Proceedings of the 2016

Tennessee Water Resources Symposium

April 13-15, 2016

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Proceedings from the

25th Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 13-16, 2016

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PREFACE

Welcome to the 25th annual Tennessee Section of the American Water Resources Association annual symposium at Montgomery Bell State Park. The theme for the conference this year is *science to solutions: connecting data and research to stakeholders and policy.* Keynote and luncheon speakers and the panel discussion on Friday will address this theme, while an excellent slate of professional and student presentations will ensure that you are challenged and informed about water resources issues in Tennessee. Despite the busy schedule, please don't pass up the opportunity to re-new old friendships, make new acquaintances, and enjoy the beauty of spring at Montgomery Bell State Park.

Our keynote speaker this year is Mr. Michael Kern, Director, The William D. Ruckelshaus Center at Washington State University. Michael will discuss "Fostering Collaborative Solutions to Water Resource Management Challenges." Our luncheon speaker, Mr. Brian Malow, is from the North Carolina Museum of Natural History, is a blogger for Scientific American, and is self-proclaimed as the Earth's Premier Science Comedian. Brian will draw on two decades as a stand-up comedian to help scientists communicate better with general audiences.

As always, the success of this meeting is due in large part to an organizing committee which starts assembling the next symposium almost a year in advance. While your participation is what guarantees a successful symposium, ultimately putting all the correct pieces into order is what makes it function so smoothly. For over two decades, Lori Weir has been leading the organizing committee to ensure that all of the pieces of the symposium come together at just the right time. This year, our organizing committee for the symposium includes Tom Allen (treasurer), Paul Davis, David Duhl (president-elect), Jack Gordon, Michael Hunt, Curt Jawdy, Alfred Kalyanapu, Deedee Kathman, Amy Hill, Tom Lawrence, Ingrid Luffman, Patrick Massey, Regan McGahen, Patrick McMahon, Paul Sloan, Daniel Saint, Scott Schoefernacker (secretary), Forbes Walker (past-president), Sherry Wang, Adrian Ward and Mike Williams. Please take a minute to thank these committee members if you have a chance.

On behalf of the organizing committee, I wish you a great symposium!

Best wishes,

Rodney Knight
President, Tennessee Section, AWRA, 2016 Conference Chair

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12:00 – 1:30 p.m.
Wednesday, April 13
Keynote Address *by* Michael Kern, Director, The William D. Ruckelshaus Center

"FOSTERING COLLABORATIVE SOLUTIONS TO WATER RESOURCE MANAGEMENT CHALLENGES"

Many of today's water resource management challenges are too complex, and involve too many competing interests, to be effectively resolved by traditional public policy approaches. In many of these situations, the toolkits of alternative dispute resolution (ADR) and collaborative governance can be applied to overcome impasse and reach creative and durable solutions that meet the needs of all parties. Michael Kern is the Director of the William D. Ruckelshaus Center, a university-based provider of ADR and collaborative governance services. His address will introduce the Ruckelshaus Center, a joint effort of Washington State University and the University of Washington, and several of its projects that have involved water resource management. This will include description of the Chehalis Basin Strategy, in which a Governor-appointed work group, facilitated by the Center, has addressed almost a century of conflict and stalemate in the second largest watershed in Washington state, to craft an approach for mitigating catastrophic flooding, enhancing aquatic resources like salmon, and supporting prosperous communities. Michael will also introduce the University Network for Collaborative Governance, which brings together centers like his from across the nation.

12:00 – 1:30 p.m.
Thursday, April 14
Lunch Presentation *by* Brian Malow, North Carolina Museum of Natural Sciences

SESSION 1A

USGS WATER RESOURCES INSTITUTE

METEOROLOGY

SESSION 1B

STORMWATER I

SESSION 2A

WASTEWATER

WATER FOR AGRICULTURE I

WATER FOR AGRICULTURE II

WATER FOR AGRICULTURE III

SESSION 2B

ACID ROCK DRAINAGE INVESTIGATION I

ACID ROCK DRAINAGE INVESTIGATION II

ENVIRONMENTAL MICROBIOLOGY I

ENVIRONMENTAL MICROBIOLOGY II

SESSION 2C

CASE STUDIES

WATER RESOURCES

STREAM RESTORATION I

STREAM RESTORATION II

SESSION 3A

EPA

BETTER OUTCOMES FOR NATURAL RESOURCES MANAGEMENT: ALIGNING FOR SUCCESS!

Speakers: S. Gain, U.S. Geological Survey; T. Calabrese Benton, TDEC;
S. Kniazewycz, TDOT Abstracts Not Available

SESSION 3B

FLOODS

SESSION 3C

SEDIMENT

STUDENT POSTERS

SESSION 1A

USGS WATER RESOURCES INSTITUTE
1:30 p.m. – 3:00 p.m.

The USGS Water Resources Research Act Program: A Federal-State Partnership
Earl A. Greene

A Systems Approach Toward Sustainability: Bringing Biogeochemistry, Ecology, Economics and Land Ethics Together
Thanos Papanicolaou

Reach Scale Sediment Source Potential in Small Urbanizing Stream Systems
Robert R. Woockman and John S. Schwartz

METEOROLOGY
3:30 p.m. – 5:00 p.m.

Throughfall Chemistry Study in the Great Smoky Mountains National Park (GRSM)
Andrew Veeneman, John S. Schwartz, and Matt A. Kulp

Knoxville Microclimates: Spatial Variability in Air Temperature Across Four Urban Neighborhoods
David Howe, Dr. Jon Hathaway, and Dr. Kelsey Ellis

Utilizing NEXRAD Data for Determination of Precipitation
T. Cropp

THE USGS WATER RESOURCES RESEARCH ACT PROGRAM: A FEDERAL-STATE PARTNERSHIP

Earl A. Greene[1]

The Water Resources Research Act (WRRA) as administered by the United States Geological Survey (USGS) established a Federal–State partnership in water resources research, education, and information transfer through a matching grant program. The WRRA authorized the establishment of State Water Resources Research Institutes (National Institutes for Water Resources) at land grant universities across the Nation. There are 54 Institutes: one in each State, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam. The WRRA Program provides an institutional mechanism for promoting State, regional, and national coordination of water resources research, promotes student education and training, and is a focal point for research coordination and information and technology transfer. This program supports each Institute and coordinates multi-year research, education, and information transfer projects with USGS Science Centers on State and regional water resources issues. The WRRA program is fostering increased coordination, cooperation, and communication between Institutes and USGS Science Centers by through its program activities of Annual Base Grants, National Competitive Grants, Coordination Grants, and Student Internships.

[1] Chief External Research, United States Geological Survey

A SYSTEMS APPROACH TOWARD SUSTAINABILITY: BRINGING BIOGEOCHEMISTRY, ECOLOGY, ECONOMICS AND LAND ETHICS TOGETHER

Thanos Papanicolaou[1]

Landscapes are the lynchpin of rural communities and our emphasis here is on land conservation. Past research guiding conservation efforts has a fragmented view by assuming that the economics of the rural systems biotic clock will function without the non-economic parts. Human nature was viewed as decoupled from the non-human. Furthermore, these efforts have somewhat failed to recognize that we live in a constantly evolving world that is disturbed by intense human activity (agriculture) and shifts in climate. Surprisingly, there is no national modeling framework for the rural environment that could be used to assess conservation practices while considering, at the same time, complex social and natural system dynamics. In this research, our long-term **vision** is to identify scientifically the ecological, economic, and ethical leverage points, or metrics, that have the greatest impact on our ability to achieve conservation goals. Because we live in a continuously evolving world, we also believe that our biophysiecological dynamic models should be complemented with decision making tools to examine trade-offs and enhance our ability to constantly re-evaluate conservation goals. While many regional or local efforts achieve in part this decision-support function, new opportunities to take advantage of emerging geoinformatic infrastructure and dynamic modeling tools that capture human and non-human responses and interactions create the need for a new modeling paradigm in nearly all agriculture regions of the country. We will pursue this vision in the state of TN by having academia working with federal and state agencies and identifying pathways for performing synergistic activities.

[1] Director of the Tennessee Water Resources Center; Goodrich endowed Professor, The University of Tennessee

REACH SCALE SEDIMENT SOURCE POTENTIAL IN SMALL URBANIZING STREAM SYSTEMS

Robert R. Woockman[1]* and John S. Schwartz[2]

Cost effectively mitigating channel degradation due to excess energy in small stream systems, caused by decreases in initial abstraction or modifications to channel erosive resistance, requires linking planning of stormwater control measure suites with stream rehabilitation needs. Integrated management plans can be accomplished through fluvial audits that observe surrogate measures of a channel's erosive versus resisting forces and continuous simulation modeling (CSM) to identify potential response trajectories. Surrogate measures of channel erosive resistance and surplus stream power are explored to identify influence on developmental states and identify potential grouping. Calibrated CSMs of hillslope processes and in-channel processes are used to validate exploratory field data analysis and explore effective mitigation practices. Ultimately, this research is expected to support stream system rehabilitation in ER67 through adaptation of mitigation practices relative to channel erosive resistance properties.

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[2] The University of Tennessee, Department of Civil and Environmental Engineering, 325 John D. Tickle Building, Knoxville, TN 37996, jschwart@utk.edu

THROUGHFALL CHEMISTRY STUDY IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK (GRSM)

Andrew Veeneman[1], John S. Schwartz, Ph.D., P.E. [1], and Matt A. Kulp[2]

Since the 1980s national air quality monitoring has shown that the Great Smoky Mountain National Park (GRSM) receives high rates of atmospheric deposition of acid pollutants compared to other regions in the United States. In the early 1990s the GRSM initiated a long-term water quality (WQ) monitoring program to investigate the extent of the impacts from acidic deposition on the Park's WQ and aquatic biota. Ongoing monitoring throughout the GRSM continues to assess effects of stream acidification by better understanding the biogeochemical processes as deposited acid pollutants are transported by water from forest cover into the soils and then to streams. A key component in the biogeochemical processes is from the throughfall inputs of acids from the forest canopy to the forest floor.

