the soccer field when the forecast rainfall is given. During this monitoring program period, a total of thirty five data sets were collected when the overflow discharge running into the soccer field. From the data collected, it indicated the direct runoff starts discharging into the soccer field as the rainfall was above 1 inch. The highest water depth recorded was in May 2011. A depth of almost 5.2 feet of water was stored on the soccer field as five inches of rain fell on CBU campus. According to the City Drainage Manual and the data of the National Weather Service or NOAA, May 2011 event was approximately a seven-five year storm in the mid-town of Memphis. The original soccer field was designed to hold a maximum of 16.9 ac-ft. of runoff that is equivalent to 9.23 ft. of storage depth. This study clearly demonstrated that the CBU detention facility can provide sufficient storage routing to handle a 100-year storm that can relieve floods to the downstream areas of the Lick Creek Drainage Watershed.

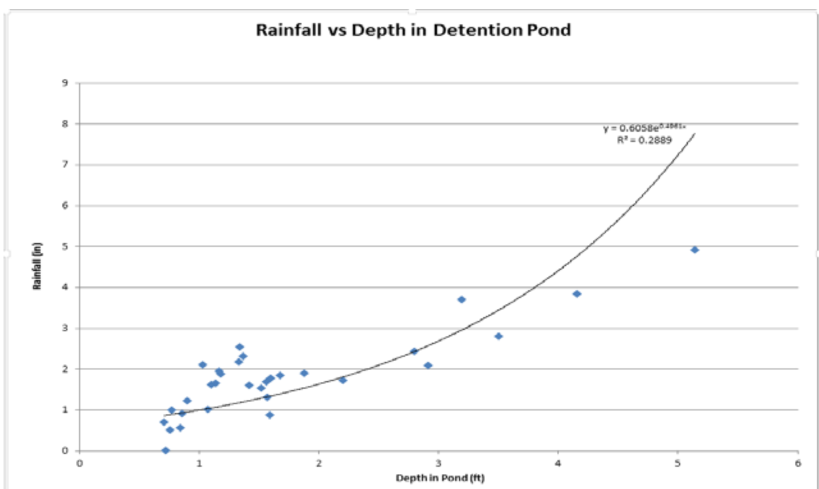



Figure 4: Rainfall Verse Water Depth on CBU Soccer Field

The flow discharge through the board crest weir into the soccer field was also determined. Figure 6 shows the result of this investigation and analysis. Approximately 50 cfs of runoff ran into the box culvert when the depth on the soccer field was 6 feet. The weir flow for this detention pond can be expressed as:

$$Discharge (cfs) = 0.9541 * Stage + 0.053$$

Because of the restrictive area of the discharge at the open weir, the stage and the discharge relationship did not follow the weir flow condition given by the manufactory.

## CONCLUSIONS

This project was granted in 2011 and completed in 2016. The monitoring program has proved that the detention has enough capacity to handle a 100-year design storm. The size of the outlet pipe has been modified and reduced from 42 inches to 24 inches. With the 3/9/2016 storm event, the highest discharges were 98 cfs corresponding to the highest rainfall of 4.16 inches. The flow was attenuated and held at the soccer field for almost four hours. The peak storage for the same storm event was at 12:20am with 3.043 feet of water stored at the soccer field. No floods were observed on the downstream neighbor area or on the street during that event. It concludes that the detention facility on CBU's soccer field is the best management practice in storm water management.

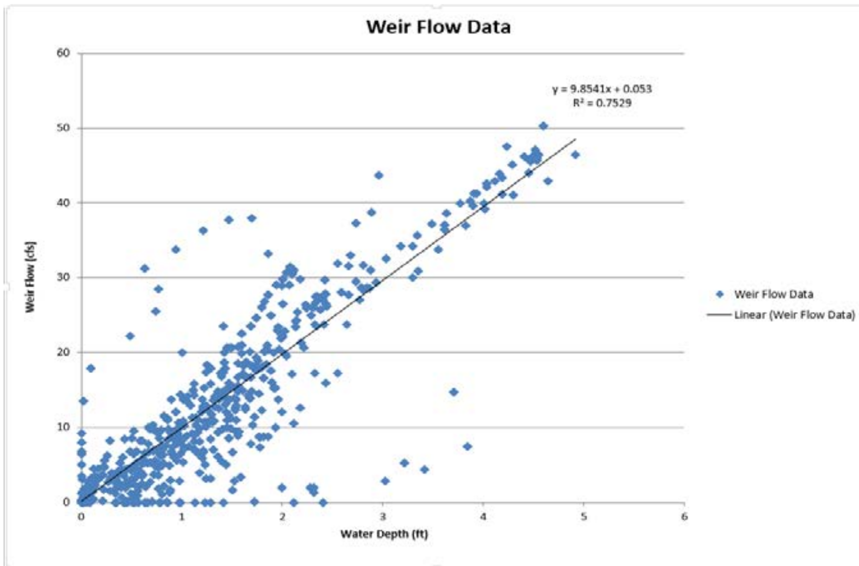



Figure 6: Weir Flow Discharge Verse Water Stage

## REFERENCES


"Rain Gauge User's Manual-RAINEW 111 Tipping Bucket Wired Rain Gauge", RainWise, Inc 2012.

"User's Guide Installation and Operation Instructions", Greyline Instruments Inc., 2012.

"Sutron's Stage-discharge Recorder SDR-001 Operations & Maintenance Manual, Sutron, 2009.

"Storm Water Management Manual- Volume 2: Best Management Practices Manual", City of Memphis of Public Works and Shelby County Public Works, 2006.

"Storm Water Management Manual- Volume 3: Best Management Practices Manual", City of Memphis of Public Works and Shelby County Public Works, 2006.

Tom Charlier, "Overton Garage Detention Basin Benefits the Community". www.phdmemphis.com/news/stormwater-proj.

Philip B. Bedient, Wayne C. Huber, and Baxter E. Vieux, "Hydrology and Floodplain Analysis", 5th Edition, Prentice Hall, 2012.

# THE ROLE OF TREES IN BIORETENTION PRACTICES

Andrew Tirpak and Whitney Lisenbee
University of Tennessee Knoxville, Dept. of Civil and Environmental Engineering

Bioretention is a stormwater control measure (SCM) implemented to ameliorate pollution and reduce runoff volume generated from impervious surfaces. Plants have been shown to improve the overall performance of these systems; however, little guidance is given for plant selection in design standards. Instead, vegetation selections are often made based on their ability to survive the environmental conditions found in bioretention practices. As a result, systems are preferentially planted with native grasses, sedges, and shrubs. Although the numerous benefits of trees in urban areas are well understood (i.e. heat island mitigation, air quality improvements, noise attenuation, etc.), knowledge of their potential contributions to stormwater management as integral components of bioretention is minimal.

This presentation reports on a series of studies designed to characterize the health of urban trees in existing bioretention practices and better understand the natural treatment mechanisms they provide. Results from a field study of bioretention trees in Tennessee and North Carolina will be discussed, where tree health was quantified through measurements of crown condition and linked to several bioretention design characteristics. The presentation will summarize a controlled mesocosm experiment designed to characterize the treatment contributions of three native tree species, and report on a preliminary performance assessment of two tree-specific stormwater treatment devices monitored for pollutant removal and hydrologic performance. Ultimately, this research will culminate in the development of specifications and guidance for designers that will explain how to best integrate trees in bioretention practices.

**NOT AVAILABLE**

## EXPLORING THE INFLUENCE OF URBAN WATERSHED CHARACTERISTICS AND ANTECEDENT CLIMATE ON IN-STREAM POLLUTANT DYNAMICS

L.E. Christian, J.M. Hathaway, T.H. Epps

Modeling pollutant fate and transport in urban watersheds is a complex endeavor, with many currently utilized models showing poor performance. Although recent studies have begun to investigate pollutant transport in urban watersheds to aid these models, these studies have primarily focused on the end-of-pipe as the point of interest. However, it is likely that in-stream processes will influence pollutants leaving urban watersheds when the system is viewed at a larger scale. In this study samples were collected from three open-channel urban streams: Second Creek, Third Creek, and Williams Creek. Although numerous other water quality constituents were analyzed, TSS, *E. coli*, fecal coliform, $Cu^{2+}$, and $NO_3^-$ are specifically investigated herein. The goals of the study included: to identify trends in water quality due to watershed characteristics using inter-storm first flush analyses, and to confirm the effects of antecedent climate factors on the first flush in Knoxville, TN, streams. Similar to other comparable studies, the results of the study showed high variability in the first flush effect, with stronger flushing noted for pollutants such as TSS than those that are transported in a dissolved state. The influence of in-stream processes also appeared, with microbes showing a more consistent first flush in this study than has been found in studies focused on the end-of-pipe. Further study is needed, but initial results suggest the importance of in-stream processes in water quality patterns in urban watersheds.

# AREA: LABORATORY AND FIELD TESTING OF STORMWATER TREATMENT DEVICES: NJCAT, NJDEP, A COMPLET EXPLANATION OF MANUFACTURED TREATMENT DEVICES TESTING

Gary Moody, WISE Hydrology

The above reference testing has undergone a transformation in definition and purpose. I will use an hourglass to explain the shape of testing development and implementation authorities over time.

In this presentation, we will follow the migration of testing from third-party scientific data and validity to first-party (in-house) marketing.  The presentation is absent bias. The information presented is not opinion. It contains no rhetorical information and no products or persons are identified or promoted. Only the test methods, mentality, and integrity are discussed.

The goal is to present the successional and current test requirements, along with a comprehensive and authoritative reference foundation that documents the systematic evolution of developing research and academic collaboration to dominate science and eliminate critical opinion.

The immediate questions are simple; Is there groundwork in place to improve the long-term outlook?

Can the intentional gaps and loopholes be recognized and replaced with meaningful scientific data?

Is the academic society financially vulnerable and unable to resist big business's influence? Does the regulatory community have the will, freedom, and authority to insist on accurate data assimilations and validated models, or are they a large part of the systemic problem and synchronized departure from science to marketing? Eliminating un-achievement or poor achievement marketed as scientific oppressionism (it's a new word) has always required tedious, detailed, examination to circumfundere (surround and dispel). Misrepresented science is corrosive to the people that promote, accept, and perpetuate it. It's especially corrosive to the persons and the environment that is its intended beneficiary but becomes indentured to it.

# THE IMPORTANCE OF PARTICLE SIZE DISTRIBUTION WHEN DEFINING 80% TSS REMOVAL EFFICIENCY

Mark B. Miller[1]

Stormwater management manuals often include design guidelines for manufactured treatment devices (MTDs) that include technologies such as hydrodynamic separation and filtration. Local jurisdictions may approve an MTD provided that testing demonstrates at least 80% TSS removal efficiency. However, this performance criterion lacks specification for an influent sediment particle size distribution (PSD) for either laboratory or field testing programs. This presentation explores the critical role that test sediment PSD plays in MTD performance testing and how those gradations affect TSS removal efficiency for both annual and per storm event sizing.

An example hydrodynamic separator (HDS) laboratory test performance curve illustrates TSS removal efficiency versus surface area loading rate for a silica test sediment having a median particle size of 110 microns (µm). This curve is compared to a series of performance curves calculated using the Peclet Number for the same tested device based on median ($d_{50}$) values of 45, 50, 67, 75, 90 and 125 µm. The resultant performance curves based on $d_{50}$ values less than 110 µm exhibit progressively decreasing HDS performance as the $d_{50}$ values decrease, while the 125 µm curve exhibits enhanced performance from that of the tested HDS. The methodology and calculations used to generate the selected $d_{50}$ performance curves are explained.

The performance curves are also used for HDS sizing for 80% TSS removal on both an annual and per storm event basis. A sizing example using the Rational Method is described for 80% annual TSS removal efficiency based on the test sediment of 110 µm and compared to sizing based on $d_{50}$ curves for 67 and 125 microns. This sizing approach utilizes curve-specific equations and 55 years of rainfall intensity data from Chattanooga, TN. The performance curves are also used to assign a loading rate that corresponds to 80% TSS removal on a per storm event basis. Example HDS sizing charts for 80% TSS removal per storm for the test sediment and the $d_{50}$ performance curves from 45 to 125 microns are described with loading rates ranging from 10 to 30 gpm/ft$^2$, respectively. Thus, HDS sizing based on individual storm event performance varies significantly depending on sediment particle size.

A number of consequences result from excluding a PSD specification for MTDs. While undersized MTDs may exhibit diminished performance for TSS removal efficiency, they can also cause concern for functionality and flow-through conveyance for undersized piping. Undersized facilities may also experience increased maintenance frequency and associated costs due to decreased storage capacity. While oversizing may provide a conservative treatment approach, it (a) increases a system's footprint including any bypass structures, (b) may limit options for limited space and retrofit installations, and (c) increases project costs. Additionally, MTD sizing should consider that when a PSD specification is too coarse, say 5,000 µm as a surrogate for debris/trash, then the MTD's maximum hydraulic capacity may be exceeded at a

[1] Research Scientist, AquaShield™, Inc., 2733 Kanasita Drive, Suite 111, Chattanooga, TN 37343, (423) 870-8888, mmiller@aquashieldinc.com

given point on a performance curve causing undesired sediment removal and adverse flow conveyance conditions.

# INVESTIGATING DESIGN AND PERFORMANCE OF REGENERATIVE STORMWATER CONVEYANCES THROUGH 3D MODELING

Jessica M. Thompson[1]*, Jon M. Hathaway[1], John S. Schwartz[1]

Regenerative Stormwater Conveyances (RSCs) are an innovative approach for connecting stormwater outfalls with streams while simultaneously treating stormwater runoff and providing groundwater recharge. RSCs utilize shallow aquatic pools consisting of a sand/wood chip media to promote microbial action and infiltration; riffle weir grade control structures constructed from large boulders and cobble to dissipate energy; and established native vegetation to promote microbial activity, nutrient reduction, and evapotranspiration[2]. Despite these benefits, design guidance for these systems is in need of verification and, if possible, improvement to provide the best performing system while maintaining structural stability.

In this study, two RSCs were designed, constructed, and monitored. One novel component of this research focuses on the evaluation of system design characteristics through three dimensional modeling, a first of its kind assessment for RSCs. The three dimensional model was developed from LiDAR imagery and simulated using the computational fluid dynamics (CFD) software program, FLOW-3D. This model allowed a detailed understanding of the complex flow characteristics within the RSC. Further, a sensitivity analysis was performed whereby key design parameters were modified to determine the most effective system configuration for volume attenuation while maintaining stability (i.e., a lack of erosion). Lastly, results from the simulations have been used to develop relationships between design parameters, such as length/depth ratios, that will assist engineers in designing an optimal system that maximizes performance while minimizing cost and materials.

---

[1] University of Tennessee, Department of Civil and Environmental Engineering. *jthom147@vols.utk.edu, JDT Engineering Building

[2] Brown, T., Berg, J., and Underwood, K., *Replacing Incised Headwater Channels and Failing Stormwater Infrastructure with Regenerative Stormwater Conveyance*, in *Low Impact Development 2010*. 2010. p. 207-217.

# SEVEN STEPS CLOSER TO FLOOD RESILIENCE

Bradley Heilwagen

During persistent drought conditions rampant throughout the United States, it is easy to forgo concern for flooding. Despite these dry weather conditions of late, the dangers associated with flooding should be forefront in mitigation planning for municipalities across the country. Whether caused by a short, intense localized rainfall, a widespread long-duration storm, a dam breach, or a coastal storm surge, flooding is a severe threat for most everyone, evident by the numerous repetitive losses and flood insurance policies. With so much population at risk of flooding, communities should strive to become more resilient against flooding using the most effective means possible. Traditionally, communities have been limited to floodplain regulation or affordable mitigation options, oftentimes eliminating structural solutions, such as reservoirs, diversions, channel modifications, and diversions due to their excessive cost. This leaves communities vulnerable to flooding, and the citizens of those communities unprotected from the dangers of flood events.

Flood resilience is a necessary responsibility and may seem like a daunting and expensive task at first, especially when faced with few practical, affordable options which can deliver community-wide results. To assist communities in the development of a viable and cost-effective plan for flood resilience, a simple, seven step approach can be taken. The approach compels communities to assess and fulfill needs in the categories of coordination, data, communications, forecasts, decision support, actions, and dissemination before considering their flood resilience plan to be practicable. Products and processes are catered to individual communities to fulfill their needs and are built based on GIS Tools and Numerical Models when available.

Coordination, the first step, involves leveraging the services already provided by Federal and State agencies, such as the NWS, USACE, and USGS. This coordination streamlines services and presents opportunities for cost-sharing. Following coordination is developing a network of data. Gathering real-time and historical precipitation and flow data are essential to any flood warning system. Step three establishes a communications plan. Getting information to where it is needed in a reasonable amount of time is crucial to the success of these projects. When coordinating with several agencies, often for the first time, a communication method eases these transitions. The fourth step is forecasts. Whether model-based or based on community knowledge, there must be a system to convert rainfall forecasts produced by the National Weather Service into flood stage forecasts. Identifying what has potential to flood during a rainfall event, or decision support, is the next step. The ability to know where and what floods at a certain flood stage is paramount. As a result of the predicted flooding, step six involves developing actions (i.e. mitigation measures or emergency response actions). The final step is dissemination, or how to appropriately notify the public. Whether flooding has potential to come in the next 30 minutes or the next 30 years, properly educating citizens about their flood risk is the final key.

This presentation will outline each of the seven steps, showing case evidence for the approach. Several products that can help communities address flood resilience will be shown. Additionally, examples of successful components from communities across the United States will be used to demonstrate that any community in the country can develop a functional and cost effective flood resilience plan. Following these seven steps will jump-start a community towards flood resilience, and allow them to better understand and develop the more traditional flood resilience measures.

## PMP/PMF AUTOMATION TOOL OVERVIEW

Trevor Cropp, BWSC

BWSC in partnership with Riverside Technology Inc. has completed the development of an interactive tool and modeling framework for completing a series of meterorologic, hydrologic, and hydraulic modeling processes for the Tennessee Valley Authority. Through the use of a graphic user interface webpage, the tool automates PMP precipitation generation, performs hydrologic computations through the use of HEC-HMS, performs hydraulic routings through the use of HEC-RAS, postulates dam failures, and generates figures for hundreds of proposed Probable Maximum Flood simulations.

This system integrates many different components of the standard workflow into a single integrated model operations environment, helping to streamline and standardize the workflow process. Data is stored in standardized databases for organized archiving, rapid access, visualization, and exporting. Further, with a standardized process, quality assurance of modeling runs is improved, rather than relying on individuals correctly updating files, results, graphs, etc. for each model scenario and hydraulic breach run.

# INVESTIGATING HYDROLOGIC NON STATIONARITY WITHIN THE OBION RIVER, TN WATERSHED

Benjamin K.B. Abban, Mohammad S. Ghaneeizad, Angela Pelle, Christopher G. Wilson and A.N. (Thanos) Papanicolaou

Climate non-stationarity, or changing trends in precipitation intensity and duration, evapotranspiration, runoff, and recharge, can significantly disrupt the water availability within an agroecosystem.  Watershed managers can no longer rely on historical data to base their decision-making.  The Obion River watershed in west Tennessee, which is a central producer for Tennessee's row crop supply, is one such system that may experience the ill effects of climate non-stationarity in the near future as both the frequency and magnitude of dry-wet cycles are expected to increase.  The watershed has already seen an increase in irrigation to balance soil moisture levels and stabilize yields.  However, this can lead to water demand issues as surface and subsurface water stores become taxed.  The long term security of a region's water resources is critical to the area's economic and environmental well-being.  In this study, we are quantifying water budgets under projected climate changes (both moderate and extreme) and land management changes using a high resolution Variable Infiltration Capacity (VIC) model.  This research specifically aims to capture changing hydrologic boundary conditions and the watershed's climatic elasticity of streamflow. Calibration and validation efforts using past data have produced good results with Nash-Sutcliffe Efficiencies ranges from 0.81 – 0.9. Understanding of non-stationarity within a watershed has major implications on the decisions both watershed managers and policy developers must make to ensure future water security.

**SESSION 2C**

**DROUGHT**
**8:30 a.m. – 10:00 a.m.**

*TVA Reservoir Operations and Drought*
Amanda K. Bowen

*The 2016 Drought in the Tennessee Valley: A Look at the Statistics, the Response, and the Results and Impacts*
Daniel P. Saint

*Droughts and Reservoir Yield: Decisions Informed by Tree Ring Data*
John Harrison

**PUBLIC OUTREACH**
**10:30 a.m. – 12:00 p.m.**

*South Carolina's New Tools to Assess Surface Water Availability and Support Regional Water Planning*
John D. Boyer

*4-H Water Camp—Georgia vs. TN*
Lena Beth Reynolds

*Tennessee Valley Authority Water Resource Stewardship Efforts*
Shannon O'Quinn and Tyler Baker

**STREAM SURVEY**
**1:30 p.m. – 3:00 p.m.**

*Application of the High Definition Stream Survey on the Harpeth and Falling Water River*
Brett Connell

*High Definition Stream Survey of the Lower Caney Fork River, TN: Assessing River Corridor Conditions and Trout Habitat at Multiple Discharge Rates*
James Parham

*Assessing the Uncertainty of 100-Year Flood Extent in a Morphologically Active River—A Case Study in the Obion River*
MD NM Bhuyian and Alfred Kalyanapu

## WATER QUALITY
## 3:30 p.m. – 5:00 p.m.

*Sulfur Isotope and Chemical Composition of Precipitation, Stream Water and Bedrock in Select Catchments in the Great Smoky Mountains National Park*
Adrian M. Gonzalez, John S. Schwartz, and Matt A. Kulp

*Presence of Fecal Indicator Bacteria in Sand by Distance and Depth at a Freshwater Recreational Beach*
Megan A. Stallard, Lara K. Jarnagin, Jordan Jatko, and Frank C. Bailey

*Experimental Studies on the Photocatalytic Degradation of Pharmaceutical Personal Care Products (PPCP) Using Rhodamine B Dye as a Surrogate*
Abibat Ahmed, Hassan Alsaud, Roger Painter, Lonnie Sharpe and Samuel Hargrove

# TVA RESERVOIR OPERATIONS AND DROUGHT

Amanda K. Bowen, P.E.[1]

## INTRODUCTION

The Tennessee Valley watershed has been periodically subjected to droughts of varying severity and duration. Extreme rainfall and runoff deficits can impact the ability of TVA to balance the multiple benefits of the Tennessee River system. As expectations and demands of the water system continue to increase, the susceptibility of the Tennessee Valley to suffer problematic impacts from drought will also increase. Realistic expectations and a coordinated response to drought conditions are essential in limiting drought impacts and balancing system benefits.

## APPROACH

TVA has developed a drought management plan with the goal to facilitate coordination and communication of drought conditions, potential impacts, and response actions in the Tennessee Valley to minimize adverse river and reservoir effects.

The drought management plan has five phases of drought response: Watch Phase, Precautionary Phase, Action Phase, Emergency Phase, and Recovery Phase. Determining the applicable drought phase for the Tennessee River system is based on published drought conditions and indices combined with an assessment of system inflows and reservoir levels.

TVA, the Seven Valley States, and other local and federal agencies must effectively coordinate and communicate information on drought conditions, impacts, and response actions. Conference calls, internet updates, e-mails, and news releases will be used to facilitate drought-related communications. The Tennessee Valley Water Partnership (TVWP) Drought Committee will facilitate communication and coordination among the seven Valley states and federal agencies. The TVWP Drought Committee will serve as a mechanism for the expeditious exchange of information regarding drought conditions, impacts, and response actions.

## RESULTS AND DISCUSSION

This presentation describes TVA Reservoir Operations, TVA's drought management plan, drought response phase determination, and the TVWP Drought Committee.

[1] Tennessee Valley Authority, 1101 Market Street, BR 4D, Chattanooga, TN 37402 akbowen@tva.gov

# THE 2016 DROUGHT IN THE TENNESSEE VALLEY: A LOOK AT THE STATISTICS, THE RESPONSE, AND THE RESULTS AND IMPACTS

Daniel P. Saint[1]

## INTRODUCTION

The Tennessee Valley Authority operates and regulates the waters of the Tennessee River and tributaries through a network of dams; this includes both main river and tributary dams. The TVA was created to oversee the benefits of the Tennessee River and to balance the benefits amongst competing demands; these benefits include: Navigation, Water Supply, Recreation, Flood-Damage Reduction, Power Generation, and Water Quality.

## APPROACH

The Tennessee Valley Authority has years of operational experience with vast ammounts of data and statistics to pour over as well as well written and defined rules of operation; all of these are used when operating and controling the flow in the the Tennessee River. However, in years of extremes the system can be very hard to balance as competing demands on the system require oversteppin other benefits.

## RESULTS AND DISCUSSION

The calander year of 2016 was very stressful on the Tennessee River System as a relatively normal spring was followed by periods of extreme drought. Many different statistics will be presented including: rainfall, runoff, and river flow data. Also to be discussed will be the governing documents that helped specify the required river flow during the summer months as well as any other requirements that were placed on the system from further downstream entities (i.e. the USACE on the Mississippi River). The purpose of this persentation will be not only to inform the audience about the difficult year that we endured during 2016, but also to make the audience aware of the chalenges that we could face in the future. Although this drought was historic in some ways, if TN continues to see population growth and increasing demands on the Tennessee River System, a drought of this magnitude could have more severe implications in future years.

[1] Tennessee Valley Authority, 400 w. Summit Hill Dr WT 10B, Knoxville, TN 37902 dpsaint@tva.gov

# DROUGHTS AND RESERVOIR YIELD; DECISIONS INFORMED BY TREE RING DATA

John Harrison, PE, D.WRE
Principal, Schnabel Engineering, LLC

In the United States, surface water supply projects are typically designed to provide adequate supply for either a 100-year drought or a drought of record. Implicit in this approach is the rationale that future droughts will not be significantly worse than past (instrumented record) droughts.

A desktop study was performed to assess the intensity and duration of drought events beyond that contained in the instrumented record. Researchers and analysts have derived various methods to correlate tree ring data with streamflow. Compared to the past 100 years, studies of tree rings by researchers indicates that droughts significantly more intense and persistent have occurred in the past 1,000 years.

This study will estimate safe yield of various hypothetical reservoirs using the drought of instrumented record, and compare that to safe yield estimates derived from streamflow reconstructed for the past 1000 years from tree ring data. The comparison can provide useful data to water suppliers for reservoir sizing and drought contingency planning.

# SOUTH CAROLINA'S NEW TOOLS TO ASSESS SURFACE WATER AVAILABILITY AND SUPPORT REGIONAL WATER PLANNING

John D. Boyer[1]

Recognizing that sustainable water resources are paramount to the prosperity of the State of South Carolina, the State recently initiated a comprehensive, five-phase program to update the State Water Plan. The five phases include surface water and groundwater availability assessments, water demand forecasting and regional planning, culminating in the update of the State Water Plan.

CDM Smith was retained to conduct the surface water availability assessment, which focused on the creation of a comprehensive surface water database, the development of unimpaired flows for each of the states eight river basins, the development of water allocations models, and a robust stakeholder involvement process. CDM Smith's Simplified Water Allocation Model (SWAM) was selected as the tool for conducting the surface water availability assessment and to ultimately support the development of regional plans. SWAM was developed to address the need for a networked, generalized water allocation model that could be easily and simply applied for planning studies by a wide range of end-users. Like most water allocation models, SWAM calculates physically and legally available water, diversions, storage, consumption, and return flows at user-defined nodes in a networked river system; however, unlike most other models, SWAM was designed to be intuitive in its use and streamlined in functionality, while still maintaining the key elements of water allocation modeling. This presentation will focus on how the recently completed models will be used to support permitting, enhance water resources planning and management, and ensure the sustainability of the resource.

[1] CDM Smith, 5400 Glenwood Ave. Suite 400, Raleigh NC 27612, boyerjd@cdmsmith.com

# 4-H WATER CAMP – GEORGIA VS TN

Lena Beth Reynolds
University of Tennessee Extension

4-H project for TN, with the topic of Water, is being developed. Pilot activities have been initiated in McMinn County, TN with $4^{th}$ through $12^{th}$ graders. The 4-H Honor Club was targeted because they meet outside of school, both junior high and high school members were involved, and these individuals were well known by the 4-H staff.

As a reward for being involved in the water project for the school year 2015-2016, the 4-H members were invited to travel to Burton 4-H Center on Tybee Island, Georgia. The group participated in the Environmental Education Program in September 2016. Classes included: Seining in the Surf, Sea Turtles, Shark Dissection, Marsh Ecology, Water Quality Testing in the Tidal Creek, and a Dolphin Cruise.

This presentation will overview the classes, as well as other activities on the trip. Results of the evaluations, including pre-test and post-test, and oral discussions will be included.

After returning from Tybee Island, an Environmental Education Camp for Tennessee 4-H is being considered. This would involve using camp facilities, Extension agents and specialists, and other agencies to develop the curriculum. Available resources at three 4-H camps are being assessed along with current activities being used.

# TENNESSEE VALLEY AUTHORITY WATER RESOURCE STEWARDSHIP EFFORTS

Shannon O'Quinn[1] and Tyler Baker[2]

The Tennessee River watershed is one of the most biologically diverse watersheds in North America. It is home to 270 fish and over 100 species of mussels. To protect and improve these resources, Tennessee Valley Authority (TVA) implements a multitude of environmental stewardship efforts across the Tennessee River Valley. This includes collecting and reporting water quality data and working with partners to implement watershed protection efforts. TVA has a long history of monitoring water resource conditions in TVA reservoirs as well as the streams and rivers that flow into them. This information is used to help TVA and its partners make management decisions, target water quality protection efforts, and track progress. TVA is working with multiple partners to enhance resource conditions in six priority watersheds: The Clinch and Powell Rivers in Virginia and Tennessee, the Elk and Duck Rivers in Tennessee, the Little Tennessee River in Tennessee and North Carolina, and Paint Rock River and Bear Creek in Alabama. Projects include conservation easements, streambank stabilization, buffer establishment, barrier removal, in-stream habitat improvements, mussel augmentation and many others. To accomplish these efforts, TVA always works with partners to prioritize and pool resources. Water Stewardship is accomplished by working together.