Weathers et al. (2006) completed a park-wide survey for throughfall deposition in the GRSM in 2000. The study developed landscape-scale maps of nitrogen (N) and sulfur (S) deposition from dry- and wet-deposition monitoring data. Since this study, forest canopy cover has changed in the GRSM due to hemlock die-off. Also, reduced deposition has been observed in this region, and measured at the Noland Divide watershed; however it is unknown in other areas of the GRSM. New throughfall deposition data is needed to analyze the effect of hemlock die-off and the reduction in acid emissions. New data is also needed to calibrate the PnET-BGC model, for better prediction of future deposition loadings and estimates of current critical loadings. This project will be conducting a throughfall chemistry study in the GRSM to meet these needs.

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[2] U.S. National Park Service; Great Smoky Mountains National Park; Gatlinburg, Tennessee 37738

KNOXVILLE MICROCLIMATES: SPATIAL VARIABILITY IN AIR TEMPERATURE ACROSS FOUR URBAN NEIGHBORHOODS

David Howe, Dr. Jon Hathaway, and Dr. Kelsey Ellis

Daily weather observations for an entire city are usually represented by a single weather station, often located at the nearby airport. This resolution of atmospheric data fails to recognize the microscale climatic variability associated with land use decisions across and within urban neighborhoods. The main focus of this project is to observe spatial and temporal patterns of various metrological data across four urban neighborhoods in Knoxville, Tennessee. The preliminary findings will give us a snapshot of resiliency and environmental sustainability of individual urban neighborhood development and help us better understand human-environment interactions at a neighborhood scale. For this conference, the analysis will center on ambient air temperature and water temperature variability.

Our team installed 10 weather stations in July of 2014. Two weather stations were installed in each of 4 urban neighborhood. The two stations within each neighborhood were chosen to have significant variability in localized tree cover. Additional stations were located on a main street downtown and within a nature center to serve as a control. Temperature readings were taken every 5 minutes for 1 year.

Tmax, Tmin, and diurnal temperature range (DTR) results show significant variability within a neighborhood as well as between neighborhoods. The presence of an urban heat island is also evident. Adding more stations within a single neighborhood will help determine if small-scale decisions play a significant role in mitigating urban heat. GIS (geographic information systems) software as well as the iTree software developed by US Forest service will help determine what factors (and at what scale) control increased temperatures in an urban environment. Of specific interest is how land cover, canopy cover, population density, and spatial pattern of green space effect air temperature variability.

UTILIZING NEXRAD DATA FOR DETERMINATION OF PRECIPITATION

T. Cropp

Localized and intense precipitation events over a smaller watershed can result in substantial flooding and property damage. Municipalities often study these types of events to identify alternatives to mitigate future flooding if a similar event were to occur. Precipitation gages are not always available in the watershed of interest, and gages in adjacent watersheds may not record any precipitation for these localized events. When this occurs, gridded rainfall is an alternative for estimating rainfall amounts to use as inputs into a hydrologic model.

Gridded rainfall can be derived from Next-Generation Radar (NEXRAD) which established a network of over one hundred Weather Surveillance Radar-1988 Doppler sites (WSR-88D) to monitor atmospheric conditions. One of the major products of the WSR-88D sites is precipitation intensity. Weather forecasters use this information for short-term forecasts and to detect immediate threats of precipitation. The National Climactic Data Center (NCDC) archives and maintains this data and makes it available to the public.

This presentation describes the challenges encountered when using the raw data provided by NCDC as inputs to the hydrologic model, including the distortions caused by the WSR-88D proximity to the watershed and temporal anomalies that require detection and removal. A methodology was developed to process the data in a way that is acceptable for input to the hydrologic model. The results of this analysis demonstrate effective use of gridded rainfall in the reproduction of localized and intense precipitation events over ungaged watersheds.

SESSION 1B

STORMWATER I
1:30 p.m. – 3:00 p.m.

Is it Time for a National Stormwater Testing and Evaluation Program for Products and Practices?
Mark B. Miller

The Health of Trees in Existing Bioretention Areas in Tennessee and North Carolina
A. Tirpak

Runoff Uncertainty Related to Fine-Scale Spatial Variability in Urban Watersheds
T. Epps

STORMWATER II
3:30 p.m. – 5:00 p.m.

Stormwater Control Measures…Metro Nashville Latest Lessons Learned
J. Hayes

Evaluation of Biofiltration Media for Optimum Stormwater Treatment Under Controlled Outflow Conditions
Jessica Fears, Duane Graves, Linxi Chen, Jacques Smith, Aaron Poresky, and Austin Orr

Solving the Sediment Dilemma: Successful Construction Site Outreach to a Difficult Audience
Thomas B. Lawrence

IS IT TIME FOR A NATIONAL STORMWATER TESTING AND EVALUATION PROGRAM FOR PRODUCTS AND PRACTICES?

Mark B. Miller[1]

This presentation explores a growing movement in the manufacturing, regulatory and consulting sectors to implement a national program for stormwater testing and evaluation of products and practices (STEPP). The national program seeks to accelerate the effective implementation and adoption of innovative stormwater management technologies and practices through highly reliable, credible and cost-effective testing, evaluation and verification. Intentions are to (a) remove barriers to innovation, (b) minimize duplicative performance evaluation needs, (c) increase confidence that regulatory requirements are met, and (d) create consistency among testing and evaluation protocols. An important initial general programmatic consideration includes initial recruitment of NPDES delegated state programs, MS4s, EPA, and the development of industrial communities to support the national program. A goal is to move to a more equitable program between public domain practices and proprietary products. New product testing protocols are not part of the national program; however, modifications to the existing protocols may evolve during evolution of the program. STEPP will draw on existing New Jersey laboratory and Washington State field testing, evaluation and verification programs as models. State and local agencies would adopt a "cafeteria approach" by specifying whether laboratory and/or field testing are required for approval. Program aspects will also be described including Services, Organizational Relationships, Operational Structure, Governance, Funding, Stakeholder Engagement and Transparency, Testing Purpose and Scope, Testing Setting, and Reciprocity. Benefits and concerns associated with a national program versus regional interests largely pertaining to diverse stormwater conditions will also be discussed.

[1] Research Scientist, AquaShield™, Inc., 2733 Kanasita Drive, Suite 111, Chattanooga, TN 37343, mmiller@aquashieldinc.com, November 24, 2015

THE HEALTH OF TREES IN EXISTING BIORETENTION AREAS IN TENNESSEE AND NORTH CAROLINA

A. Tirpak

Bioretention is a commonly used stormwater control measure (SCM) that can be implemented to improve water quality and reduce runoff volume generated from impervious surfaces through biogeochemical processes. Plants and vegetation have been shown to improve the nutrient removal performance and lifespan of these systems. However, little guidance is given for plant selection within these systems, and often times all varieties of vegetation are considered equal in terms of their contribution to the effectiveness of the system (though some studies have shown this is not the case). Although the numerous benefits of trees in urban areas are understood (i.e. heat island mitigation, air quality improvements, noise attenuation, etc.), knowledge of their potential contributions to stormwater management as an integral component of bioretention is minimal.

The first step toward understanding tree health in bioretention areas is to examine their vitality in existing practices. Thus, field assessments were conducted in over 30 bioretention systems in Tennessee and North Carolina following guidance developed by the United States Forest Service. Tree health was quantified through measurements of crown conditions and leaf chemistry. These assessments were paired with site-specific bioretention characteristics compiled through additional observations and design plan consultations. Findings from these field surveys will be used to determine the overall health of trees in bioretention systems and to identify any design components and species selections that influence tree health. Ultimately, this research will culminate in the development of design specifications and guidance for bioretention systems that will aid in maximizing tree growth and health.

RUNOFF UNCERTAINTY RELATED TO FINE-SCALE SPATIAL VARIABILITY IN URBAN WATERSHEDS

T. Epps

Refining urban hydrology models to incorporate high-resolution data and fine-scale process controls is necessary to address the spatial variability in surface cover and hydrologic conditions in urban watersheds. Lumped models are unable to address distributed effects on hydrology and how surface connectivity and urban drainage impact runoff processes. Thus, spatially distributed models are being sought to achieve better urban hydrologic modeling by capturing the local effects and interactions that propagate downstream. These models utilize high-resolution data that has become widely available but often fail to represent key dimensions of urban hydrology at the scale of the runoff process or by fully capturing the variability in urban conditions. For example, rainfall from a single gage representing an entire watershed is often used as input to hydrologic models; vegetative cover inhibits runoff by interception and evapotranspiration yet it is rarely accounted for with spatial specificity; and pervious areas are often incorporated into urban hydrology models as infiltrative resources despite many studies showing their diminished performance due to soil compaction. This study focuses on sensitivity analysis for highly distributed urban runoff models related to the spatial distribution of rainfall, vegetative coverage, and soil infiltration. Rainfall radar measurements, vegetation cover data, and a statistically sound spatial distribution of in-situ infiltration rates will be used to improve runoff models. Differences in results using typical representation of these three elements and more spatially-distributed measurements will be assessed to determine the degree to which these processes impact hydrology in 5 urban watersheds in Knoxville, TN. Subsequent efforts will involve developing methodologies for incorporating such high resolution data in existing models to better reflect the spatial variability in urban watershed hydrologic processes.

STORMWATER CONTROL MEASURES…METRO NASHVILLE LATEST LESSONS LEARNED

J. Hayes

In Metro Nashville, permanent Stormwater Control Measures (SCMs) are required to be installed to treat post-development stormwater runoff for development/redevelopment activity involving land disturbances of more than 10,000 square feet. Per Metro regulations and the maintenance agreements recorded with the deed of the property, owners must maintain their stormwater practices in perpetuity. Metro Nashville's development regulations has brought about the installation of more than 3,000 individual SCMs across the county. SCMs have been installed under several versions of Metro's stormwater regulations. For example, some of the earlier structures were primarily designed as water quantity flood control measures, whereas, the more recent SCMs (since 2000) were also designed to improve the quality of stormwater runoff. Due to the vast number and variability of SCMs installed throughout Metro Nashville, Metro's Stormwater Program is now confronting a new challenge: How to ensure that these controls are being properly maintained and functioning as designed? This is important challenge to overcome, because if an SCM is not maintained and becomes non-functional, then the runoff from the impervious structures are basically bypassing with little to no stormwater treatment.

In an effort to develop a strategy to ensure SCMs are functioning as designed, Metro has implemented various pilot inspection/reporting/maintenance studies over the last few years and, as a result, have learned some valuable lessons. While a comprehensive SCM maintenance strategy has not been finalized, Metro believes it is important to share some of the important lessons learned with other MS4 communities as this will, if not already, also be a challenge for them to overcome.

EVALUATION OF BIOFILTRATION MEDIA FOR OPTIMUM STORMWATER TREATMENT UNDER CONTROLLED OUTFLOW CONDITIONS

Jessica Fears[1], Duane Graves[1], Linxi Chen[1], Jacques Smith[1], Aaron Poresky[2], and Austin Orr[3]

INTRODUCTION

Significant effort is ongoing across the country to identify appropriate biofiltration media blends that effectively remove pollutants and support vegetation, while minimizing leaching of nutrients and metals. A private developer in southern California plans to construct regional biofiltration facilities as part of a major land development project that will require thousands of cubic yards of biofiltration media. Additionally, the land developer will condition the sale of parcels to require that parcel-based best management practices (BMPs) be installed, many of which will incorporate biofiltration media. The biofiltration media must meet stringent requirements for permeability, treatment performance, fertility for biofiltration system vegetation, quality control during supply and placement, and other factors. Geosyntec conducted a column study of candidate biofiltration media blends to help select an optimum mix to meet the performance goals for the development project. The column apparatus tested the media mixes at full thickness to represent full-scale system design. A unique feature of the column apparatus was the ability to control the outflow rate to maintain a flow of 70-100 mL/min. Lab-scale testing was important for verifying hydraulic design parameters prior to full-scale implementation. The results of this study provided information that will be used to develop construction specifications for the procurement and quality installation of biofiltration media for the major land development project in California.

APPROACH

A column apparatus (Fig. 1) was carefully designed and constructed to distribute stormwater evenly across columns, maintain constant hydraulic head, operate at a filtration rate of 9 inches per hour, and maintain a saturation zone in each column. The components of the biofiltration media were selected based on previous chemical and hydraulic testing and included combinations of two sands, coconut coir peat, activated carbon coconut shell, compost, peat, biochar, and zeolite (Table 1). Estimated cost of raw materials for each media blend (not including labor for mixing and packing) ranged from \$30 per cubic yard (CY) to \$117 per CY.

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Table 1
Biofiltration Media Design

Material	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Control*
Site Sand	75%	50%	75%		70%	100%
Compost				30%		
Peat	15%	10%			15%	
Coco Peat			15%		15%	
Biochar	10%	20%	10%			
Zeolite		20%				
Washed Sand				70%		

*Control column contained choking layer (gravel and sand) only for Batch 1

The columns were initially flushed with tapwater over a 32-hour period to condition the media. Three separate batches (1,000 gallons each) of stormwater were collected from Third Creek in Knoxville, Tennessee within 24 hours of storm events that occurred in July and August of 2015. Cumulative rainfall depth at the time of stormwater collection ranged from 1.25 to 2 inches. The stormwater was amended according to the amounts listed in Table 2 to represent expected stormwater quality of the land development project site. The amended stormwater was pumped from the holding tanks to an inflow manifold that delivered continuosly mixed flow to each column. Process measurements (turbidity, electrical conductivity, and pH) were taken at hour 1, 5, 9, 11.5, and 31 during each batch. Water quality grab samples were collected from each column at equal time intervals over a 4-day period. Composite samples were analyzed for *E. coli*, nutrients (total kjeldahl nitrogen [TKN], ammoniacal nitrogen [NH_4-N], nitrate-nitrite nitrogen [$NO_{2,3}$-N], total phosphorus [TP]), total and dissolved metals (aluminum [Al], copper [Cu], iron [Fe], lead [Pb], and zinc [Zn]), total suspended solids (TSS), and total organic carbon (TOC).

Table 2
Stormwater Amendment Materials

Element or Compound	Amendment Material	Mass Added
-	-	lbs/1000 gal
Nitrogen	bloodmeal	0.06
Phosphorus	bonemeal	0.01
Phosphorus, dissolved	potassium phosphate (K_2HPO_4)	0.00
Copper	copper sulfate ($CuSO_4$)	0.00
Zinc	zinc sulfate ($ZnSO_4*7H_2O$)	0.00
Aluminum	aluminum sulfate ($Al_2[SO_4]_3*18H_2O$)	0.02
Iron	ferrous sulfate ($FeSO_4*7H_2O$)	0.01
Ammonia	ammonium chloride (NH_4Cl)	0.02

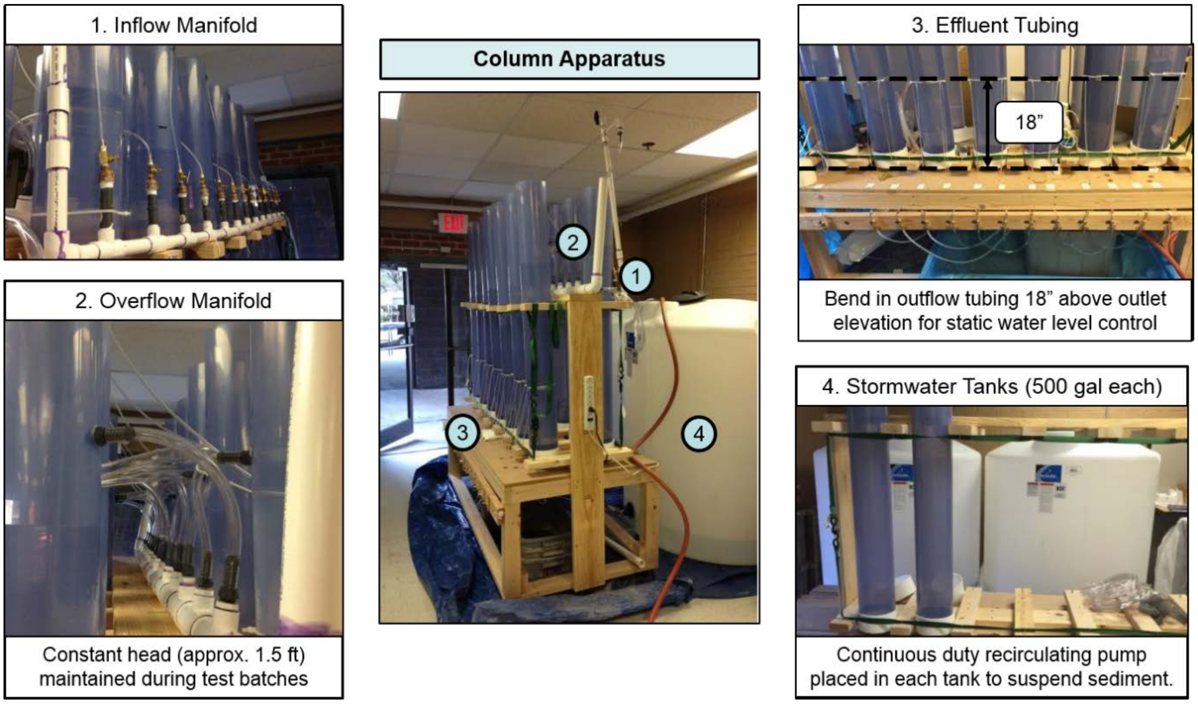

Figure 1: Column apparatus with inflow manifold, overflow manifold, outlet valves and stormwater collection tanks shown and several design features highlighted.

RESULTS AND DISCUSSION

The five media mixes selected for testing provided a range of materials and unit costs for comparison of water quality performance across mixes. Two media blends contained the same proportion of sand, peat, and biochar, but differed by the type of peat. The mix using coconut coir peat slightly outperformed the mix with peat composed of recycled plant materials with respect to TKN, TP, and dissolved Cu. Maximum average percent removal of dissolved aluminum was 20% higher for the mix with plant-based peat compared to the mix with coconut coir peat. Overall, maximum total metals removal was 90% or better on average for both mixes. Two other media blends represented the highest and lowest cost options. The high cost mix contained sand, peat, zeolite and biochar while the low cost mix contained washed sand, plant-based peat, and coconut coir peat. Maximum average percent removal of TKN and dissolved iron was higher for the high cost mix than the low cost mix; however, maximum average percent removal of TP, total lead, total and dissolved Zn and $NO_{2,3}$-N was lower for the high cost mix compared to the low cost mix. Generally, the observed water quality performance was similar for both mixes, despite the difference in cost. The fifth and final mix comprised 70% sand and 30% compost as specified by the local California county. This media blend exported TKN, TP, TOC, and dissolved iron. However, it demonstrated 90% or more maximum total metals removal.