[1] Tennessee Valley Authority, 106 Tri-Cities Business Park Drive, Gray, TN
[2] Tennessee Valley Authority, 4601 North Access Road, Chattanooga TN

# APPLICATION OF THE HIGH DEFINITION STREAM SURVEY ON THE HARPETH AND FALLING WATER RIVER

Brett Connell[1]

The High Definition Stream Survey (HDSS) approach was created to rapidly gather continuous geo-referenced data in a single pass for a broad range of stream and streambank conditions by integrating GPS, video, depth, water quality and other sensors. Results from HDSS data can be used to determine the extent and distribution of instream habitat, locate areas that contribute to poor stream conditions, define the geomorphic condition for the stream, identify infrastructure impacts, document restoration results and provide a powerful "virtual tour" experience. The HDSS method is fast. For example, we surveyed 80 miles of the Harpeth River, TN in only five days with just 2 people. The HDSS method provides better data. We collect data on water depth, water quality, habitat type, bank condition, substrate, channel capacity continuously at approximately 1m resolution over these long survey reaches. The HDSS method is cost-effective. We have completed projects at 50 to 75% lower costs than traditional approaches. Example applications of the HDSS approach will be shown from the over 450 miles of surveys completed for numerous different federal, state, and private organizations throughout the southeastern United States.

[1] Trutta Consulting, truttaconsulting@gmail.com, 419-215-7897

# HIGH DEFINITION STREAM SURVEY OF THE LOWER CANEY FORK RIVER, TN: ASSESSING RIVER CORRIDOR CONDITIONS AND TROUT HABITAT AT MULTIPLE DISCHARGE RATES

James Parham, Ph.D.[1]

Below the Center Hill Hydroelectric Dam, the discharge of the Caney Fork River is regulated for power production. In addition, the river below the dam supports a high quality trout fishery. We surveyed 28 miles of the Caney Fork River from Center Hill Dam downstream to the Cumberland River using the High Definition Stream Survey method to assess river channel conditions prior to changes in the flow schedule associated with new power generation turbines at the dam. High Definition Stream Survey method gathers detailed multi-attribute streambank and channel data each second, allowing rapid surveys of complete stream channels. In addition to the single pass survey on the 28 mile segment, we also surveyed 5 miles immediately downstream of Center Hill Dam at 3 different discharge rates to better understand the impacts of the power peaking discharges on trout habitat. While we were surveying the habitat, the Tennessee Wildlife Resources Agency (TWRA) was conducting their trout sampling. We added video and GPS to their electro-fishing boat and were able to capture the exact locations of their sampling effort. This collaborative approach allowed us to expand the fisheries information gathered by the TWRA's standard survey to assess trout habitat use, availability, and selection. The results from the Caney Fork River High Definition Stream Survey show the effectiveness of the approach for use in stream channel assessments, water quality and quantity studies, habitat assessments, and community outreach.

[1] Parham & Associates Environmental Consulting, LLC., 149 Hedgelawn Drive, Hendersonville, TN 37075
(615) 461-0010, Jim.Parham@ParhamEnvironmental.com

**ASSESSING THE UNCERTAINTY OF 100-YEAR FLOOD EXTENT IN A MORPHOLOGICALLY ACTIVE RIVER – A CASE STUDY IN THE OBION RIVER**

MD NM Bhuyian[1] and Alfred Kalyanapu[2]

The Obion River watershed is located in North-West Tennessee. It has predominantly agrarian land use with small urban settlements. Significant increase in agricultural activity has been observed in last few decades in that region. Since 1980, annual lowest water level (LWL) in stream gages along the North Fork, Middle Fork, South Fork and Rutherford Fork show declining trend but stream gages from confluence at Rives to Bogota show the opposite. However, no major change in the hydrology has been reported. We hypothesize that river bed aggradation and degradation is responsible for this spatial and temporal trend of LWL. The rationale for this hypothesis is that in the given study area the change in LWL is more than water depth during dry period. Moreover, this phenomena can be manifested by bed level erosion in upstream in sedimentation beyond the confluence at Rives. This should change the river conveyance in individual reaches and decrease longitudinal slope causing increase in flood stage for a particular discharge. Therefore, assuming the hypothesis granted we intend to produce synthetic river bathymetries that demonstrate the Obion River at different periods since 1980 and implement them in a hydrodynamic model. Our objective is to show the uncertainty in 100-year flood extent for the study area if river bed morphology is assumed static. The focus of this research is to demonstrate the need for considering dynamic nature of river morphology for flood risk.

[1] Md Nowfel Mahmud Bhuyian, Graduate Student (PhD), Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Prescott Hall 314, Cookeville, TN 38505, Phone: 931-210-9514, Email: mnbhuyian42@students.tntech.edu
[2] Alfred Kalyanapu, Assistant Professor, Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Box 5015, Cookeville, TN 38505, Phone: 931-372-3561, Email: akalyanapu@tntech.edu

# SULFUR ISOTOPE AND CHEMICAL COMPOSITION OF PRECIPITATION, STREAM WATER AND BEDROCK IN SELECT CATCHMENTS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Adrian M. Gonzalez[1], John S. Schwartz[1]*, and Matt A. Kulp[2]

The essential nutrient sulfur is supplied to, and cycled within, the forested watersheds of the Great Smoky Mountains (GRSM) by numerous biogeochemical processes. Primary sources of sulfur to GRSM watersheds are atmospheric deposition and mineral components in bedrock geology. Sulfur in watersheds exists in many different chemical species and is found in almost all ecosystem components. Current research studies, using traditional chemical analysis and stable isotope ($\delta^{34}S$ and $\delta^{18}O$) analysis, seek to understand the quantities and characteristics of sulfur transformed from source to stored sulfur to exported sulfur within GRSM. Results will be presented showing water chemistry and $\delta^{34}S$ values in (1) rain collected from a monitoring station located at the headwaters of Noland Creek, (2) stream water collected from several small high-elevation catchments (study sites), and (3) select bedrock samples collected throughout the region encompassing the study sites. The influence of pyrite sulfur released from exposed bedrock on stream water composition is evident not only in $\delta^{34}S$ values, but in sulfate concentrations, pH, ANC, and dissolved metals concentrations. These results show some correlation to composition of bedrock underlying the drainage areas sampled. In catchment drainage areas not dominated by pyrite bedrock, the influence of acidic pollutant deposition is not necessarily evident. Ongoing studies of soil composition and sulfur content seek to explain stream water composition in these sandstone bedrock-dominated catchments. Results from these and future studies will provide Park managers with detailed information to better manage the valuable ecological resources of the Great Smoky Mountains.

[1] Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN 37996 (Phone: 865-974-7721; Email: jschwart@utk.edu)

[2] U.S. Department of Interior, National Park Service, Great Smoky Mountains National Park, Gatlinburg, TN 37738

# PRESENCE OF FECAL INDICATOR BACTERIA IN SAND BY DISTANCE AND DEPTH AT A FRESHWATER RECREATIONAL BEACH

Megan A. Stallard[1], Lara K. Jarnagin[1], Jordan Jatko[1], and Frank C. Bailey[1]

*Escherichia coli* is a fecal indicator bacteria (FIB) the Environmental Protection Agency and other regulatory agencies use as a surrogate to assess potential water quality impairment from fecal pathogens. Typically, *E. coli* is assessed in water with little emphasis on other matrices, such as sediment or sand, which serve as secondary habitats for fecal bacteria once they reach aquatic systems from storm water runoff or other sources. Sand contact has been implicated as a potential health risk to beachgoers due to presence of fecal bacteria, viruses, and associated pathogens, but no federal criteria have been developed for fecal pathogens in sand. Most research has focused on the presence of fecal indicators and pathogens in beach sand from coastal and Great Lakes locations, while studies on other inland recreational beaches are less represented in the literature. The objectives of this study were to investigate the presence of *E. coli* in sand at depth (0-10, 10-20, and 20-30 cm) and distance from shoreline (0, 3, 6, 9, 12 m) at Cedar Creek Recreational Area, a freshwater recreational beach at Old Hickory Lake in central Tennessee. Samples were collected at 25 transect points from dry beach sand (onshore) and wet sand (offshore) and analyzed for *E. coli* using the IDEXX culture method. The highest concentrations of *E. coli* (~14,000 MPN/100g sand) were found in the 0-10cm sections and closest to shore. Findings of FIB in inland beach sand could prompt regulators to create criteria for potential pathogens in beach sand.

[1] Middle Tennessee State University, Murfreesboro, TN USA

# EXPERIMENTAL STUDIES ON THE PHOTOCATALYTIC DEGRADATION OF PHARMACEUTICAL PERSONAL CARE PRODUCTS (PPCP) USING RHODAMINE B DYE AS A SURROGATE

Abibat Ahmed[1]*, Hassan Alsaud[1], Dr. Roger Painter[1], Dr. Lonnie Sharpe[2]
and Dr. Samuel Hargrove[2]

## ABSTRACT

Rhodamine B dye ($C_{28}H_{31}ClN_2O_3$) was investigated in the presence of UV irradiation. This work is an extension of the model generated in a previous study (Aarthi and Giridhar, 2007). $TiO_2$ catalyst was used as the photocatalytic material to determine the kinetics of the degradation process by applying the quasi-steady-state-assumption for all intermediate species. The effect of $Cu^{2+}$ as an electron scavenger was also investigated by using a detailed Langmuir-Hinshelwood kinetic model. A catalyst loading of 0.05g/L and 0.02g/L was employed throughout the experiments. All reactions were performed at room temperature. The $Cu^{2+}$ concentration ranged from 0 - 500 µg/L and the dye ranged from 0 - 500 µg/L. This range of concentration was studied because it is representative of the significant levels of PPCP in the environment. Each sample was analyzed by fluorimeter every hour. Linear and non-linear regression was performed on the data to obtain values for the reaction rate constants and adsorption equilibrium constants. The electron scavenging properties of $Cu^{2+}$ were exploited to isolate the direct hole and electron degradation pathways. It was shown that the dye degrades primarily via the electron pathway for OH* production. The results indicated that the degradation was pseudo-first order in the dye concentration but rate limited by the adsorption equilibrium of the dye and $CU^{2+}$ on the $TiO_2$ particle surface.

*Keywords*: Photo-catalysis, catalyst, metal ions, dye, contaminant, Langmuir-Hinshelwood kinetic model

## REFERENCE

T. Aarthi and Giridhar Madras*. ‘Photocatalytic Degradation of Rhodamine Dyes with Nano-TiO2’. Department of Chemical Engineering, Indian Institute of Science, Bangalore 560012, India. Ind. Eng. Chem. Res. 2007, 46, 7-14

[1] Civil engineering, Tennessee State University, Nashville, TN
[2] Mechanical Engineering, Tennessee State University

## SESSION 3A

## WATERSHED RESTORATION PLANNING
**8:30 a.m. – 10:00 a.m.**

*Using Bioassessments to Track Changes in Stream Conditions in Response to Stream Restoration Projects*
Veronica Logue

*A Monitoring and Assessment Framework to Evaluate Stream Restoration Needs in Urbanizing Watersheds*
John S. Schwartz, Sue L. Niezgoda, Tess M. Thompson, and Joanna Crowe Curran

*Visionary by Design: Contemplating a New Century of Innovation in the Tennessee River Valley*
Brad Collett

## PLANNING FOR GROWTH AND AQUATIC RESOURCES IN TENNESSEE
**10:30 a.m. – 12:00 P.m.**

*Speakers:* M. Hunt, Nashville Metro Water Services, Storm Water Division, NPDES Office; Robbie Karesh, TDEC Statewide Stormwater Coordinator, Division of Water Resources; Stephanie A. Durham, TDEC Assistant General Counsel; Andrea Ludwig, Associate Professor and Watershed Faculty Consortium Chair, UTK Department of Biosystems Engineering and Soil Science; Chris Granju, Knox County Stormwater Management Director; Shelby Ward, Counsel for Tennessee Clean Water Network (Abstracts Not Available)

# USING BIOASSESSMENTS TO TRACK CHANGES IN STREAM CONDITIONS IN RESPONSE TO STREAM RESTORATION PROJECTS

Veronica Logue[1]*

There are several ways to assess water quality and improvements in stream conditions. In the past, our methods have focused mainly on tracking physiochemical properties, such as dissolved oxygen or bacteria levels. These methods are useful to provide snapshots of the condition of a waterbody, but do not provide the integrative measure of overall health of a stream. Biological assessments can provide an integrated, comprehensive assessment of the health of a waterbody over time. In addition, macroinvertebrates can be utilized to identify aquatic life stressors, set pollutant load reductions, and indicate the relative success of stream restoration. Cathy Jo Branch is a small headwater steam that flows through the grounds of the Nashville Zoo and is currently listed as an impaired (Category 5) stream on the 2016 Draft Version 303(d) list. In 2014 The Cumberland River Compact, KCI Technologies and the Zoo at Grassmere began a stream restoration project to solve a stormwater issue and ultimately improve the water quality and stream habitat in Cathy Jo Branch. Semi-Quantitative Single Habitat samples along with habitat assessments were collected and conducted in reaches downstream of stream restoration activities. Before and after samples and assessments were conducted in an attempt to track stream improvements and provide a better understanding of what leads to success or failure in such projects. Improved habitat in this stream could potentially lead to delisting for certain parameters and ultimately provide a higher quality environment for species of interest found in this watershed (i.e. Nashville Crayfish and Streamside Salamander).

[1] Metro Water Services, Stormwater/NPDES, 1607 County Hospital Road, Nashville, TN 37218
veronica.logue@nashville.gov

# A MONITORING AND ASSESSMENT FRAMEWORK TO EVALUATE STREAM RESTORATION NEEDS IN URBANIZING WATERSHEDS

John S. Schwartz[1], Sue L. Niezgoda[2], Tess M. Thompson[3], and Joanna Crowe Curran[4]

Urbanization has a significant impact on rivers and streams, modifying flows, sediment loads, channel morphology, water quality and nutrient processing, and aquatic biota. Because of these impacts, a majority of the streams in urban and urbanizing watersheds are reported on §303(d) state lists as impaired from siltation, habitat alteration, nutrients, bacteria, and other stressors. States are required to develop total maximum daily loads (TMDLs) under 40 CFR 130, and watershed-scale implementation plans are produced to rehabilitate impaired streams by achieving target TMDL allocations. Stream restoration practices are commonly used as corrective measures to meet TMDLs, particularly for siltation and habitat alteration. However for various reasons, urban stream restoration typically consists of reach-scale projects that may not be well integrated into a watershed corrective plan. Project scope and location are commonly determined by local perceptions of need and accessibility rather than a geomorphic, hydrologic, and ecological assessment of potential watershed recovery. Potential recovery is dependent on a changing system hydrology and sediment yields as development continues to occur over time until ultimate build-out, and on how infrastructure constrains channel planform stability. In order to achieve heightened ecological and water quality benefits from restoration projects, projects must be planned within a watershed context where assessments are integrated with stormwater management practices. The objective of this paper is to present a framework for monitoring and assessment protocols for urban and urbanizing watersheds, with the aim to better support planning of stream restoration projects and improve restoration outcomes. This is the product of a joint task committee by the Urban Stream Committee of the Urban Water Resources Research Council and the River Restoration Committee of the Hydraulics and Waterways Council of the American Society of Civil Engineers.