Overall, the most expensive media mix did not provide significant advantages over the lowest cost mix. No substantial differences were observed between media blends with coconut coir peat compared to plant-based peat. Similar metals removal was observed across all mixes. Export of $NO_{2,3}$-N and TOC were most commonly observed, which is likely explained by the presence of organic materials (i.e. peat and compost) in all of the media mixes. As expected, the control column containing only sand and gravel did not export TOC during the study. In general, each mix provided TSS removal below the lab detection limit. However, limitations in TSS delivery from the stormwater tanks to the inflow manifold prevented columns from reaching maximum TSS loads (i.e. clogging conditions).

Due to short holding time, *E. coli* grab samples were collected twice per batch; therefore, sample size was too small to evaluate trends in bacteria removal. However, observed *E. coli* removal was generally strong with 80% to 90+% removal for each column. Physical filtration was likely a dominant process in bacteria removal.

From a hydraulic standpoint, effluent flow rate was fairly consistent over time for all columns. Clogging due to minor sediment accumulation in feeder lines and/or air bubbles likely contributed to observations of reduced flow rates from some columns. The choking layer (6 in. washed pea gravel and 4 in. washed sand) and outlet flow control contributed to a reduction in turbidity for all columns. Turbidity control was fairly consistent over time with effluent typically 35 NTU or less.

Beyond the specific project goals, these results are expected to provide valuable information for developing design specifications for biofiltration media in the future, particularly in areas where bacteria and nutrient removal are important for meeting effluent standards and protecting receiving water bodies.

SOLVING THE SEDIMENT DILEMMA: SUCCESSFUL CONSTRUCTION SITE OUTREACH TO A DIFFICULT AUDIENCE

Thomas B. Lawrence[1]

Construction site pollution prevention is not hard to understand, nor difficult to do, yet runoff from construction sites has been identified as one of the primary sources of pollution Statewide. Current municipal NPDES permits place a primary emphasis on public education and outreach, while also requiring pollution prevention from construction sites. Education is also included in many industrial NPDES permits, as well as other types of permits.

Municipal NPDES program managers agree that great success is achieved by utilizing effective public education and by coordinating education with other activities such as enforcement. This integrated approach was utilized with a focus on construction sites, resulting in a noticeable increase in the proper use and maintenance of construction site EPSC measures, as well as creating a positive relationship between regulator and regulated.

This presentation will cover construction site educational and outreach approaches that have proven effective in actual environmental education outreach campaigns. The variety of examples of campaigns that worked will provide the attendees with ideas for cost-effective approaches that they can use to address specific issues within their community. Additionally, tips for evaluating a campaign's effectiveness and some examples of campaign approaches that did not work will be discussed.

BIO: Thomas B. Lawrence is a registered Professional Engineer in California, Illinois and Tennessee. He has been active in the field of environmental engineering for over 25 years, specializing in water resources protection. He has worked for the Los Angeles County Department of Public Works, the City of Memphis Public Works Division and two consulting firms. He is currently a storm water consultant focusing on solutions for municipal and industrial permit compliance.

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SESSION 1C

INTEGRATED WATER RESOURCES APPROACHES
1:30 p.m. – 3:00 p.m.

The Water Quality Protection Program — An Innovative Approach to Surface Water Monitoring in Oak Ridge, Tennessee
M. Peterson, S. Gregory, W. Goddard, L. Muhs, and C. Valentine

Progress Toward Fully Supporting Urban Streams: A Partnership Between Non-Profits, Government and the Consulting Communities
Mekayle Houghton

Characterization of Baseflow Along the Duck River Between Columbia and Centerville, Tennessee, September 2015
Greg C. Johnson

GROUNDWATER
3:30 p.m. – 5:00 p.m.

Groundwater Flow within the Western Limb of the Stones River Syncline, Rutherford County, Central, Tennessee
Mark J. Abolins and Albert Ogden

Recharge Mechanisms to the Unconfined Memphis Aquifer, Fayette County, Western Tennessee
Dan Larsen, John Bursi, Brian Waldron, Scott Schoefernacker, and James Eason

Historical Trends of the Water-Table Aquifer in Shelby County, Tennessee
B. Tanner Ogletree and Scott Schoefernacker

THE WATER QUALITY PROTECTION PROGRAM – AN INNOVATIVE APPROACH TO SURFACE WATER MONITORING IN OAK RIDGE, TENNESSEE

M. Peterson[1]*, S. Gregory[2], W. Goddard[2], L. Muhs[2], and C. Valentine[2]

INTRODUCTION

The Water Quality Protection Program (WQPP) is a surface water monitoring program developed at Oak Ridge National Laboratory (ORNL). A requirement of ORNL's 2008 and 2014 National Pollutant Discharge Elimination System (NPDES) permits, the WQPP represents a first-of-its-kind, cooperative arrangement between the Tennessee Department of Environment and Conservation (TDEC) and the Department of Energy (DOE). The program has several unique features for an NPDES monitoring program. First, the program takes a watershed based approach, with a spatial and temporal strategy that focuses on the key compliance and human and ecological risk variables that impact the surface water system. Watershed-level conceptual models were developed for the major contaminants of concern in White Oak Creek (WOC). Second, the program developed a multidisciplinary working group that used new communication strategies to engage multiple organizations and stakeholders, taking advantage of knowledge sharing and leveraging of resources. Third, the program utilized an adaptive management and investigatory framework to surface water monitoring – a very different approach compared to traditional NPDES compliance monitoring. Studies were targeted and focused on potential causes of impairment, resulting in more frequent monitoring adjustments to take advantage of newly acquired information. Because of this relatively rapid feedback loop, there is a decreased emphasis on rote monitoring for the sake of meeting reporting requirements and an increased emphasis on conducting studies, interpreting results, finding sources of water quality impairment, and identifying opportunities to implement management actions that have real and measurable effects.

APPROACH

The benefits of surface water monitoring programs are maximized if program designers spend significant effort in planning, and setting clear monitoring goals (Vos et al. 2000, Caughlan and Oakley 2001). Caughlan and Oakley (2001) indicate that the most important investment in a monitoring program is in a planning process for setting objectives that are connected to the institution's goals. In ecological risk assessment, the formal planning process is termed "problem formulation," and Suter (2000) believes that this process would ensure the usefulness of results of monitoring programs.

The strategy used for the WQPP is a good example of program planning that includes establishing clear goals as a basis for monitoring. A WQPP working group was formed in early 2008 to define the goals of the WQPP and to design an effective monitoring plan and strategy for water quality protection and abatement. The working group met regularly for approximately six months and was comprised of a multi-organizational group of individuals with diverse

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knowledge of ORNL Clean Water Act (CWA) compliance activities and results, facility actions and abatement, local water chemistry, and ecological impacts. The goals of the WQPP were developed, first and foremost, by meeting the WQPP-specified requirements of the ORNL NPDES Permit. Further discussions among the WQPP working group led to the following broad objectives for the WQPP:

- Improve the quality of aquatic resources on the ORNL site
- Prevent further impacts to aquatic resources from current day activities
- Identify the stressors that contribute to impairment of aquatic resources
- Integrate water quality monitoring, biological monitoring, habitat assessment, best management practices/policies and abatement activities to achieve common short term and long term goals
- Set specific goals for each update of the WQPP and prioritize them
- Use available resources efficiently
- Increase communication and sharing of information between WQPP team members, decision makers and stakeholders
- Meet all regulatory requirements

With these objectives in mind, the WQPP working group defined a long-term monitoring strategy that used an "adaptive management" approach. The term "adaptive management" has been used in a variety of ways over the years by numerous agencies and programs, including the Environmental Protection Agency (EPA), the Department of Interior, and the Department of Defense (Satterstrom et al. 2007). It has evolved into a type of experimental management that is iterative in nature. Adaptive management blends monitoring, scientific investigation, and practical management into a framework that "learns by doing." The general strategy emphasizes 1) setting goals and targets (for surface water monitoring this includes regulatory and public input), 2) defining appropriate characterization and monitoring metrics to evaluate watershed condition (the core monitoring plan), 3) adjust and adapt with new investigations where monitoring information is incomplete (here, the WQPP uses a stressor identification process), and 4) provide feedback to decision makers so that specific actions can be taken to improve water quality. A special investigation component of the WQPP was a direct outcome of adopting an adaptive management strategy, which promotes experimental work and rapid feedback loops as an important part of any long-term monitoring and restoration program. To prioritize the stressors and/or contaminant sources that may be of greatest concern to water quality, and to define conceptual models that would guide any special investigations, the WQPP working group used EPA's stressor identification guidance (EPA 2000) within the context of the adaptive management strategy. The stressor identification guidance involves five major steps to identifying the cause of impairment: 1) define the case, 2) list candidate causes of impairment (based on historical data and a working conceptual model), 3) analyze the evidence from the case, 4) analyze the evidence from elsewhere, and 5) characterize the cause. An example for how the stressor identification process and conceptual model development was used in the context of an adaptive management strategy to address mercury impairment is provided in Figure 1.

RESULTS

The WQPP used stressor identification strategies to prioritize study efforts. Early studies focused on investigating the sources of mercury in fish tissue, the sources of polychlorinated biphenyls

(PCBs) in fish tissue, and the causes of biological community impairments (benthic macroinvertebrate and fish communities). The studies thus focused on three of the major water quality impairments identified in the NPDES permit. The identification of biological impairments was further refined by narrowing investigations to the WQPP working group's evaluation of the most likely causes of biological impairment. Major stressors to the biota in WOC were thought to fall into four broad categories: toxics, episodic factors, nutrients, and habitat. Studies were then performed to evaluate the role of these stressors on biological communities (Figure 2).