[1] University of Tennessee, Dept. of Civil and Environmental Engineering, Knoxville, Tennessee 37996; jschwart@utk.edu
[2] Gonzaga University, Civil Engineering Department, Spokane, Washington 99245; niegoda@gonzaga.edu
[3] Virginia Tech, Dept. of Biological Systems Engineering, Blacksburg, Virginia 24061; tthompsom@vt.edu
[4] Northwest Hydraulic Consultants, Seattle, Washington 981880; JCurran@nhcweb.com

# VISIONARY BY DESIGN: CONTEMPLATING A NEW CENTURY OF INNOVATION IN THE TENNESSEE RIVER VALLEY

Brad Collett, ASLA, RLA, LEED AP
University of Tennessee School of Landscape Architecture

## INTRODUCTION

The Tennessee River Valley is looked to the world-over as a model landscape of innovative, integrated resource management. From the Middle East's Jordan River Valley to China's Yangtze River, the influence of the Tennessee Valley Authority's multifunctional infrastructures and its watershed approach to providing for flood control, commercial navigation and rural electrification–prevailing challenges throughout the Valley during the early- and mid-20$^{th}$ century–is far reaching.

As the communities that rely upon the Tennessee River system for energy, commerce, water supply and recreation look ahead to the 21$^{st}$ century, new and increasingly complex challenges present themselves. Unprecedented population and economic growth, dynamics of a changing climate and protecting a level of aquatic biodiversity unrivaled in North American river systems headline this list of emergent challenges, each compounded by aging infrastructure, shifting landscapes of agricultural and industrial production, and pressures from point- and non-point sources that will impact the river's water quality.

Meeting these emergent challenges requires best practices, novel ideas and multi-scalar thinking along the river system and throughout the Tennessee River's 41,000-square-mile watershed advanced by a range of constituencies, including land owners, public officials and agencies, and water resource professionals.

Architects and landscape architects may not immediately come to mind as the most likely group of 21$^{st}$ century river stewards, though large-scale ecological and cultural systems, long-range planning, and multifunctional infrastructures represent emergent practice territories for these professions.

Collaborative design creates a productive space through which innovative *possibilities* can be discovered, including how the river system, the communities it supports, and the watershed's elemental landscapes and infrastructures may be recalibrated to thrive amidst the grand challenges of the next century. These capacities are put to the test in the UT School of Landscape Architecture and School of Architecture.

## VISIONARY BY DESIGN

Two recent initiatives within the UT College of Architecture and Design task faculty and aspiring design professionals with exploring innovative water quality improvement projects for Southeast Tennessee and envisioning bold 21$^{st}$ century visions for the Tennessee River System.

*Hydro Lit: A Water Quality Improvement Playbook for Southeast Tennessee* will be published in February of 2017. Developed through partnership with the Southeast Tennessee Development

District and the UT School of Landscape Architecture, this resource connects regional development, waste management, educational and transportation systems to prevailing water quality challenges and proposes innovative, cooperative solutions that move beyond territories of green infrastructure and stormwater BMPs.

During the fall semester of 2016, students from the University of Tennessee College of Architecture and Design helped launch the *Tennessee River Project*, a new multi-year, multi-discipline research initiative that took them on a tour of the Tennessee River Valley that covered more than 1,100 miles and introduced them to the many voices that influence the river system, including TVA.

This initiative, led by the UT School of Landscape Architecture in partnership with the college's Governor's Chair for Energy and Urbanism, is aimed at gaining an understanding of the Tennessee River system's contemporary challenges and inserting design and planning disciplines more robustly into discussions around the Tennessee River. With a mission to contemplate speculative, visionary proposals that steward the Valley's resources while maintaining its legacy of leadership and innovation, six students from the School of Landscape Architecture and six from the School of Architecture embarked on this 15-week regional Tennessee River Studio under the leadership of Brad Collett, Assistant Professor of Landscape Architecture.

A 1,100-mile listening tour of the Tennessee River's main stem, GIS-based research, and interactions with River System stakeholders informed student proposals that included new regional recreation amenities, concepts for novel waterfront economies, and land use planning frameworks that enable new levels of accessibility and resource protection.

This presentation shares the intentions and outcomes to-date of these ongoing initiatives, highlights the role of planners and designers in a new century of visionary thinking and innovative resource management in the Tennessee River Valley and beyond, and solicits partnership from TNAWAR leadership and membership in upcoming Tennessee River Project activities.

## SESSION 3B

## MODELING
## 8:30 a.m. – 10:00 a.m.

*Hydrological Model Calibration and 2D Hydraulic Analysis of Ralston Creek*
Jeffrey B. Shaver

*Supplemental Tools for Natural Channel Design*
Patrick McMahon and Ken Barry

*Advances in Hydrologic Assessment Techniques for Mixing Zone Modeling*
Brian Ham, Ginny Gray Davis, Shaun Winter

# HYDROLOGICAL MODEL CALIBRATION AND 2D HYDRAULIC ANALYSIS OF RALSTON CREEK

Jeffrey B. Shaver[1]

## INTRODUCTION

After the historic 2010 floods in Middle Tennessee, the City of Franklin, TN conducted an assessment of the streams in their jurisdiction. Ralston Creek was one stream identified for potential restoration and stabilization to address flooding and improve water quality. It is 303(d) listed for loss of biological integrity due to siltation and alteration of stream-side littoral vegetation. Ralston Creek originates between Huffines Ridge Drive and I-65 near Centennial High School in Franklin and flows in a southwesterly direction before entering into the Liberty Hills Subdivision Retention Pond. The retention pond also receives flow from an eastern channel along Liberty Pike, which is listed as part of the headwaters for Ralston Creek. After leaving the retention pond through its outlet structure, Ralston Creek flows through the Royal Oaks Subdivision where the City of Franklin has received a number of complaints from residents regarding flooding due to stormwater from Ralston Creek overtopping its banks. There are also areas along Ralston Creek that are experiencing bank failure.

The City of Franklin engaged CEC, Inc. to determine potential ways to address flooding and streambank erosion along Ralston Creek in the Royal Oaks Subdivision.

## APPROACH

The process of determining the potential ways to address the flooding and streambank erosion along Ralston Creek involved several stakeholders such as the City of Franklin, residents living adjacent to the retention pond and Ralston Creek, TDEC, and the Corps of Engineers. Perceptions from the public involvement related to this project range from those that view the retention basin as an amenity that needs to be maintained as it is; to modifying the retention basin to increase its flood storage to mitigate for downstream flooding and bank erosion.

The watershed draining to Ralston Creek is urban with residential lots of various sizes, commercial regions, a school campus, and some undeveloped meadow and forested regions. The watershed is underlain with various soils types. The developed regions of the watershed contain storm sewer systems with curb and gutters, stormwater inlets, catch basins, swales, pipes, culverts, concrete lined channels and detention basins. To reduce the cost and burden of surveying the retention pond's contributing watershed in order to develop the hydrological model for this project, the pond's response to rainfall events was measured. Rainfall, pond level, and discharge from the pond's outlet structure were collected to calibrate the hydrological model developed for the retention pond's contributing watershed. After the hydrological model was calibrated to the field-collected data, various rainfall events were simulated.

---

[1] Civil & Environmental Consultants, Inc., 325 Seaboard Lane, Suite 170, Franklin, TN 37067 jshaver@cecinc.com

To evaluate flooding and alternatives to mitigate for the eroding stream banks along Ralston Creek downstream of the retention pond, a two dimensional (2D) hydraulic analysis was performed. To build the 2D hydraulic model, field surveyed cross sections were collected to represent the current alignment of Ralston Creek and the area that lies directly adjacent to the stream. Back yard topographical information, fences, other residential structures, utilities and back of house corners that were located in in the cross sections were also collected. To supplement the field survey, the City of Franklin provided aerial-produced topographic information of the area. The retention pond's outflow hydrographs from the calibrated hydrological model were used for the inflow in the 2D hydraulic model. The results of the 2D hydraulic model were checked against data provided by a resident living adjacent to Ralston Creek. The resident provided depth of the water surface below a bridge along with the date and time the measurements were obtained for two storm events during the data collection period.

## RESULTS AND DISCUSSION

With both the hydrological and hydraulic models calibrated, alternatives to reduce the peak flow from the retention pond, increase the flood storage volume, and drain the retention pond replacing it with a natural channel were evaluated. The 1-year, 24-hour and 10-year, 24-hour storm events as well as the field collected observed data were evaluated for each alternative. For storm events larger than the 10-year, 24-hour, the retention basin is overtopped, and its primary outlet structure is bypassed by a portion of the discharge.

Increasing the flood storage volume of the retention pond resulted in a one to five percent reduction of the peak flow discharged from the retention pond. Modifying the outlet structure of the retention pond would realize a two to nine percent reduction of the peak flow discharged from the retention pond. And a combination of increasing the flood storage and modifying the outlet structure of the retention pond would produce a five to ten percent reduction of the peak flow discharged from the retention pond.

Preparations are underway for a public meeting in early 2017 to obtain additional public input for the project.

## SUPPLEMENTAL TOOLS FOR NATURAL CHANNEL DESIGN

Patrick McMahon, PhD, PE and Ken Barry PE, D.WRE

This presentation will review the use of continuous simulation modeling (CSM) and 2-dimensional (2D) hydraulic modeling techniques to supplement the Natural Channel Design (NCD) approach with an emphasis on applications in urban settings. The NCD approach promoted by the U.S. Environmental Protection Agency and others is strongly dependent on the quantification of the bank full flow rate and associated channel geometries of a given stream. In an urban setting, the determination of bank full flows is often a difficult prospect given the complex nature of urban hydrology, the highly modified morphology and hydrology of urban streams, and the often subjective indicators of bank full stage that can be observed in the field. This presentation will describe the application of CSM to supplement bank full flow interpretations on urban streams. CSM involves application of a continuous record of historical precipitation data to hydrologic and hydraulic models for a given watershed. This technique is useful for the estimation of the frequency of flows of a given magnitude, such as the bank full flow as well as the evaluation of the potential impact of future hydromodification within a watershed. Another difficulty that arises in the application of the NCD approach in urban settings is the need for reference reach data. Reference reach data is intended in part, as a means to evaluate long term dynamic stability of the restored reach. Reach data is also used as a surrogate for analyses of the suitability of the hydraulic habitat in the restored reach for \anticipated transient and resident species. Given the degree of anthropogenic impacts to urban watersheds and their receiving streams, a suitable reference reach may be difficult to identify. This paper presents the application of 2D modeling techniques to supplement the use of any available reference reach data in the evaluation of potential failure modes for restored streams and evaluation of the hydraulic suitability of the restored reach for the anticipated species.

# ADVANCES IN HYDROLOGIC ASSESSMENT TECHNIQUES FOR MIXING ZONE MODELING

Brian Ham, PG, GISP[1]; Ginny Gray Davis[2], Shaun Winter[3]

As our understanding of hydrologic flow regimes is better refined with enhanced modeling and new statistical methods, this new information is incorporated into assessments to be protective of aquatic ecosystems. Technological advances in hydrologic instruments have also provided a significant advantage with the development of tools like the Sontek acoustic doppler current profiler (ADCP). The efficiency of these new instruments and the valuable, high resolution data that they provide have become an integral component in hydrologic assessments. These advanced tools provide important data that can be used to model surface water conditions and mixing zones for discharges associated with industry.

Case studies will be presented to highlight sources of historical hydrologic information, advances in field data collection, and the modeling tools used to evaluate mixing zones between outfalls and receiving waters. EnSafe Inc. recently conducted two assessments for National Pollutant Discharge Elimination System outfalls using this optimized approach and provided unique solutions to engineer multi-port diffuser outfall systems that are protective of the aquatic environments. The presentation will include a summary of research methods, field data collection techniques, geographic information system representations (including a 3-dimensional bathymetric survey), and an overview of the USEPA-supported mixing zone modeling program CORMIX.

[1] EnSafe Inc., 220 Athens Way, Suite 410, Nashville, Tennessee 37228 bham@ensafe.com
[2] EnSafe Inc., 308 North Peters Road, Suite 200, Knoxville, Tennessee 37922 ggray@ensafe.com
[3] EnSafe Inc., 220 Athens Way, Suite 410, Nashville, Tennessee 37228 swinter@ensafe.com

## SESSION 3C

## TOOLS AND TECHNIQUES
**8:30 a.m. – 10:00 a.m.**

*Creating an Application-Specific Tool for Loading Data into WQX*
Gerald A. Burnette

*Identification of Potential Water Quality Trading Markets in Tennessee:  A Spatial Analysis*
Ayuska Ojha and Christopher D. Clark

*Potential of Neutralized Bauxite Residual in the Removal of Aqueous Phosphorus*
Yongfeng Wang and Qiang He

# CREATING AN APPLICATION-SPECIFIC TOOL FOR LOADING DATA TO WQX

Gerald Burnette[1]

## ABSTRACT

Organizations that collect water quality data are encouraged (and often required) to share their data with others through EPA's Water Quality Exchange (WQX). EPA's guidance offers three potential paths for accomplishing this: establishing an Exchange Network node explicitly for the organization, use of a generic Exchange Network client application (Node Client Lite), and submission using the WQX Web interface. A fourth option exists, however, that can be more efficient and effective. EPA has created a Dynamic Link Library (DLL) of functions that interact with the Exchange Network directly. EPA will share this DLL with organizations that request it. Using this DLL, organizations may create custom applications that accomplish the data sharing objective while reducing the burden of data formatting. This presentation will compare the costs, advantages/disadvantages, and procedures associated with each of the methods. Examples from a live application used by the US Army Corps of Engineers will be presented to illustrate how the custom application improves the process.

## BACKGROUND

Since the 1970's, EPA has been tasked with gathering and sharing water quality data collected by Federal, State, and other Agencies. The first system developed for addressing this requirement had the rather generic moniker of the STorage and RETrieval system (STORET). For this mainframe-based database, data were loaded by submitting ASCII files to the system managers and data were retrieved by directing requests to the same. Data were limited to identification of sampling locations and basic lists of results. In the mid-1990's, EPA determined that the data model for STORET was outdated and too simplistic. To fix the situation, EPA created a much more robust data model that they incorporated into a new version of STORET. This data model addressed most of the shortcomings of the earlier version by imposing metadata requirements to help users evaluate the applicability and quality of a particular parameter value.

The new paradigm presented a problem, however: loading relational data into a central database was impractical using text files. EPA addressed this issue by creating a desktop version of STORET that shared the same database structure as the main system and included forms for locally managing data. Users entered their data into the local copy of STORET, then exported their entire database and sent it to EPA for inclusion in the national data warehouse.

In the early 2000's, introduced another new approach. The new concept was part of a larger network designed to share all sorts of environmental data. The overall system was called the Exchange Network; the water quality portion was designated as the Water Quality Exchange (WQX). While WQX maintained the most recent STORET data model, STORET was eliminated as a separate product. Organizations were left to their own devices for local management of their water quality data. Submission of data to WQX was accomplished through

1

the Exchange Network's infrastructure.

## STANDARD OPTIONS FOR SUBMITTING WQX DATA

From the perspective of the Exchange Network, the process for loading data to WQX consists of three steps. First, the XML file is submitted to the Central Data Exchange (CDX). CDX checks the format of the file to ensure that it is valid according to the generic rules of XML. If the file fails this validation, notice is recorded in the results file and processing stops. Second, if the file passes basic XML validation, it is passed to the target exchange (e.g., WQX). The specific exchange validates the file according to its internal data integrity rules. If the file fails this validation, notice is recorded in the results file and processing stops. Finally, if the file passes exchange validation, the data are loaded. Results associated with each completed step are stored in files that are made available for download by the account that submitted the original file.

The entry point into the process is the submission of the data file. When WQX was first introduced, EPA offered two options for submitting data to WQX (both are still available). One approach – the more robust – requires developing a node on the Exchange Network and programming that node to accommodate the data flows of WQX. This is a relatively expensive and somewhat intimidating undertaking, but it has the advantage of enabling full access to the Exchange Network by the node owner. This facilitates acquisition and distribution of a wide variety of environmental data. Building a node requires dedication of hardware resources, developing application software that follows specific protocols, and publishing services out to the Network.

Most organizations do not have the resources to develop a full node. For these organizations, the simpler approach involves running a client software package on a PC that emulates a subset of node functions. EPA provides such a program: Node Client Lite. Node Client Lite allows you to perform two of the actions available to more traditional nodes – sending data to an exchange or pulling data down from an exchange – without the investment required to develop a full-blown node.

Around 2010, EPA created a third option – WQX Web – that allowed users to once again submit data in plain ASCII format. WQX Web is a web site that allows users to post flat files of data, then analyze and manipulate those files into acceptable XML format and submit the XML files to WQX. While conceptually simpler, this process can be cumbersome and time-consuming. There are no less than 12 different file types that either may or must be loaded and processed in order to post data to WQX through WQX Web. Each file submitted requires an accompanying import configuration file, so the number of files can quickly become intimidating.

## EXCHANGE NETWORK DLL

A fourth option exists: creation of a custom application using a Dynamic Link Library (DLL) that includes functions that interact with Exchange Network nodes. The DLL can be obtained by requesting a copy from EPA's STORET team. The DLL was developed using Microsoft's .NET framework and can be invoked from any application based on that framework.

Creating a custom application using the DLL is not difficult. The DLOL provides functions and capabilities similar to those found in Node Client Lite. A custom application offers some

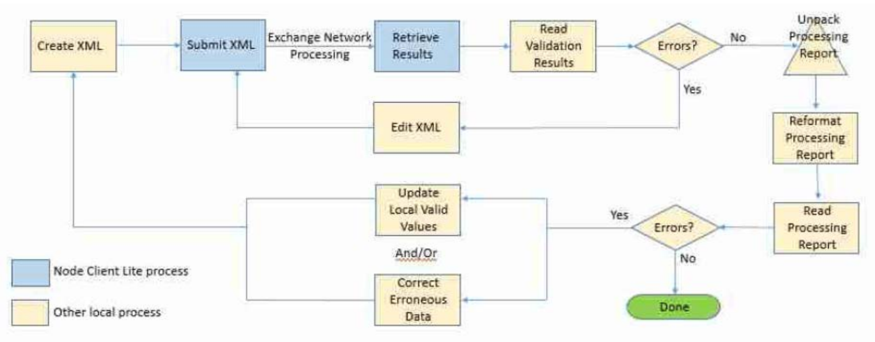



**Figure 1. Submitting data to WQX using Node Client Lite.**

advantages over the standard EPA generic client. For instance, Node Client Lite has some unnecessary limitations (e.g., inability to specify default directories, no provision for displaying downloaded files). More importantly, Node Client Lite does not create XML files for

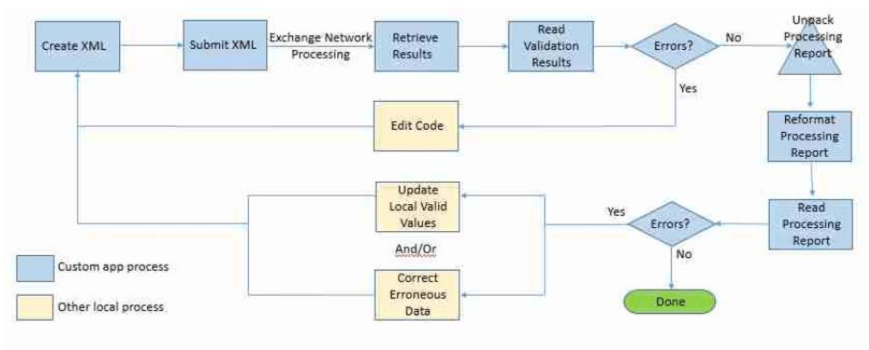



**Figure 2. Submitting data to WQX using a custom application.**

submission. Use of a single application that both creates the XML and communicates with the WQX therefore offers a vast improvement in efficiency of the total process.

Figure 1 illustrates the steps required to successfully submit data to WQX using Node Client Lite. The items with a blue background represent the steps that are managed within Node Client Lite. All other activities must be executed using other programs.

Figure 2 shows the steps required to successfully submit data to WQX using a custom solution that uses the DLL. The specific steps remain essentially the same since the process itself does not vary. As in Figure 1, the items with a blue background are managed within the custom application. The significant difference lies in the number of steps that are managed within the application itself. The only operations in this scenario that are beyond control of the application are those related to correcting errors in the data.

Note also the difference that occurs when errors are discovered at the first error check – problems due to XML formatting issues.  Depending on the package used to create the XML file, resolving these issues in the first scenario may not be possible through any means other than directly editing the XML file itself.  With the custom application, it is the application itself that creates the XML file, so these are considered bugs in the software.  All errors of this type should be identified and resolved during software development and testing, so the likelihood of encountering these errors is greatly diminished.

## REQUIREMENTS FOR CUSTOM DEVELOPMENT

Development of a custom application for comprehensive management of the WQX submission process presents relatively few new requirements.  Basic requirements apply to all submission methods:

- $ a thorough understanding of the WQX metadata requirements can be gleaned from documentation available for download from EPA's STORET site,
- $ the required level of knowledge regarding XML structure can be acquired by examining examples available for download from EPA and other resources, and
- $ experience with the Exchange Network submission process is available in tutorials and publications available from EPA.

The only requirements particular to creation of a custom application are related to software development skills and experience.  The developer must understand the data model utilized in the management of local data in order to meet the WQX metadata requirements, they must be able to extract and manipulate data from local storage using any .NET language, and they should be comfortable with DLL function calling procedures.  The biggest impediment to successful program development is the lack of documentation related to the DLL functions.

## CONCLUSION

The most widely publicized methods for submitting data to WQX are targeted at organizations at the extreme ends of the data volume spectrum.  Organizations with large volumes of data can benefit from creating a node on the Exchange Network.  Organizations that submit data occasionally can tolerate the complexities and quirks of Node Client Lite and WQX Web.  For most other organizations, the advantages offered by a custom application that generates and manages submissions is well worth the effort it takes to create.  Table 1 compares the requirements, costs, and resulting capabilities for each of the four options discussed in this article.

**Table 1. Requirements, Costs, and Capabilities of Various WQX Connection Options.**

| Item | Dedicated Node | Node Client Lite | WQX Web | Custom Application |
|---|---|---|---|---|
| Requirements | | | | |
| Hardware | Server | Desktop PC | Desktop PC | Desktop PC |
| Purchased Software | IIS and other software associated with a web server | Node Client Lite | Web browser | Development platform |
| Developed Software | Node services | None | None | Application |
| IT Support Level | Very high | Low | Very low | Moderate |
| Software Installation Required | Depends on local node operations | Yes | No | Yes |
| Costs | | | | |
| Development | Very high | None | None | Moderate |
| Operational | Moderate to high | Minor | None | Low |
| Maintenance | Moderate to high | Minor | None | Low |
| Capabilities | | | | |
| Send data to any Exchange | Yes | Yes | No | Yes |
| Retrieve data from any Exchange | Yes | Yes | No | Yes |
| Send data to WQX | Yes | Yes | Yes | Yes |
| Retrieve data from WQX | Yes | Yes | No | Yes |

# IDENTIFICATION OF POTENTIAL WATER QUALITY TRADING MARKETS IN TENNESSEE: A SPATIAL ANALYSIS

Ayuska Ojha[1] and Christopher D. Clark[2]

## INTRODUCTION

Water quality impairment is a prominent issue in Tennessee. Many water bodies in the Tennessee are unable to support their intended use (TDEC, 2014). Water quality trading (WQT) has been promoted as a flexible mechanism to reduce water quality impairment at lower cost (Ribaudo and Gottlieb, 2011). However, the results of trading programs, to date, are not encouraging (Jones and Vossler, 2014). Given the inherent spatial limitations of WQT programs, the spatial locations of potential buyers and sellers of credits and impairments are keys to program success (Roberts et al., 2008). Therefore, the purpose of this study is to analyze the spatial feasibility of nutrient-related WQT markets in Tennessee to identify priority areas for WQT implementation.

## APPROACH

This analysis updates and extends the stepwise screening technique used by Roberts et al., 2008. As a first step, nutrient-related impairments, point sources (PS) with nutrient-related limits, and agricultural non-point sources (NPS) in Tennessee were geospatially located. HUC-12s that neither contain nor are upstream of a nutrient-related impairment were eliminated. The remaining HUC-12s were aggregated to form flow-linked “impairment zones” based on contribution to the same impairment. Thereafter, impairment zones with no contributing PS were eliminated from the analysis. The remaining zones form potential “WQT markets”.

## PRELIMINARY RESULTS

A preliminary analysis shows that agriculture is the cause for fifty seven percent of impaired water bodies in Tennessee. Similarly, twenty eight percent of water bodies are impaired due to nitrogen, phosphorus or oxygen-related impairments. 125 “impairment zones” for nitrogen, 105 zones for phosphorus and 90 zones for oxygen were formed by aggregating HUC-12s that are either impaired or are upstream to an impairment. After eliminating zones without contributing PS, potential markets for nitrogen, oxygen and phosphorus were identified and analyzed.

## REFERENCES

Ribaudo, M. O., and Gottlieb, J., 2011. Point-Nonpoint Trading–Can It Work? *JAWRA Journal of the American Water Resources Association* 47(1), p 5-14.

[1] Graduate student in Department of Agriculture and Resource Economics, University of Tennessee
[2] Professor in Department of Agriculture and Resource Economics, University of Tennessee

Jones, L. R., and Vossler, C. A., 2014. Experimental tests of water quality trading markets. *Journal of Environmental Economics and Management*, 68(3), p 449-462.

Roberts, D. C., Clark, C. D., Park, W. M., and English, B. C., 2008. A spatial assessment of possible water quality trading markets in Tennessee. *Applied Economic Perspectives and Policy* 30(4), p 711-728.

Tennessee Department of Environment and Conservation, 2014. The Status of Water Quality in Tennessee-- The 2014 305 (b) report: Nashville, Tennessee, Division of Water Resources, p. 39-46.

## POTENTIAL OF NEUTRALIZED BAUXITE RESIDUAL IN THE REMOVAL OF AQUEOUS PHOSPHORUS

Yongfeng Wang[1]* and Qiang He

## ABSTRACT

The beneficial reuse of bauxite residue, a highly alkaline waste generated from aluminum production, is desirable for the sustainable management of this waste stream. Given the alkaline nature of bauxite waste, treatment typically involves acid neutralization. With the iron oxide-rich mineralogy of bauxite residual, this study investigated the potential of neutralized bauxite residual in the removal of aqueous phosphate via adsorption at concentrations relevant to stormwater runoff. Three types of bauxite residual were tested, exhibiting phosphate adsorption capacity ranging from 0.93 to 1.58 mg P/g. The parallel-first-order model suggested the phosphate adsorption process followed two-phase adsorption. The phosphate adsorption capacity was found to be affected by sulfate concentration, pH, initial phosphate concentration, and temperature. The increase in sulfate concentration, initial phosphate concentration and temperature lead to the increase in phosphate adsorption capacity. The phosphate adsorption isotherms showed good fit to the Freundlich model, indicating that heterogeneity in adsorption sites played an important role in phosphate adsorption by neutralized bauxite residual.

[1] Department of Civil and Environmental Engineering, The University of Tennessee, Knoxville, TN 37996
ywang157@vols.utk.edu

## STUDENT POSTERS

**Undergraduate**

*Groundwater Hydrology in a Karst Aquifer at Tennessee State University, Nashville, TN.*
Renas Barzanji, Lonnie Sharpe, Jr., acknowledgement Tom Byl

*Monitoring Discharge and Hydrograph Response Times for a Large Karst Spring, The Boils, Jackson County, TN*
Bethany Boggs, Karaline Deaton, and Evan A. Hart

*Development of a Hydrologic Modeling System for the Dry Valley Catchment, Putnam County, Tennessee*
John Brackins, Alex J. Davis, Sarah E. Wilson, and Alfred J. Kalyanapu

*Mapping the Extent of Coal Mining Damage in the Waterways of Wilder, Tennessee and Surrounding Areas, 2015-17*
Zachary Hodge

*Effects of Water Hardness on Bacterial Attachment to Fine Sand*
Lara Jarnagin, Megan A. Stallard, and Frank C. Bailey

*Determining the Presence of Traditional and Alternative Fecal Indicators in Murfreesboro, TN Storm Drain Biofilms*
Jordan Jatko, Megan A. Stallard, and Frank C. Bailey

*Stimulatioin of Plant Growth by Groundwater Naturally Rich in Sulfide and Calcium*
Dannelle Solomon

**Graduate**

*Hydrology of an Urban Wetland at Tennessee State University, Nashville, TN*
JeTara Brown, Lonnie Sharp, Jr., acknowledgement Tom Byl

*Modeling Paleofloods in the Tennessee Valley: Associating Flood Deposits with Flows and Performing Frequency Fitting*
Hannah R. Kubas

*Effects of Different Cover Crop Species on Soil and Water Quality*
Mingwei Chu, Sindhu Jagadamma, Michael Buschermohle, and Forbes Walker

*Seasonal Variations and Statistical Analysis of the Physicochemical Characteristics in a Developing Wetland in Nashville, Tennessee, 2017*
Mark C. Okafor, De'etra Young, and Thomas D. Byl

*Development of an eDNA Protocol to Detect and Quantify Streamside Salamanders* (Ambystoma barbouri) *in Low-Order Streams of Middle Tennessee*

Nicole Witzel, Ali Taheri, and William B. Sutton

**Doctoral**

*Critical Shear Stress Measurement of Cohesive Soils in Streams:  Identifying Device-Dependent Variability Using an In-Situ Jet Test Device and Conduit Flume*
Badal Mahalder, John S. Schwartz, Angelica M. Palomino, and Athanasios N. Papanicolaou

*Influence of Environmental Characteristics on Fecal Indicator Measurements in Streams*
Lu Yang and Qiang He

*Effect of Nutrient Addition During Phytoremediation on Lead Partitioning in Dredged Sediment*
Tianxue Yang, Qiang He, Chunguang He, Aixia Wang, and Lianxi Sheng

## PROFESSIONAL POSTERS

*Assessing the Success of DRAINMOD and Reference Wetlands for the Prediction of Hydrology in Wetland Restoration Sites in North Carolina*
Eric Neuhaus, Kirsten Gimbert, Jeff Keaton, and John Hutton

*Estimated Use of Water in the Cumberland River Watershed in 2010 and Projections of Public-Supply Water Use to 2040*
John A. Robinson

# GROUNDWATER HYDROLOGY IN A KARST AQUIFER AT TENNESSEE STATE UNIVERSITY, NASHVILLE, TN

Renas Barzanji[1] Lonnie Sharpe, Jr.[2], acknowledgement – Tom Byl[3]

Karst refers to carbonate bedrock with fractures, caves, and sinkholes and has complex hydrology. The objective of this project was to characterize the hydrogeology of the karst aquifer at the Tennessee State University (TSU) research farm in Nashville, TN. At the farm, there are 9 wells drilled into bedrock with depths ranging from 175 to 250 feet below ground surface. A westerly groundwater flow was calculated using the triangulation method and water level measurements. Three aquifer pump tests were conducted using three different pumping wells. The transmissivity ranged from a low of 13 square feet / day, with a median of 317 sq ft/day, and a high of 705 sq ft/day. The storativity of the bedrock aquifer ranged from a low of 0.0000019 gallons / square foot, to a median of 0.000197 g/sq ft, to a high of 0.00021 g/sq ft. During the same aquifer pump test, measurements were taken and found that the cone-of-depression radiating from the pumping well extended approximately 350 meters from the pumping wells. These values demonstrate the high transmissivity and storativity variability found karst aquifers.