The mercury investigation initially centered on determining the sources of mercury within the most contaminated outfall at the facility, and evaluation of flow rerouting that might decrease mercury flux. Later, a second outfall was investigated where there was evidenced of a potable water leak that may have

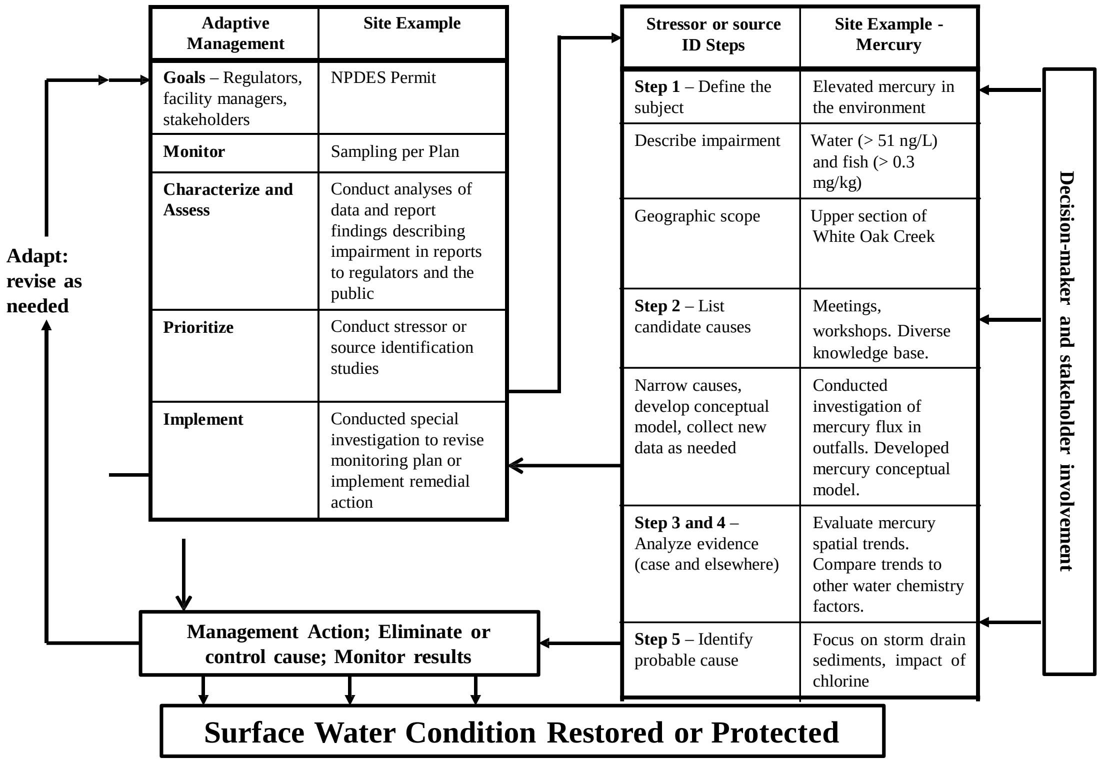

Figure 1. Flow path for how adaptive management and stressor identification strategies were used to define a mercury monitoring and investigation strategy in Oak Ridge, Tennessee.

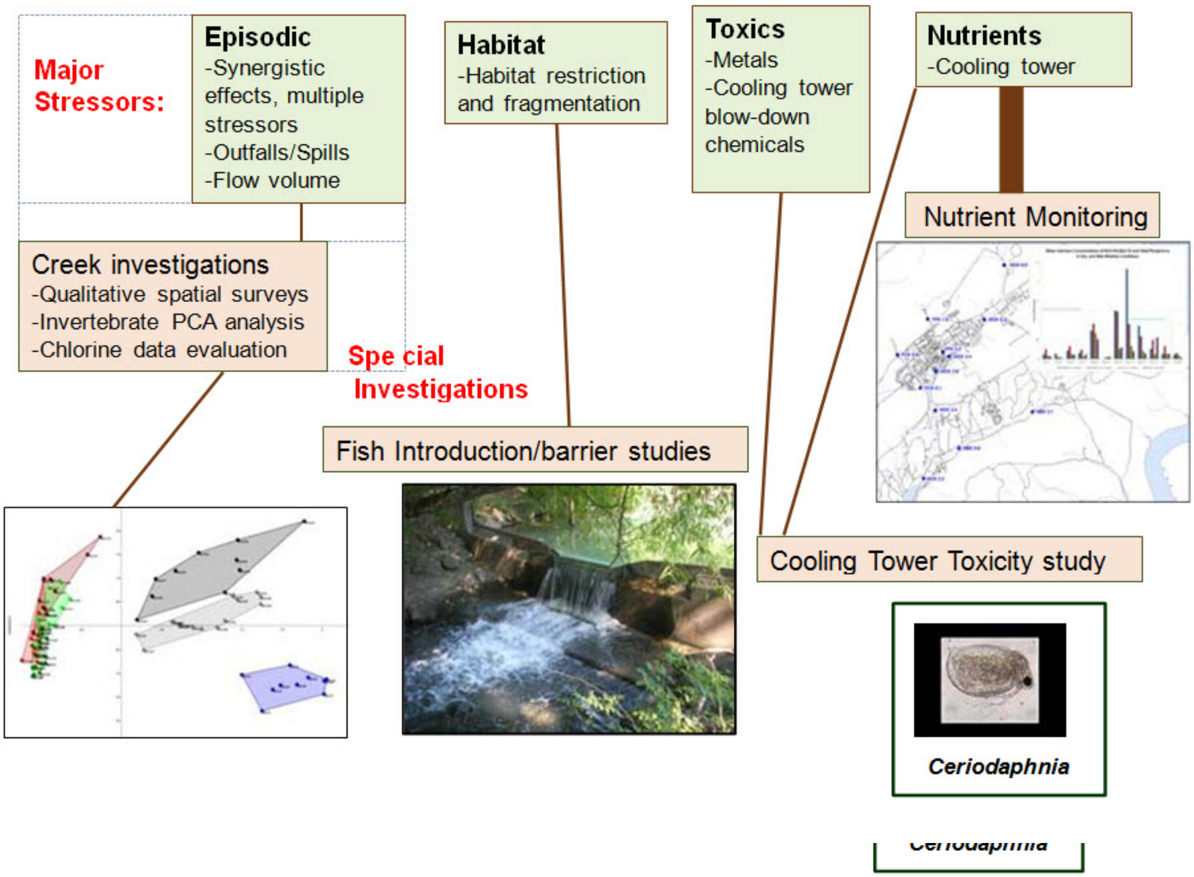

Figure 2. WQPP investigations of potential stressors impacting biological communities in WOC, 2008-2015.

exacerbated the release of dissolved mercury from the storm drain. The PCB investigation used Asiatic clams and semi-permeable membrane devices (SPMDs) as source identification tools to investigate facility outfalls and the storm drain network. As part of past conventional NPDES monitoring only fish would be evaluated; whereas the WQPP approach focused on determining the source of the PCBs to the system. To evaluate biological impairments, multiple studies were conducted over a multi-year period (Figure 2), including 1) using principal components analysis to evaluate invertebrate community impacts, 2) conducting fish introduction studies to evaluate the impacts of barriers and culverts, 3) nutrient investigations, and 4) evaluation of cooling tower toxicity. The WOC impairments, study findings, and actions taken by the WQPP are summarized in Table 1.

Table 1. Summary of WOC impairments, WQPP investigations, and follow-on monitoring and management actions, 2008-2015.

Water Quality Impairment	Investigation Findings	Follow-on Actions
Mercury	• Determined importance of outfall 211 and lower Fifth Creek • Found potable water leaks in Fifth Creek storm drains	• Rerouted flow in mercury contaminated drain line • Abated potable water leak, positively affecting mercury concentrations in water • Water and fish mercury concentrations in upper WOC decrease to below action levels
PCBs	• First Creek and major storm drain sources identified • PCBs in former Building 2000 area may be a more important source than first thought	• Continue narrowing of PCB source(s) in storm drain network feeding First Creek. • Identify soil and/or shallow groundwater source
Biological		
-Toxics	• Major cooling towers toxic; unclear effect further downstream • Localized copper loading	• Continue cooling tower toxicity tests to determine cause • Increased focus on cooling tower chemicals used • Defining spatial extent of high copper in stream
-Nutrients	• Localized elevated nitrogen and phosphorus • Biota community studies point to nutrient impacts some sites	• Quarterly nutrient sampling to help narrow source areas
-Episodic	• Identified likely importance of chlorine historically • Potable water may put more mercury in solution	• Invertebrate studies in upper Fifth Creek and WOC • Findings have led to chlorine-mercury investigations at DOE sites
-Habitat	• Successful introduction of some fish species at some sites • Upper section still not suitable for many species	• Fish barrier evaluations – removal prioritization decision-support tool • Removal of barrier to fish movement • Riparian improvements ongoing

CONCLUSIONS

Since the WQPP was implemented, multiple management actions have been implemented to address water quality issues. Some of those abatement actions are a direct outcome of the WQPP approach. As a result of abating sources of mercury, aqueous mercury levels in upper WOC have dropped approximately five fold and mercury concentrations in muscle tissue from redbreast sunfish collected at locations in WOC dropped and are below state and federal fish consumptive advisories (Mathews et al. 2012).