[1] Tennessee State University, College of Engineering, 3500 John A Merritt Blvd, 37209, barzanjirenas@yahoo.com
[2] Tennessee State University, College of Life & Physical Science, 3500 John A Merritt Blvd, 37209, sharpe@coe.tnstate.edu
[3] US Geological Survey, Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Suite 100 Nashville, TN 37211, tdbyl@usgs.gov

# MONITORING DISCHARGE AND HYDROGRAPH RESPONSE TIMES FOR A LARGE KARST SPRING, THE BOILS, JACKSON COUNTY, TN

Bethany Boggs[1*], Karaline Deaton[1*], Evan A. Hart[1]

Karst aquifers that are dominated by conduit recharge are at a high risk of contamination because there is little filtration or sorption of contaminants in the water. Identifying flow paths through conduit aquifers is required in order to delineate basin boundaries and potential areas at risk from groundwater contamination. In this study we report on the first continuous (~1 yr) discharge and hydrograph response times collected from the Boils spring on the Roaring River, a major tributary of the Cumberland River. The Boils drains the Roaring River-Spring Creek system, a State Scenic River and Wildlife Management Area. At the Boils, we measured discharge, temperature, and specific conductance for an approximate one-year period. The average annual discharge of the Boils during 2015 was 2.1 $m^3/s$, with storm discharge reaching as much as 14 $m^3/s$. Conductivity at the Boils spring ranged from 310 µS at baseflow to 290 µS during storm events. Water temperature of the spring varied seasonally from 9 to 22 °C. The dye trace revealed a direct connection to the Boils from a sink located 9 km away (straight-line distance), with a travel time of about 12 hr. A second trace at another sink covered a straight-line distance of 1.5 km in 4 hr. The rapid travel times suggest that this aquifer is dominated by conduit flow and that further research to sample water quality is warranted. Our data help to fill an important gap in data about major spring discharge and water quality in Tennessee.

[1] Dept of Earth Sciences, Tennessee Tech University, Cookeville, TN 38505 brboggs42@students.tntech.edu kadeaton42@students.tntech.edu

# DEVELOPMENT OF A HYDROLOGIC MODELING SYSTEM FOR THE DRY VALLEY CATCHMENT, PUTNAM COUNTY, TENNESSEE

John T. Brackins[1]*, Alex J. Davis[2]*, Sarah E. Wilson[3]*, Alfred J. Kalyanapu[4]

## INTRODUCTION

The natural geology and topography of Putnam and surrounding counties have created a drainage system reliant on karst features such as sinkholes and caves. One limiting feature of such a system is the potential for greater flow demand than the capacity of these often-narrow swallets and cave openings, which can lead to increased flooding scenarios. Within Putnam County, the Dry Valley Watershed southeast of Cookeville, Tennessee, which spans roughly 7580 acres, experienced massive flash flooding due to this effect in July of 2015. The objective of this study is *to explore the karst drainage flooding problem in the Dry Valley area and develop a HEC-HMS model to simulate the 10-year, 50-year, 100-year and 500-year floods for this region while also analyzing previous storm events*. To achieve this objective, the project team collected survey and meteorological data and imported these data into the ArcGIS and HEC-HMS models to develop basin and meteorological models using Soil Conservation Service (SCS) Technical Release 55 (TR-55) methods in order to force HEC-HMS solutions for the various expected flood recurrence intervals. These solutions were used to estimate potential storm runoff hydrographs at points of interest within the study region, and potential engineering solutions were explored to aid in ameliorating the flooding situation within this watershed.

## REFERENCES

Hart, E.A., Mills, H.H., and Li, P. (2009). "Report on sinkhole flooding and determination of 100-year sinkhole floodplains for the city of Cookeville, TN". Depart of Earth Sciences Tennessee Tech University.

Soil Conservation Service (SCS). (1986). "Urban hydrology for small watersheds". Technical Release 55, Soil Conservation Service, Washington, D.C.

[1] John Brackins, Undergraduate Student, Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Cookeville, TN 38505, Phone: 615-973-1182, Email: jtbrackins42@students.tntech.edu

[2] Alex Davis, Undergraduate Student, Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Cookeville, TN 38505, Phone: 615-517-0813, Email: ajdavis43@students.tntech.edu

[3] Sarah Wilson, Undergraduate Student, Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Cookeville, TN 38505, Phone: 865-223-3647, Email: sewilson43@students.tntech.edu

*This research is done entirely independently by the first three authors. Dr. Kalyanapu serves as the research advisor for the project.

[4] Alfred Kalyanapu, Assistant Professor, Civil and Environmental Engineering, Tennessee Technological University, 1020 Stadium Drive, Box 5015, Cookeville, TN 38505, Phone: 931-372-3561, Email: akalyanapu@tntech.edu

# MAPPING THE EXTENT OF COAL MINING DAMAGE IN THE WATERWAYS OF WILDER, TENNESSEE AND SURROUNDING AREAS, 2015-17

Zachary Hodge[1]

## INTRODUCTION

Coal mining has been a major source of energy production and capital for entrepreneurs for years. However, unregulated coal mining can cause major environmental problems that can persist for decades. The mining process, besides creating erosion and slide zones, crushes sulfides in the surrounding rock while ore is removed. The crushing process increases the reactive surface area of the sulfides by many orders of magnitude. This makes the material more reactive with water which would be present in both stip and shaft mining situation. The water mixes with crushed materials and forms sulfuric acid. This acidified water is then free to contaminate local water sources and will persist until reactive material is depleted.

## ABSTRACT

Coal mining has caused problems in Wilder Tennessee for more than a century. Everything from civil unrest to widespread pollution. In affected areas the PH ranges 2.8 - 3.9 in severe areas and from 3.95 - 5 in less contaminated areas. The goal of this project is to create a visual representation of the pollution in Wilder's waterways to help promote awareness of the damage done to the region.  To achieve this goal a variety of methods were used. *In situ data* was collected using a GPS and a portable PH probe. Water samples were collected on site and analyzed using the facilities at the Monterey Water Treatment Plant. GIS was used to delineate a watershed for the area. The data collected on site and in the lab was then digitized and used in ARCmap to create a visual representation of the damage. The result shows clear correlation between knowns mining areas, the coal seam, and polluted waterways.

[1] Work for this project was done by Zachary Hodge as an undergraduate in the Earth Sciences department, Tennessee Technological University, Cookeville, TN

## EFFECTS OF WATER HARDNESS ON BACTERIAL ATTACHMENT TO FINE SAND

Lara Jarnagin[1], Megan A. Stallard[1], and Frank C. Bailey[1]

Groundwater geochemistry is influenced by geology, residence time, microbiology and land use. Four wells on the TSU research farm were sampled and monitored in 2015. The purposes of this research were to provide an overview of the change in water chemistry overtime, characterize the spatial distribution of groundwater quality parameters including specific conductivity, water level, pH, and temperature, and determine potential hydraulic connections between wells. Preliminary results indicated high concentrations of sulfide in three of the wells but the source was unknown. Water quality data, geophysical logs, and coordinates were collected at each well. During the sampling period, variation of water level ranged from 0.47 to 6.65 m, change in sulfate concentration ranged from -237 to +119 mg/L, and change in alkalinity ranged from -167 to -466 mg/L. Two conduit openings were found in the wells. Water elevation, chemistry and geophysical logs were used in the Arc Hydro Groundwater tool to determine potential flow paths.

[1] Middle Tennessee State University, Department of Biology, Murfreesboro, TN 37132 lkj2m@mtmail.mtsu.edu

## DETERMINING THE PRESENCE OF TRADITIONAL AND ALTERNATIVE FECAL INDICATORS IN MURFREESBORO, TN STORM DRAIN BIOFILMS

Jordan Jatko[1], Megan A. Stallard[1], Frank C. Bailey[1]

*Escherichia coli* (*E.coli*) is a traditional fecal indicator bacteria (FIB) used by regulators to assign impairment to recreational waters. One drawback to use of *E. coli* as an FIB is its ability to multiply in the environment outside of the host gut. Because of this, the USEPA has developed methods for detection of alternative indicators of fecal pathogen impairment with minimal replication outside of the gut, such as bacteria in the order *Bacteroidales* and viruses known as coliphages. Evidence exists for FIB proliferation in matrices outside of the gut, such as biofilms within stormwater infrastructure. Dislodged fecal bacteria from biofilms transported to a waterway could prompt or maintain federal impairment status (303d-listing) even without recent fecal inputs. In the present study, biofilm samples were collected from outfalls emptying into three non-impaired and three impaired Murfreesboro, TN streams at 48 and 96 hours after three different rain events (>0.15”). We investigated the presence of *E. coli* in storm drain biofilms using membrane filtration with mTEC agar. *Bacteroidales* were also assessed using quantitative polymerase chain reaction (qPCR), and coliphages were measured using a single agar layer (SAL) procedure (EPA Method 1602). The 48 hour *E. coli* concentrations (10,065 colony forming units/gram (CFU/g; n=6)) were not found to be different than the 96 hour concentrations (6,662 CFU/g; n=6). Impaired outfalls had higher *Bacteroidales* concentrations (copies/gram) at 48 hours, but not 96 hours. These results imply that secondary habitats can serve as reservoirs of fecal pathogens. Coliphage data is currently being analyzed.

[1] Middle Tennessee State University, Department of Biology, Murfreesboro, TN jtj2y@mtmail.mtsu.edu

# STIMULATION OF PLANT GROWTH BY GROUNDWATER NATURALLY RICH IN SULFIDE AND CALCIUM

Danelle Solomon[1], De'Etra Young[1] acknowledgement – Tom Byl[2]

Previous research found sterile water artificially enriched with sulfide stimulated plant biomass. This study's objective was to determine if groundwater from Tennessee State University's farm wells, naturally rich in sulfide, stimulated plant growth. Lettuce, radish and oat raised using waters from a well containing high sulfide (65-115 mg/L) were compared to groundwater with no sulfide. Seeds were germinated in tissue soaked in the experimental waters and raised in a growth chamber at 20$^{o}$C. The oat plants raised in sulfur-water had 3x more lateral roots and 18% greater biomass than plants raised in fresh-water. Lettuce and radish plants raised in sulfur-water were 35% and 13% larger than those raised in fresh-water, respectively. Plant peroxidase activity significantly ($p < 0.05$) increased in plants exposed to sulfide, giving them stronger, more compact cell. Oat plants raised in sulfide-water had more efficient photosynthesis capacity as compared to oat plants raised in freshwater. There was 10% more chlorophyll and 3x greater uptake of $CO_2$ in the sulfide-raised oats as compared to those raised in aerobic water without sulfide.

[1] Tennessee State University, College of Agriculture, 3500 John A Merritt Blvd, 37209, danellesolomon96@gmail.com dyoung23@tnstate.edu
[2] US Geological Survey, Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Suite 100 Nashville, TN 37211, tdbyl@usgs.gov

# HYDROLOGY OF AN URBAN WETLAND AT TENNESSEE STATE UNIVERSITY, NASHVILLE, TN

JeTara Brown[1] Lonnie Sharpe, Jr.[2], acknowledgement – Tom Byl[3]

Tennessee State University is a historically black college/university founded in 1912 as a public land grant institution. The 500 square acre main campus is not only home to thousands of students, but also to a unique biodiversity of ducks, turtles, and beavers that thrive at a wetland located in the northern region of the campus. The landscape started off as a down-gradient urban watershed draining 2.3 square miles throughout the northern region of downtown Nashville. The area was modified in 1996 due to the implementation of a new road and drainage system. The wetland was formed after persistent beavers moved into the area and built several dams along a drainage ditch that flooded the lowland for several years after an urban watershed was modified for road construction. The objective of this study was to illustrate the transformation from storm-drainage ditch to marsh wetland using GIS, and evaluate conductivity.  Orthophotos from 2008 to 2016 were obtained and analyzed using Google Earth Pro. The watershed grew from a 4-foot wide drainage ditch to 26-acre marsh. Old roads and animal pastures have now been replaced by standing water, cattails, and other wetland plants.

[1] Tennessee State University, College of Agriculture, 3500 John A Merritt Blvd, 37209, jtlbrown@yahoo.com

[2] Tennessee State University, College of Life & Physical Science, 3500 John A Merritt Blvd, 37209, sharpe@coe.tnstate.edu

[3] US Geological Survey, Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Suite 100 Nashville, TN 37211, tdbyl@usgs.gov

# MODELING PALEOFLOODS IN THE TENNESSEE VALLEY: ASSOCIATING FLOOD DEPOSITS WITH FLOWS AND PERFORMING FREQUENCY FITTING

Hannah R. Kubas

Flood frequency estimations for large flows have been studied extensively over the past 50 years, but many approaches used are often inexact with large uncertainties. For effective and safe flood operations, accurate flood levels and frequencies are critical to informing river operation organizations, such as the Tennessee Valley Authority (TVA), who provide flood control of river systems. The TVA manages 49 dams in the Tennessee River Valley's system, which involves extensive monitoring of the area. More recent studies have highlighted the use of paleohydrology as a new source of data to extend historical records of extreme floods. Paleohydrology has been studied primarily in dry climates, not humid regions such as East Tennessee, where this study is located. This study used historical flood data and the TVA's Naturals HEC-RAS model. The goal of this study was to associate the flood deposits, found by teams of geologists, with flows by first calibrating the TVA's Naturals model to known floods. Frequency fitting is to be performed between the natural's model and the current model the TVA uses today. This work demonstrates the need for a better understanding and acceptance of how to use past, unrecorded events to aid in flood frequency estimations. These results can be used to support paleoflood techniques for the Tennessee Valley which will in turn provide a method for gaining more accurate flood frequency data.

# EFFECTS OF DIFFERENT COVER CROP SPECIES ON SOIL AND WATER QUALITY

Mingwei Chu, Sindhu Jagadamma, Michael Buschermohle, Forbes Walker
Department of Biosystems Engineering and Soil Science,
University of Tennessee, Knoxville, TN

Soil erosion is the major cause for the nonpoint source pollution of nutrients to the waterbodies. Prudent crop management strategies can not only benefit the crop and soil, but also can improve the water quality. No-tillage is followed in the agricultural belt of Tennessee to reduce erosion. However, the fallow period between the growing seasons may still encounter soil erosion from heavy rainfall. Cover crops (CCs) can provide ground coverage in this fallow period and reduce the off-site transport of water and soil. Row crop producers typically grow a single CC or a combination of two CCs after the harvest of the main crop. In recent years, Natural Resources Conservation Service (NRCS) has been encouraging the use of a mixture of cover crops. A field experiment was started in 2013 at the Research and Education Center in Milan, Tennessee to evaluate the effect of single CC (Wheat, Cereal rye), double CCs (Cereal rye and Hairy vetch, Cereal rye and Crimson clover) and NRCS recommended CC mixture (Cereal Rye, Whole Oats, Daikon Radish, Crimson Clover, Hairy vetch) on yield of corn and soybean. We collected soil samples from this experiment in October 2016 to determine the effect of different cover crop species on soil organic matter accumulation and nutrient availability. From the data on soil properties and ground coverage of CCs, we gained insights on the potential of different cover crop species in causing the off-site movement of water and nutrients to the nearby waterbodies.

# SEASONAL VARIATIONS AND STATISTICAL ANALYSIS OF THE PHYSICOCHEMICAL CHARACTERISTICS IN A DEVELOPING WETLAND IN NASHVILLE, TENNESSEE, 2017

Mark C. Okafor[1]*, De'etra Young[1]*, and Thomas D. Byl[1]*,[2]*

## INTRODUCTION

At a watershed scale level, wetlands improve water quality. Wetlands are vital in urban metabolism and some of the ecosystem services provided by wetlands include storage and filtration of stormwater runoff, recharging groundwater aquifers and habitat for wildlife organisms. Globally, wetland ecosystems are under pressure from rapidly increasing urban populations in coastal areas (Ehrenfeld, 2000). Wetland systems combine biochemical removal processes as well as physical processes in runoff treatments. Research related to wetland efficiency can assist in determining how well these wetlands remove pollutants in the Nashville urban area. This research is carried out on the TSU research wetland located at the greenhouse facility and focuses on water chemistry in the wetland.

## APPROACH

We collected random (Sarkar&Upadhyay,2013) base-flow grab samples via a long-handled plastic dipper according to the Department of Environmental Protection, State of Maine and deliver it directly into 500ml HDPE plastic sample bottles. The EPA has determined that sample collection at a "representative point" is suitable to characterize water quality conditions in streams adequately (U. S. EPA, 1975). A minor modification to this technique involved collecting composite samples from several points in order to get a better representation of the population (Weiss et al, 2002). Prior to any statistical assessment we would compartmentalize our data into 4 fixed seasons. Descriptive statistics would show us the normality of our data.

## RESULTS AND DISCUSSION

The data represented are from (JAN – SEPT) 2016. Results showed a (7%, 3%, 34%, 49%, 25%, 14%, 12% and 51%) removal efficiency for (K, Mg, S, B, Na, Si, Ca and NO3-N) respectively. Traces of some metals like Al, Pb, Cu, Zn and Ni in our samples were below the measuring range.

## REFERENCES

U.S. Army Corps of Engineers. (1987). Corps of Engineers Wetlands Delineation Manual.
Ehrenfeld, J. G. (2000), Defining the Limits of Restoration: The Need for Realistic Goals.
Sarkar A. and Upadhyay B. (2013). Assessment of the variations in Physico-chemical characteristics of water quality of the wetlands in district Mainpuri (u.p.) India. International

[1] Tennessee State University, 3500 Merritt A. boulevard, Nashville, TN 37209.
[2] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211

Journal of Geology, Earth and Environmental Sciences ISSN: 2277-208. Vol. 3 (1) pp.95-103.Restoration Ecology, 8: 2–9.

# DEVELOPMENT OF AN Edna PROTOCOL TO DETECT AND QUANTIFY STREAMSIDE SALAMANDERS *(AMBYSTOMA BARBOURI)* IN LOW-ORDER STREAMS OF MIDDLE TENNESSEE

Nicole Witzel*, Ali Taheri, and William B. Sutton
Tennessee State University, 3500 John A Merritt Blvd, Nashville, TN 37209

The Streamside Salamander (*Ambystoma barbouri*) is an Ambystomatid salamander that occurs in Middle Tennessee where it is geographically isolated. This salamander species is active for a few months during winter and spring months when it emerges to breed in low-order, ephemeral streams. As these animals are cryptic and only surface-active for several months, they can be difficult to detect using traditional survey methods. Surveys that target environmental DNA (eDNA) in the form of sloughed skin, sperm, and eggs provide a potentially effective method for detecting the presence of this species. However, before this method can be used, it is essential to develop species-specific genetic primers that will correctly identify presence and absence of the target species. An initial objective of this study is to identify a primer that is specific to and will successfully amplify only the DNA of A. barbouri without amplifying DNA of congeners. Primers were selected by choosing *A. barbouri* cytochrome B mitochondrial DNA segments with base pairs that differed from *A. texanum*, a closely related species. These were used to amplify *A. barbouri* DNA and tested for specificity among other Ambystomatid congeners in Tennessee. Following initial tests of specificity, we will develop a quantitative PCR approach to evaluate the quantity of environmental DNA in stream water samples. The long-term goal of this study is to provide a replicable eDNA approach to identify *A. barbouri* populations in Tennessee. This information will provide a method which can be used to further the knowledge and conservation of the species.

# CRITICAL SHEAR STRESS MEASUREMENT OF COHESIVE SOILS IN STREAMS: IDENTIFYING DEVICE-DEPENDENT VARIABILITY USING IN-SITU JET TEST DEVICE AND CONDUIT FLUME

Badal Mahalder, Graduate Student, UTK; John S. Schwartz, Ph.D., UTK; Angelica M. Palomino, Ph.D., UTK; and Athanasios N. Papanicolaou, Ph.D., UTK

Cohesive soil erodibility and threshold shear stress for stream bed and bank are dependent on both soil physical and geochemical properties in association with the channel vegetative conditions. These properties can be spatially variable therefore making critical shear stress measurement in cohesive soil challenging and leads to a need for a more comprehensive understanding of the erosional processes in streams. Several in-situ and flume-type test devices for estimating critical shear stress have been introduced by different researchers; however reported shear stress estimates per device vary widely in orders of magnitude. Advantages and disadvantages exist between these devices. Development of in-situ test devices leave the bed and/or bank material relatively undisturbed and can capture the variable nature of field soil conditions. However, laboratory flumes provide a means to control environmental conditions that can be quantify and tested. This study was conducted to observe differences in critical shear stress using jet tester and a well-controlled conduit flume. Soil samples were collected from the jet test locations and tested in a pressurized flume following standard operational procedure to calculate the critical shear stress. The results were compared using statistical data analysis (mean-separation ANOVA procedure) to identify possible differences. In addition to the device comparison, the mini jet device was used to measure critical shear stress across geologically diverse regions of Tennessee, USA.

# INFLUENCE OF ENVIRONMENTAL CHARACTERISTICS ON FECAL INDICATOR MEASUREMENTS IN STREAMS

Lu Yang[1] and Qiang He[2]
Department of Civil and Environmental Engineering, University of Tennessee

Fecal indicators are commonly used in evaluating the microbiological quality of surface water. One challenge to interpreting fecal indicators data has been the large variations in test results without apparent causes. To identify factors contributing to the large variations in fecal indicator measurements, samples were collected from three impaired streams in East Tennessee. *Escherichia coli* and total coliform were quantified as indicators to study the relationship between environmental characteristics and fecal indicator organisms using both plate counting and cultivation-independent qPCR methods. Results show significant correlation between *Escherichia coli* and total coliform ($p<0.05$, $r=0.788$) as well as the correlation between *Escherichia coli* and volatile suspended solids (VSS) ($p<0.05$, $r=.517$). During dry periods, the duration of antecedent dry period did not appear to affect *E. coli* levels in stream water. However, events of precipitation did seem to influence *E. coli* levels in stream water. Preliminary results also suggest that land use pattern could impact fecal contamination. These findings may provide insight into the interpretation of fecal indicator data for water quality management.

[1] lyang35@vols.utk.edu
[2] qianghe@utk.edu

# EFFECT OF NUTRIENT ADDITION DURING PHYTOREMEDIATION ON LEAD PARTITIONING IN DREDGED SEDIMENT

Tianxue Yang[1], Qiang He[2], Chunguang He[1]*, Aixia Wang[3], and Lianxi Sheng[1]*

Dredging can be practiced to remove sediment impacted by persistent contaminants, such as heavy metals, of which lead is of particular concern due to its toxicity. Therefore, dredged sediment requires further actions of mitigation. One method for lead mitigation is phytoremediation of dredged sediment. In this study, the partitioning of lead in sediment during phytoremediation by willow *(Salix integra)* was assessed regarding the effect of nutrient addition to stimulate willow growth. Results showed that, in general, the bioavailable forms of Pb declined with increased nutrient addition which appeared to enhance the Fe-Mn oxide fraction and residual inert fraction. In contrast, the addition of excess phosphorus decreased the bioavailable fractions of Pb, while the bioavailable fractions of Pb increased with additional potassium addition. Overall, the concentration of bioavailable fraction of Pb was the lowest with excess P and the highest with excess K addition.

**Key words:** inorganic nutrients; Pb partitioning; Pb concentrations; dredged sediment

---

[1] State Environment Protection Key Laboratory of Wetland Ecology and Vegetation Restoration, Northeast Normal University, Changchun 130117, China *Corresponding Authors: Chunguang He, Email: he-cg@nenu.edu.cn, Telephone Number: 18543102473 | Lianxi Sheng, Email: shenglx@nenu.edu.cn, Telephone Number: 13804462178

[2] Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, Tennessee, U.S.

[3] Key Laboratory of Nanobiosensing and Nanobioanalysis at Universities of Jilin Province, Department of Chemistry, Northeast Normal University, 5268 Renmin Street, Changchun, Jilin Province 130024, PR China

# ASSESSING THE SUCCESS OF DRAINMOD AND REFERENCE WETLANDS FOR THE PREDICTION OF HYDROLOGY IN WETLAND RESTORATION SITES IN NORTH CAROLINA

Eric Neuhaus[1], Kirsten Gimbert, Jeff Keaton, and John Hutton

Many of the complex interactions that occur in wetlands are dictated by the hydrology. For wetland mitigation to be successful, accurate hydrology needs to be restored to reproduce high functioning ecological systems. Wetlands need to experience fluctuating hydroperiods with times of saturation and drawdown. To estimate how stream and wetland restoration designs will affect the hydrology and hydroperiod of proposed projects, modeling techniques and the use of reference wetland hydrology data have been utilized. DRAINMOD is often used to predict the effect of proposed restoration work on the hydrology of wetlands.

This study compares wetland reference hydrology, DRAINMOD results of predicted hydrology, and corresponding monitoring data for multiple wetland restoration sites in North Carolina. The Lyle Creek Stream & Wetland Mitigation Project improved 9.5 acres of wetlands on an active tree farm located in the headwaters of Lyle Creek in rural Catawba County, NC. The Little Troublesome Creek Mitigation Project restored 18.0 acres of wetlands in Rockingham County, NC. The Underwood Mitigation Project in northwestern Chatham County, NC restored and created a total of 13.8 acres of riparian wetlands and restored and enhanced 1.5 acres of non-riparian wetlands. The Owl's Den Stream and Wetland Mitigation Project restored approximately 10.0 acres of riparian wetlands in Lincoln County, NC. The Henry Fork Mitigation Site restored approximately 4.0 acres of riparian wetlands in Catawba County, NC. DRAINMOD, as well as reference wetland hydrology data was used on all the above sites to predict how construction of the project would improve site hydrology.

[1] PE, Water Resources Engineer; Wildlands Engineering, Inc., 167-B Haywood Road, Asheville, NC 28806; 828.774.5547, x105; eneuhaus@wildlandseng.com

# ESTIMATED USE OF WATER IN THE CUMBERLAND RIVER WATERSHED IN 2010 AND PROJECTIONS OF PUBLIC-SUPPLY WATER USE TO 2040

John A. Robinson[1]

Adequate water resources are vital for municipal, industrial, and agricultural water-use needs in the Cumberland River watershed. As a result of continuing population growth, moderate to extreme droughts and floods, demands for competing water resources, and aging infrastructure, the evaluation of ongoing water-resources issues has become increasingly important to Federal, State, and local water-resources managers. Comprehensive water-use information, by reservoir catchment area or subwatershed, is not currently available but is needed by decision makers in the Cumberland River watershed to help them evaluate the effects of current and projected water-use demands on the available water resources. In the coming decades, growth and development in the watershed and surrounding areas will continue to affect water resources, and the ability to understand and manage the effects of future demand on ecosystems, water availability, and water quality is needed.

In order to assist local decision makers in the Cumberland River watershed, the U.S. Geological Survey began a study to document groundwater and surface-water withdrawals for public-supply, self-supplied industrial, irrigation, and thermoelectric uses during 2010. Estimates of water use for public supply were projected in 10-year increments through 2040 and were based on 2010 public water-supply data and population projections for 2020 to 2040. Additionally, estimates of consumptive use, wastewater releases, and thermoelectric power and industrial return flows were calculated. All estimates were presented for the entire watershed and for the ten reservoir catchment areas within the watershed. The results of the investigation, which are expected to be published in 2017, will benefit the State of Tennessee, the State of Kentucky, Federal and local agencies, water-supply systems, economic development districts, environmental groups, and other stakeholders across Tennessee and Kentucky. The water-use data will support water-resource planning efforts by the USACE, Nashville District, the Cumberland River Compact, and others by allowing assessment of water-resource issues in the Cumberland River watershed.

[1] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Suite 100, Nashville, Tennessee 37211, jarobin@usgs.gov

# EXHIBITORS and SPONSORS

A special thank you is extended to these companies that have supported the TN Section AWRA by participating this year as both sponsors and exhibitors.

---

**Amec Foster Wheeler Environment & Infrastructure, Inc.**
3000 Ezell Road, Suite 100
Nashville, TN 37221
Contact:
Brad Heilwagen
Phone: (615) 333-0630
Email: brad.helilwagen@amecfw.com
Dana Waits
Phone: (615) 477-8404
Email: dana.waits@amecfw.com

http://www.amecfw.com/

Amec Foster Wheeler (formerly AMEC) is a recognized leader in providing a comprehensive set of municipal stormwater management services to local governments throughout North America and internationally. These include both water quality and quantity services, and range from being site-specific to watershed-wide solutions. With offices in Chattanooga, Knoxville, and Nashville, Amec Foster Wheeler services cover both institutional and technical needs for clients throughout the State of Tennessee.

---

---

**OTT Hydromet**
5600 Lindbergh Drive
Loveland, CO 80539
Contact: Bill Harrington
Phone: 512-528-9775
Cell: 970-232-8594
Email: bharring@otthydromet.com
[www.ott.com](http://www.ott.com)

TT Hydromet helps water resource professionals generate reliable data throughout the entire water cycle. We go beyond simply providing solutions by partnering with our customers in designing effective answers to the challenges they encounter in their vital role of monitoring the world's water.

Proudly formed from five separate companies (OTT, Hydrolab, ADCON Telemetry, Sutron and Lufft), OTT Hydromet offers the combined strength and expertise of leaders in the water quality, quantity and telemetry fields and over 140 years of experience in environmental measurement.