Six native fish species have been introduced into the WOC watershed, artificially eliminating physical barriers that have prevented natural fish migration. It was believed that improvements in water quality in WOC over recent decades might allow these additional species of fish to inhabit the WOC watershed, and it was also recognized that improvements in fish species richness in the WOC watershed was limited by weir and culvert barriers to fish migration (McManamay et al. 2016). So far, the introduction effort has been successful for five of the six target species, although fish communities remain impacted in the upstream reaches of the creek. Of longer-term benefit there is an increased focus on the impact of fish barriers, and in 2015 a barrier was removed.

The WQPP is an example of an integrated, watershed scale, science-based surface water monitoring strategy. Using science approaches to monitoring and remediation is a national priority (Peterson 2011, EPA 2013), and the WQPP experience may of value to other complex industrial or urban sites. Key aspects of this approach include:

1) using multiple lines of evidence to define objectives and identify and address high priority stream impairments identified in the conceptual model,
2) improving communications across programs, facilities, regulatory organizations, and the public to help ensure surface water monitoring addresses key shared goals and data is leveraged and costs minimized,
3) emphasizing research and investigation to better define source areas and stressors such that prudent changes in operations, abatement, or remedial actions can be made, and
4) incorporating adaptive management feedback loops that ensure adaptation in sampling priorities and protocols as necessary.

The demonstrated improvement in WOC water quality is one justification for the WQPP approach, which could not have been implemented without the support and flexibility from the CWA regulatory agency, the TDEC. Although regulatory flexibility has been essential to the program, it most certainly was based on trust that the facility was committed to water quality improvement and had the resources and wherewithal to implement– highlighting a potential challenge to wider application of the approach. An argument for facilities and permittees to take such an investigative approach is that with improved water quality, fewer financial resources will be needed for NPDES compliance and monitoring in the future – a long-term resource benefit. Of additional value is that the WQPP approach has made a broader science impact and some of the lessons learned have helped guide monitoring and research approaches at other sites.

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PROGRESS TOWARD FULLY SUPPORTING URBAN STREAMS: A PARTNERSHIP BETWEEN NON-PROFITS, GOVERNMENT AND THE CONSULTING COMMUNITIES

Mekayle Houghton[1]

INTRODUCTION

Metro Nashville Davidson County Water Services and the Cumberland River Compact have a partnership dating back to 2009. At that time, Metro Water and the Compact established ambitious goals to engage citizens in non-point source pollution mitigation with small-scale green infrastructure – primarily consisting of rain gardens and an enhanced urban canopy. With funding through a Supplemental Environmental Program associated with Nashville's Consent Decree, the Cumberland River Compact was tasked with seeing 300 rain gardens installed and 10,000 trees planted by 2015. These targets were surpassed with broad based citizen engagement throughout Davidson County.

In 2013 we began to envision a plan that would yield more than citizen engagement. We sought to achieve measurable improvements in water quality through actionable science, targeted investments and mobilization of a volunteer corps.

To the existing team of Metro Water Services and the Cumberland River Compact, we added the Nature Conservancy, Tennessee Chapter and the Nashville Mayors Office and several consultant teams. Building on policy goals set and reiterated by elected officials and citizen groups, this team tasked itself with developing a Watershed Stewardship Plan. Recognizing that Metro Water is able to identify infrastructure failures and is conscientiously eliminating known sources of pollutant loading, this plan seeks to engage citizens in non-point source pollution mitigation. The plan calls for education that motivates action. As citizens are mobilized through education, we tasked ourselves to have a strategy of small scale BMPs designed to bring Nashville's streams into compliance with water quality standards.

APPROACH

Set the goal moving from existing conditions: Current conditions are similar to other urban settings in that the majority of Nashville's streams are impaired. The city's most affluent watersheds are also its most impaired. The watersheds that still have some unimpaired streams are experiencing extreme development pressures. The former Mayor's environmental council and Metro Water Services reiterated a goal of delisting Nashville's waters by 2020. While this goal is daunting and the timeline might be considered impossible, we consider it an opportunity and a welcome mandate.

Using most current hydrologic modeling techniques, set volume targets: After impairments resulting from infrastructure failures are identified and rectified, impairments resulting from non-point source pollution should be treated by reducing volume and velocity of stormwater flows

[1] Executive Director, Cumberland River Compact

into streams. Under contract of Metro Water, SUSTAIN modeling was conducted by Tetra Tech with very specific volume reduction recommendations.

SUSTAIN is a decision support system that assists stormwater management professionals with developing and implementing plans for flow and pollution control measures to protect source waters and meet water quality goals. SUSTAIN allows watershed and stormwater practitioners to develop, evaluate, and select optimal best management practice (BMP) combinations at various watershed scales based on cost and effectiveness.[1]

BMP Optimization and Placement: With cost calculations from Metro Water, TetraTech used SUSTAIN to optimize BMP scenarios for cost and effectiveness. Then SUSTAIN, Metro Water and Compact worked on BMP placement within the drainage basin. Variables considered for BMP placement included public vs private ownership and landowner willingness.

Implementation of modeling recommendations Cumberland River Compact with funding from the Frist Foundation and hundreds of volunteer hours is in the process of implementing the SUSTAIN recommendations. This process involves doing what we're already experienced in – rain gardens, bio-swales, street trees as well as learning new skills. Among the SUSTAIN recommendations were 43 impervious retrofit projects. Depave is training the Cumberland River Compact to lead volunteer impervious retrofit projects. This work is popular in Portland, Oregon and parts of Canada. We are excited to bring this form of civic engagement to the Cumberland Basin.

Feedback loop to adjust model for the next drainage basin: Baseline, on-going and post project monitoring conducted by a local advocacy oriented watershed group Richland Creek Watershed Association will help to document the effectiveness of this work. Official monitoring data from Metro Water and TDEC will determine whether the streams meet water quality standards.

Moving to the next sub-watershed: We will use LSPC modeling to identify sources of pollutant loading in Nashville's 11 other sub-watershed. Once smaller drainage basins contributing heavy pollutant loads are identified, SUSTAIN's BMP optimization tool will be used to economically pinpoint BMP implementation sites.

LSPC is the Loading Simulation Program in C++, a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model.[2]

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[1]http://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain
[2]http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=75860&CFID=44147778&CFTOKEN=29334535

CHARACTERIZATION OF BASEFLOW ALONG THE DUCK RIVER BETWEEN COLUMBIA AND CENTERVILLE, TENNESSEE, SEPTEMBER 2015

Greg C. Johnson[1]

The U.S. Geological Survey (USGS), in conjunction with the Duck River Agency, conducted a seepage investigation to determine the location of gaining and/or losing reaches on the Duck River downstream of Columbia, Tennessee. This information will inform decisions about potential locations for establishment of future water supply intakes, which is particularly important at baseflow conditions. Twenty-six discharge measurements were made, using acoustic Doppler flow meters following standard USGS methods, on the Duck River between Columbia, Tennessee and Centerville, Tennessee from September 22 -24, 2015. The reach was bounded by stream gages at mile 132.8 (site 1) and mile 72.7 (site 26) with 5 major tributaries between sites 2 and 23 evaluated to determine their contribution to the discharge in the Duck River. Measured discharge ranged from 221 cubic feet per second (cfs) at Columbia (site 1) to 479 cfs at Centerville (site 26). Discharge measurements made above and below five major tributaries indicate that the tributaries contribute to a 12.5-percent increase in discharge along the studied reach. A minor storm peak occurred on September 13, 2015, prior to the study, and the Duck River was receding with small changes in discharge during the study, indicating that most of the flow in the Duck River was from groundwater contribution. To standardize the discharge measurements for the recession of discharge over the three days, the discharge at each site was increased based on the decrease of discharge at site number 26 (USGS 03601990) and site number 6 (USGS 03600358). Standardized discharge between site 1 and 21 increased fairly linearly with standardized yields ranging from 0.18 to 0.20 cfs/ square mile. Standardized discharge in the Duck River increased from 221 cfs at Columbia (site 1) to 294 cfs near Williamsport (site 12), to 318 cfs at site 21 near the Maury/Hickman County line (River Mile 99.9). Additional measurements may be needed to verify apparent gaining and losing discharge on the Duck River measured between sites 22 and 26. A stretch of the Duck River near Parsons Bend (site 4) has been proposed as a candidate for additional water-supply development (Doug Murphy, Duck River Agency, personal communication January 7, 2016). Although standardized discharge in the reach upstream between Columbia (site 1) and Parsons Bend (site 4) increased 37 cfs over 12.8 miles, yields remained relatively constant.

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Table 1. Results of the Duck River seepage study, September 22-24, 2015.

[a; indicates a bridge measurement; RM, river mile; Q, discharge; cfs, cubic feet per second; Q-std, standardized discharge; cfs/ sq mi, cubic feet per second per square mile; Yield-std, standardized yield; Latitude and Longitude are reported as degree, minute, and second in NAD 83.]