---

**Stevens Water Monitoring Systems, Inc.**
12067 NE Glenn Widing Drive
Portland, OR 97220
Phone: (800) 452-5272
Contact: Fred Holloway
Email: [fholloway@stevenswater.com](mailto:fholloway@stevenswater.com)
[http://www.stevenswater.com/](http://www.stevenswater.com/)

Please stop by the Stevens booth to see latest in true cloud-based remote monitoring technology. See the new eTracker which is the gateway between the sensors and the cloud, the Cell-Net cellular telemetry solution for new or existing remote monitoring stations, and Stevens-Connect, a cloud-based data acquisition and management software system that enables the collection, analysis, reporting and storage of data from remote monitoring locations.

---

**Trutta Consulting LLC**
149 Hedgelawn Drive
Hendersonville, TN 37075
Contact: Brett Connell
Phone: (419) 215-7897
Email: brett.connell@truttasolutions.com
http://truttasolutions.com/

TRUTTA
ENVIRONMENTAL SOLUTIONS

Trutta Environmental Solutions provides stream channel and aquatic habitat surveying and assessment services for the energy, transportation, and industrial sectors, as well as federal and state agencies, and nonprofit organizations. We have developed and use the High Definition Stream Survey (HDSS). HDSS is a stream survey system that integrates GPS, video, depth, side-scan sonar, and water chemistry sensors to allow many miles of stream (typically 15 miles) to be surveyed in a single day, with data collected approximately every meter. By using this multi-attribute data collection technique, we have the ability to change from guesses and broad extrapolations about the condition of the study area to high-resolution (1m) maps of the stream and stream channel. The range of data collected is highly useful for GIS mapping, hydrologic modeling, and habitat identification applications.

---

**Tennessee Water Resources Research Center**
The University of Tennessee, Knoxville
U.T. Conference Center, B060
Knoxville, TN 37996-4134
Phone: (865) 974-2151
Fax: (865) 974-1838

TNWRRC Contact: Tim Gangaware
Email: gangwrrc@utk.edu

ISSE Contact: Dr. Randy Gentry
Email: rgentry@utk.edu
Website: http://isse.utk.edu

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.

# Sponsors

---

**ARCADIS**
Contact: Jeff Hoilman, PE
Email: jeff.hoilman@arcadis-us.com
1210 Premier Drive, Suite 200
Chattanooga, TN 37421
(423) 756-7193

https://www.arcadis.com/en/united-states/

3200 West End Avenue, Suite 500
Nashville, TN 37203
(615) 783-2850

114 Lovell Road, Suite 202
Knoxville, TN 37934
(865) 675-6700

Connecting your vision to our global know-how, we create value through built and natural assets that work in harmony with their surroundings. Whether it's maximizing city space, making wasteland habitable or simply taking what you do further, Arcadis delivers outcomes that improve quality of life for you and your community.

---

**ASCE Tennessee Section/Environmental and Water Resources Institute**
Contact: Ashley Smith, P.E., M.ASCE
TN ASCE President
Phone: (615) 969-0273
Contact: Randal Braker, P.E., M.ASCE
TN EWRI Chair
Phone: (931) 455-6458

http://sections.asce.org/tennessee/

The Tennessee Section of the American Society of Civil Engineers (ASCE) represents more than 2,000 members of the civil engineering profession in Tennessee. ASCE is America's oldest national engineering society with more than 147,000 members worldwide. ASCE's vision is to position engineers as local, national and global leaders building a better quality of life. The Environmental and Water Resources Institute (EWRI) is ASCE's technical source for environmental and water-related issues. EWRI is one of nine ASCE technical institutes.

---

**Barge, Waggoner, Sumner & Cannon, Inc.**
211 Commerce Street, Suite 600
Nashville, TN 37201
Phone: (615) 252-4329
Fax: (615) 255-6572
Contact: Adrian Ward, P.E.
Senior Project Engineer, Environment and Water Resources
Email: Adrian.Ward@bwsc.net
http://www.bargewaggoner.com

Barge, Waggoner, Sumner & Cannon, Inc. is a professional services firm that includes engineers, architects, landscape architects, surveyors, planners, and scientists. BWSC has 13 offices located throughout Tennessee, Alabama, Georgia, and Ohio. The staff of BWSC uses their experience in planning, design and permitting to provide environmental services that will aid in conservation of our water resources and protect our natural communities. Our team offers comprehensive knowledge that incorporates modeling, mapping, engineering, and regulatory compliance to support integration of the natural resources component into engineering projects.

---

**Buchart Horn, Inc.**
3150 Lenox Park Blvd, Suite 300
Memphis, TN 38115
Phone: (901) 363-6355
Contact: Nicole Craven
Email: ncraven@bh-ba.com
http://bucharthorn.com/

At Buchart Horn, we focus on the built environment that makes our world work. Whether its providing clean water, developing a bridge or roadway system, or designing the buildings where we live, work, and play, our engineers and architects are committed to designing practical solutions that strengthen our communities

---

**Center for Applied Earth Science and Engineering Research (CAESER)**
3675 Alumni Avenue
Memphis, TN 38152
Contact: Scott Schoefernacker
Phone: (901) 678-4315
Email: sschfrnc@memphis.edu
http://strengthencommunities.com/

At CAESER, we're rooted in academia, but not limited by it. Our center is comprised of industry professionals, University faculty and highly-motivated students—all working together to provide the best service possible. We give students hands-on experience within a diverse, multi-disciplinary environment that makes them much more marketable upon graduation.

We consider our clients to be partners and work closely with them to develop a detailed scope of work. And because we're a nonprofit institution, we're also deeply committed to offering the most cost-effective solution available.

---

**Center for the Management, Utilization and Protection of Water Resources**
**Tennessee Technological University**
P.O. Box 5033
Cookeville, TN 38505
Phone: (931) 372-3507
https://www.tntech.edu/research/faculty-research-directory/centers-and-facilities/wrc/
Fax: (931) 372-6346

The Center for the Management, Utilization and Protection of Water Resources promotes and fosters interdisciplinary research and development in solving societal and industrial problems associated with water and environment management and sustainability, which are issues of critical importance to the region, the State of Tennessee, and the world at large, to:

- Research and develop innovative solutions to current knowledge and technology barriers associated with safe and sufficient water resources and natural ecosystems.
- Develop transformational technology and tools in support of integrated systems involving water-land-energy-agriculture interactions.
- Through aggressive global outreach, support industry and state/federal agencies and communities in water analysis, resources management and applications.
- Support TTU academic programs through student and faculty development and laboratory infrastructure access.
- Play a vital role in economic and rural community development of the State of TN and nation at large

---

**Civil & Environmental Consultants, Inc.**
325 Seaboard Lane, Suite 170
Franklin, TN 37067
(800) 763-2326
Contact: Jeff Duke
Phone: (615) 333-7797
Email: jduke@cecinc.com
http://www.cecinc.com

Civil & Environmental Consultants, Inc.

CEC, with offices in Franklin and Knoxville, is a full-service engineering and environmental consulting firm, specializing in ecosystem restoration, biological assessments, water resource engineering, EPSC and stormwater BMP design, MS4 compliance, wetland ecology, survey, infrastructure, and solid waste. Our staff is comprised of engineers, biologists, geologists, and environmental scientists.

---

**KCI Technologies**
7003 Chadwick Drive, Suite 343
Brentwood, TN 37027
Contact: Adam Spiller
Phone: (615) 377-2499
Email: adam.spiller@kci.com
http://www.kci.com/

KCI Technologies is a multi-disciplined engineering firm with offices in Middle Tennessee. KCI offers many services throughout the water market. We specialize in natural resources mitigation, stream and wetland restoration, dam removal, stormwater management, and watershed planning. Our experience also covers Geospatial and GIS services, including asset management and MS4 compliance. KCI is also a licensed construction contractor in Tennessee, specifically focused on ecological restoration and stormwater construction projects.

---

**Neel-Schaffer, Inc.**
201 25th Avenue, North, Suite 800
Nashville, TN 37203
Phone: (615) 383-8420
Fax: (615) 383-9984
Contact: Tom Allen
Email: tom.allen@neel-schaffer.com

http://www.neel-schaffer.com/

Providing solutions that its clients can build upon is the essence of Neel-Schaffer, Inc. Made up of engineers, planners, environmental scientists, landscape architects and surveyors, Neel-Schaffer is an employee-owned firm. Since 1983, it has grown from a company of 20 individuals to over a 400-member-strong multi-disciplined firm. With offices located across the South, it services public and private clients, including federal, state, and local governmental agencies.

More than 70 percent of Neel-Schaffer's business comes from existing clients, which attests to the firm's ability to perform quality work. The expertise is recognized nationally as well. Neel-Schaffer consistently ranks among much larger national and international firms. It is currently listed in the Engineering News Record Top 500 Design Firms in the country and has been since 1994. It earns recognition annually from organizations such as the American Council of Engineering Companies (ACEC), the Solid Waste Association of North America and Associated General Contractors.

---

# Exhibitors

---

**Ecosystem Planning and Restoration**
17442 North Eldridge Parkway
Tomball, TX 77377
Contact: Kevin Tweedy
Phone: (919) 388-0787
Email: ktweedy@eprusa.net http://www.eprusa.net/

EPR was created in 2012 to be a premier environmental planning and ecosystem restoration company. Our desire is to provide environmental services with the highest quality products, and to improve the science and application of stream and wetland restoration through innovative projects and applied research.

---

**EnviroScience, Inc.**
1722 General George Patton Drive
Suite B100
Brentwood, TN 37027
Chad Armour (206) 963-6514
carmour@enviroscienceinc.com
Neal Hess (216) 308-2567
nhess@enviroscienceinc.com

http://enviroscienceinc.com/

EnviroScience specializes in providing high quality biomonitoring services both in the laboratory and in the field. Our dedication and technical excellence has resulted in many repeat clients and established EnviroScience as the “go-to” firm in our service areas.

---

**Eureka Water Probes**
2113 Wells Branch Pkwy, Suite 4400
Austin, TX 78728
Contact: Jonathan Evans
Phone: (678) 983-2818
Email: jevans@waterprobes.com
http://www.waterprobes.com

Reliable data is Eureka's Top Priority. We start with the best sensors on the market and finish with our famously simple user-interface. Using, the Manta is really easy. Plug the Manta into a USB port and see live water quality data a few seconds later. Most users teach themselves the Manta operating software in about 15 minutes. Why pay more to maintain your water quality monitoring equipment? The Manta's hardware design saves in ongoing maintenance costs. Its optical DO replacement cap has a 3-year life, and its rebuildable (refillable) pH reference electrode eliminates the need to replace the pH sensor every 6 months to a year. The Manta's LED diagnostic tool tells you when the sonde is set to log, if the Manta is getting ample voltage from line power, battery voltage remaining for models equipped with battery packs, communicating RS-232, and more! The Manta is the only multiprobe in the industry that can support and record simultaneously, the values from up to 12 sensors. The gives the end user flexibility in configuring a multiprobe for specific applications. Excellent Customer Service is standard equipment. A human is always available to answer your call or email.

**HydroTech ZS Consulting**
1700 Bryant Drive, Suite 103
Round Rock, TX 78664
Contact: Zak Sihalla
Phone: (512) 846-2893
Email: zak@hydrotechzs.com
http://hydrotechzs.com

We manufacture, sell, support, service, and repair water quality monitoring equipment worldwide.

**TTU, Professional Science Master's**
P.O. Box 5152
Cookeville, TN 38505
Contact: Peter Li
Phone: (931) 372-3752
Email: pli@tntech.edu

https://www.tntech.edu/is/ses/psm/

The program is designed for students with a bachelor degree to get solid and rigorous training in GIS, business management and statistics. Students are required to take on internship opportunity to work for a company. With such training, students would be able to get real-world and problem-solving skills in additional to learning from the classroom. The program is open to anyone with strong learning desire and ambition to be a great professional in managing natural resources with computer-based analytical and critical methods.

---

**Ragan Smith Associates**
315 Woodland Street
Nashville, TN 37122
Phone: (615) 244-8591
Contacts:
Laura Jones
Email: ljones@ragansmith.com
Marion Keith
Email: mkeith@ragansmith.com

http://www.ragansmith.com/

Ragan-Smith is a multi-disciplined consulting firm providing services for the Middle Tennessee areas since 1933. Our firm provides surveying, landscape architecture, land planning, civil engineering, transportation engineering, and environmental services with over 100 employees with various degrees of expertise in the noted fields. What separates Ragan-Smith from other firms is having a high level of involvement from our senior level partners and Associates on our projects focusing on utilizing their numerous years of experience to deliver a project that meets the goals of the client.

**S&ME, Inc.**
1413 Topside Road
Louisville, Tennessee 37777
Contacts:
Ken Barry, P.E.
Email: kbarry@smeinc.com
Phone: (865) 970-0003
Pat McMahon
Email: pmcmahon@smeinc.com
Phone: (865) 776-3602

S&ME
ENGINEERING INTEGRITY.

http://www.smeinc.com/

S&ME, Inc. is an employee owned full service engineering, design, planning, natural resources, and construction services firm. Founded in 1973, we have grown to a 1,200-person corporation operating from 36 offices across the US. S&ME is a leader in its field, having won 80 Engineering Excellence Awards from state chapters of the American Council of Engineering Companies for "achievements which demonstrate the highest degree of merit and ingenuity." We care about our clients and devote our abundant resources and technical expertise to helping them safely and efficiently meet their objectives.

---

**Stantec Consulting Services, Inc.**
10509 Timberwood Circle
Louisville, KY 40223
Contacts:
Brady McPerson
Phone: (502) 212-5084
Email: brady.mcpherson@stantec.com
Oakes Routt
Phone: (502) 212-5000
Email: oakes.routt@stantec.com

Stantec

http://www.stantec.com/

We're active members of the communities we serve. That's why at Stantec, we always design with community in mind.

The Stantec community unites approximately 22,000 employees working in over 400 locations globally. Our work—engineering, architecture, interior design, landscape architecture, surveying, environmental sciences, project management, and project economics, begins at the intersection of community, creativity, and client relationships. Stantec has the unique ability to advance the quality of life in communities worldwide. Visit us at stantec.com or find us on social media.

---

---

**Stream Mechanics**
5645 Normanshire Drive
Raleigh, NC 27606
Contact: Will Harman
Phone: (919) 747-9448
Email: wharman@stream-mechanics.com
https://stream-mechanics.com

Stream Mechanics works with its partners to improve stream restoration and mitigation through the development of assessment and design-review tools. We provide workshops and trainings to federal agencies, non-profit organizations, and private consulting firms on function-based stream assessments, natural channel design review, and mountain stream assessment and design. We also provide workshops that demonstrate function-based design techniques.

---

XYLEM Analytics/YSI

9843 18th Street, North, Suite 1200
St. Petersburg, FL 33716
Contact: Scott Kindelberger
Phone: (863) 280-0945
Email: scottt.kindelberger@xyleminc.com
http://www.ysi.com/

Xylem and the YSI brands have specialized in the design, installation and maintenance of water quality monitoring and sampling systems for over 20 years. Utilizing Xylem's full line of water level sensors from Waterlog, flowmeters from Sontek, water quality instrumentation from YSI and turn-key monitoring solutions from our Integrated Systems and Services division, Xylem is capable of providing a full range of solutions and optional field services for the most challenging monitoring and sampling applications. YSI is committed to developing and supporting innovative technologies that improve on our ability to efficiently and effectively monitor the health of our planet.

---