Site Number	USGS Station number	Date	Time	RM	Q (cfs)	Q-Std[A]	Drainage Area (sq mi)	Yield (cfs/ sq mi)	Yield-Std (cfs/ sq mi)[A]	Latitude	Longitude	Site Name
1	03599500	9/22/2015	9:05	132.8	221	221.0	1208	0.18	0.18	35 37 04.74	87 01 56.43	Duck River at Columbia, TN
2	03600285	9/22/2015	9:35	125	254	255.5	1396.54	0.18	0.18	35 39 52.06	87 05 38.87	Duck River near Athendale below Knob Creek, TN
3	03600352	9/22/2015	11:30	122	259	264.5	1423.94	0.18	0.19	35 40 31.01	87 08 08.36	Duck River at Roberts Bend Near Gant, TN
4	03600354	9/22/2015	12:51	120	253	258.3	1428.67	0.18	0.18	35 42 00	87 08 04.99	Duck River Parsons Bend Below Coal Branch, TN
5	03600356	9/22/2015	14:14	118	259	265.4	1430.16	0.18	0.19	35 41 33.43	87 09 12.6	Duck River Near Cave Bluff Near RM118, TN
6	03600358	9/22/2015	12:42	116.5	267	270.1	1433.31	0.19	0.19	35 41 13.36	87 10 43.95	Duck River at Craig Bridge Rd ab Williamsport, TN
7	03600359	9/22/2015	11:08	115.5	265	269.0	1433.88	0.18	0.19	35 41 09.5	87 11 31.5	Duck River Above Snow Creek Near Arkland, TN
8	03600372	9/22/2015	12:05	115.4	267.7	269.6	1460.83	0.18	0.18	35 41 08.6	87 11 38.9	Duck River Below Snow Creek Near Arkland, TN
9	03600375	9/22/2015	13:08	115.1	276	281.8	1461.51	0.19	0.19	35 41 18.5	87 12 07.5	Duck River Above Leipers Creek Near Arkland, TN
10	03600382	9/22/2015	13:47	114.9	280	287.0	1499	0.19	0.19	35 41 18.9	87 12 21.9	Duck River Below Leipers Creek Near Arkland, TN
11	03600405	9/22/2015	14:07	113	275	278.2	1501.23	0.18	0.19	35 41 06.3	87 13 48.3	Duck River Above Poplar Creek Near Williamsport, TN
12	03600415	9/22/2015	13:17	112.8	287	294.1	1507.9	0.19	0.20	35 41 00.7	87 13 52.4	Duck River Below Poplar Creek Near Williamsport, TN
13	03600425	9/23/2015	10:47	111	277	292.9	1510.68	0.18	0.19	35 40 31.9	87 15 04.7	Duck River Above Greenfield Island Near RM111, TN
14	03600440	9/23/2015	12:07	110	271	286.6	1513.11	0.18	0.19	35 39 07.1	87 14 45.4	Duck River Above Big Bigby Creek Near RM109, TN
15	03601510	9/23/2015	12:52	109.8	294	310.9	1642.17	0.18	0.19	35 39 07.2	87 14 52.6	Duck River Below Big Bigby Creek Near RM109, TN
16	03601515	9/23/2015	10:51	108.6	283	299.3	1642.45	0.17	0.18	35 39 32.18	87 15 23.51	Duck River Above of Catheys Creek Near Pipkins Bluff, TN
17	03601555	9/23/2015	11:57	108.4	281	297.2	1689.91	0.17	0.18	35 39 47.52	87 15 31.46	Duck River Below of Catheys Creek Near Pipkins Bluff, TN
18	03601557	9/23/2015	13:25	106	290	308.4	1691.69	0.17	0.18	35 40 08.36	87 16 51.35	Duck River Above of Delk Island Near Potato Knob, TN
19	03601558	9/23/2015	15:20	103.5	290	308.4	1695.58	0.17	0.18	35 41 11.29	87 17 31.52	Duck River Above of Greenfield Bend Near Hoover Gap, TN
20	03601559	9/23/2015	16:35	102	291	309.4	1697.64	0.17	0.18	35 41 45.7	87 16 38.6	Duck River Above of Baker Slough Near Ruins, TN
21	036015595	9/23/2015	17:06	99.9	299	317.9	1700.41	0.18	0.19	35 42 11.5	87 15 15.1	Duck River at Shelby Bend Near Church Bluff
22	03601600	9/22/2015	14:09	97	332	352.3	1705	0.19	0.21	35 43 14.12	87 15 57.7	Duck River near Shardy Grove, TN
23	03601625	9/24/2015	10:56	95.6	282	298.2	1706.84	0.17	0.17	35 43 56.75	87 15 56.21	Duck River Below of Dunlap Creek Near Ferry Hills, TN
24	03601635	9/22/2015	15:35	95	347	357.3	1714.13	0.20	0.21	35 45 15.78	87 17 02.66	Duck River at Bratton Road, TN
25	03601645	9/24/2015	11:52	91.5	304	330.5	1740	0.17	0.19	35 46 16.5	87 17 17.5	Duck River at Anderson Bend Near RM91.5
26	03601990	9/23/2015	12:00	72.7	479	506.5	2048	0.23	0.25	35 47 03	87 27 36	Duck River at HWY 100 Centerville TN

[A]Standardized discharge (Q-norm) and yield are based on recession of discharge at the gages at Craig's Bridge (site number 6) and Centerville (site number 26) so that discharges are corrected to be equivalent to the higher discharge at the beginning of the seepage run.

GROUNDWATER FLOW WITHIN THE WESTERN LIMB OF THE STONES RIVER SYNCLINE, RUTHERFORD COUNTY, CENTRAL TENNESSEE

Mark J. Abolins[1] and Albert Ogden[2]

ABSTRACT

Within an approx. 93 km^2 rectangle centered on part of the Stones River syncline, the only dye traces bearing 342-008° (length-weighted mean of 346°) have injection points, detection points, or (most commonly) both within the western limb of the north-south trending syncline. These traces comprise only 16% of the approx. 58.0 km of traces within the rectangular study area which has a north-south dimension of 11.1 km and an east-west dimension of 8.4 km. The study area is located in the northern Murfreesboro 7.5’ quadrangle and the Walterhill 7.5’ quadrangle, Rutherford County, central Tennessee and includes parts of the cities of Murfreesboro and Smyrna. The Stones River flows north through the study area and Tennessee State Route 840 crosses the southern part of the study area. Published fracture orientation measurements from the northern and southern parts of the study area (Abolins et al., 2015) suggest that the orientation of the traces reflects the orientation of a joint set. For example, at a northern location on the western edge of the western limb, 12 of 29 joints define a 334-001° set having a mean strike and dip of 344°/76°E. Joints may be related to the hypothetical Stones River fault, a subsurface east-side-down normal fault inferred to lie beneath the western edge of the Stones River syncline.

INTRODUCTION

Hydrogeologists have long recognized that the orientations of many central Tennessee groundwater dye traces are similar to the orientations of widespread joint sets (e.g., Ogden et al., 1998; Ogden et al., 1999). Specifically, the orientation of many dye traces is similar to that of a widespread joint set striking approx. 300-330°, and other dye traces share the orientation of a joint set striking approx. 035-055°. Also, some dye traces have approx. the same orientations as the north-trending hinges of gentle folds described in Moore et al. (1969). This extended abstract describes the orientation of dye traces and joints within an approx. 93 km^2 area (Figure 1) centered on the Stones River syncline.

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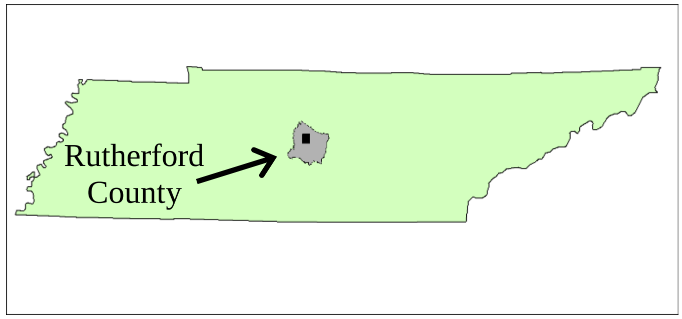
Figure 1. Location of study area (black rectangle) within northwestern Rutherford County, Tennessee.



Relative to existing papers, reports, and maps, this paper contains the following new information.

- A quantitative analysis of the orientation of dye traces in the vicinity of part of the Stones River syncline.
- A brief description of joint orientation measurements made within the same area and published recently (Abolins et al., 2015). A brief explanation of the relationship between joints and the hypothetical Stones River fault zone (SRFZ).
- In light of both of the above bullets, conclusions about groundwater flow through fractures within the Stones River syncline.

Dr. Ogden and colleagues performed dye traces over an interval of several years while working on a variety of local and regional projects. Most of the traced flow was through the Ordovician Ridley limestone. The traces described in this paper are from Ogden and Scott (1998), Ogden et al. (1998), Ogden and Powell (1999), Ogden et al. (1999), Ogden et al. (2001), and Ogden et al. (2002).

Dr. Abolins and colleagues began investigating the structural geology of the study area while involving future middle school and high school teachers in scientific research with financial support from a National Science Foundation (NSF) Research Experience for Undergraduates (REU) Site grant (NSF EAR1263238 to Drs. Mark Abolins and Heather Brown) during 2013-2015. This research led to the hypothesis that the syncline formed in the hanging wall of a subsurface normal fault (Abolins et al., 2015). Abolins et al. (2015) is a road guide, and Stops 5 and 6, referenced throughout the rest of this paper, refer to stops in that guide.

DYE TRACES

Within the study area, most dye traces (length-weighted) trend 311-330° or 071-080° (Figures 2 and 3), and, together, traces having these orientations account for 42% of the length of the 58.0 km of traces. In contrast, traces having an orientation of 342-008° (length-weighted mean of 346°) have injection points, detection points, or (most commonly) both within the western limb of the syncline, and these traces account for only 16% of the length of traces within the study area.

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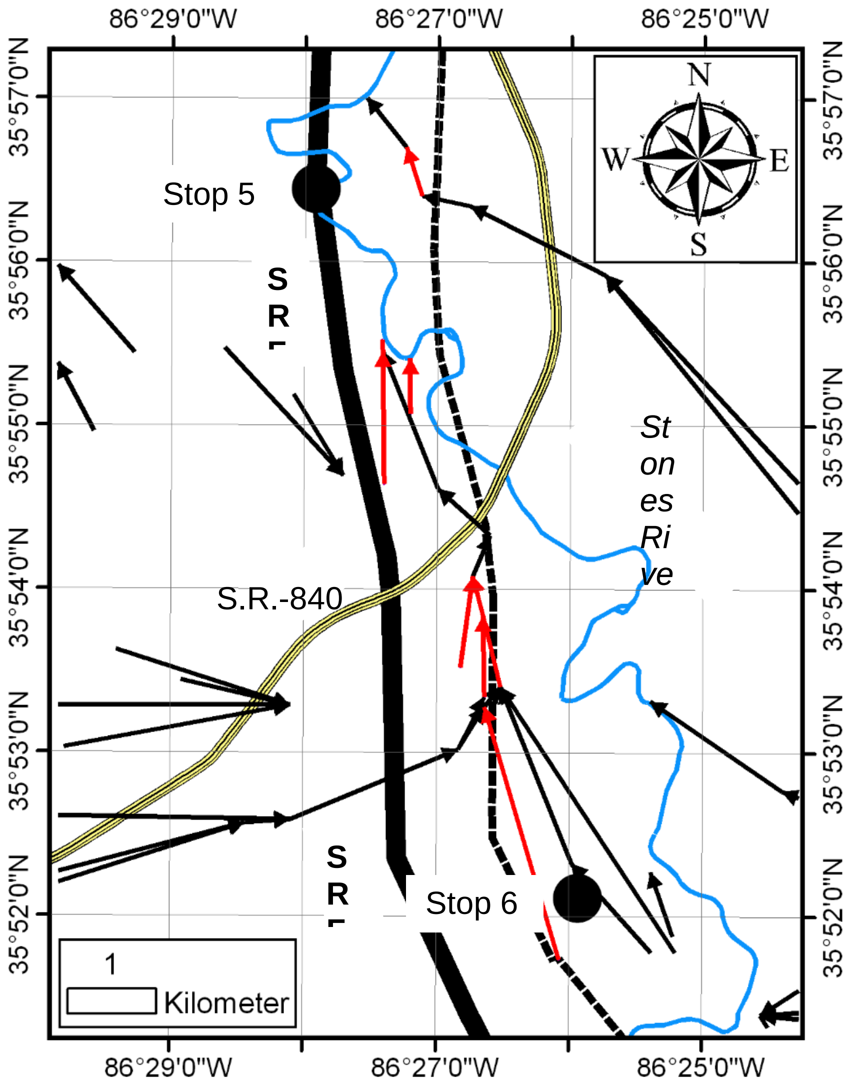


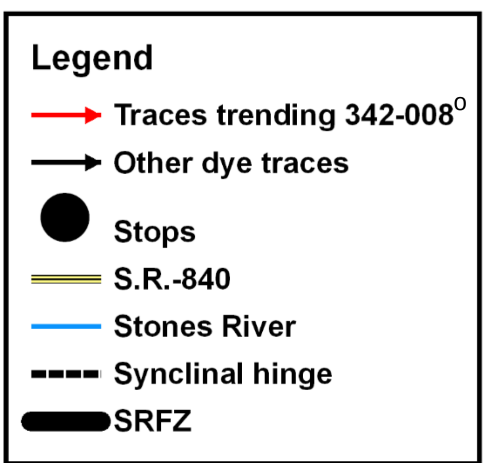
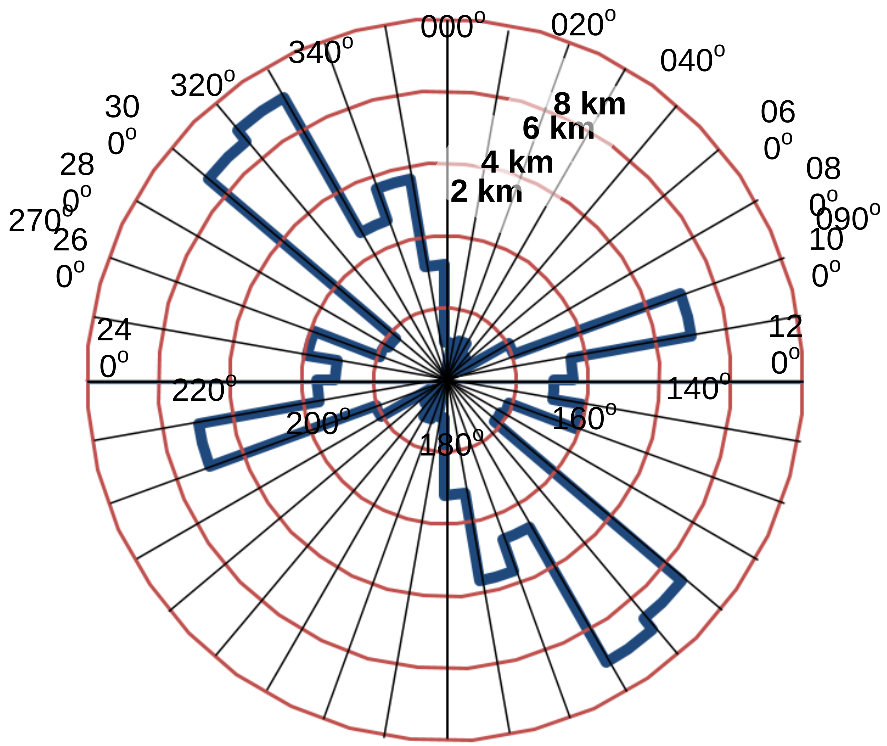


Figure 2. Dye traces and geologic structures within the study area. The Stones River fault zone (SRFZ) is a hypothetical subsurface structure, but is depicted as a solid bold line for clarity. Stops 5 and 6 are described briefly in the text of this paper and more fully in Abolins et al. (2015). See Fig. 1 for location of study area within Rutherford County and Tennessee.

Figure 3. Rose diagram of dye trace trends within the study area. The bin size is 10°. The radial scale is length of traces in kilometers, and the outermost circle is 10 km. See Fig. 2 for map of traces and see Fig. 1 for location of study area.

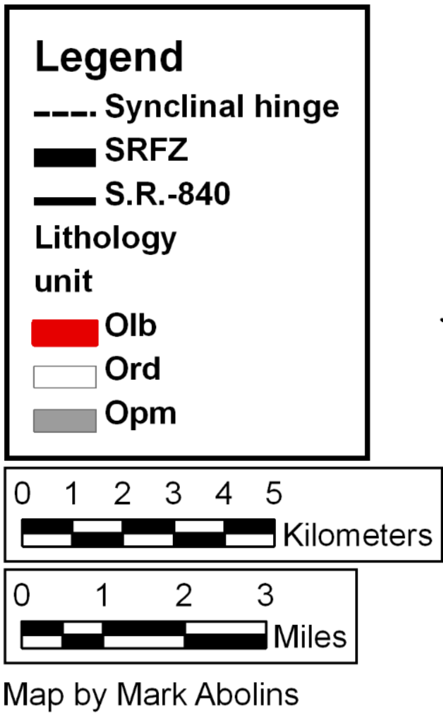


STONES RIVER SYNCLINE AND HYPOTHETICAL STONES RIVER FAULT

As described in Abolins et al. (2015), the Stones River syncline is more than 22 km long, stretching north from the northwestern part of the City of Murfreesboro in Rutherford County, TN. Although the location of the hinge is broadly similar to that of the hinge depicted in Moore et al. (1969), the location of the hinge depicted in Abolins et al. (2015) differs in detail. The Stones River syncline is primarily defined by a north-south belt of Ordovician Lebanon limestone surrounded by strata of the older Ordovician Ridley, Pierce, and Murfreesboro limestones (Figure 4). The outcrop pattern in Figure 4 is based on Wilson and Hughes (1963), Wilson (1964), and Wilson (1965). When examining Figure 4, keep in mind that the outcrop pattern of the Lebanon limestone is generally thought to be accurate, but subsurface investigations (Farmer and Hollyday, 1999) and geologic mapping (Abolins, 2014) suggest that the Ridley, Pierce, and Murfreesboro limestones have been inaccurately mapped in many places. Abolins et al. (2015) suggests that the syncline formed in the hanging wall of the SRFZ, a hypothetical east-side-down subsurface normal fault. The fault hypothesis is largely based on fractures exposed at the surface. Specifically, a map by Galloway (1919) depicts a minor fault at a location now beneath Percy Priest Lake, and, at another location (Stop 5 on Figures 2 and 4), Abolins et al. (2015) describes 12 joints ranging in strike from 334° to 001° (mean of 344°) and ranging in dip from 57-88°E (mean of 76°E). Although the number of measurements is small, these joints are approx. 41% of the joints measured at Stop 5, and they are unlike most joints in the study area because they are not sub-vertical. For example, the orientation of these 12 joints contrasts with the orientation of joints at another location just 300 m to the northeast of Stop 5. At that location, most of the 44 measured joints belong to a set striking 278-307° (mean of 301°) or a set striking 023-058° (mean of 037°), although 2 joints have north-northwest strikes. On Figures 2 and 4, the location of the SRFZ is based on the location of the Galloway (1919) minor fault, Stop 5, the outcrop pattern of the geologic units, and, at its southern end, bedding plane attitudes described in Abolins et al. (2015). The SRFZ is essentially coincident with the western edge of the Stones River syncline.

Based on fissure orientation measurements at Stop 6, the west-southwest-to-east-northeast width of the belt of north-northwest-striking fractures may be at least 2.0 km, and the belt may extend as much as 600 m to the east of the hinge of the Stones River syncline. At that stop, measurement of the orientation of 109 sub-vertical fissures revealed a set striking 345-005° with a mode of 350-355° (Abolins et al., 2015).

The north-northwest trend of the Stones River syncline and the SRFZ are broadly similar to the strike of many cratonic faults, although north-northeast striking faults are more common in the midcontinent and north-striking faults are more common in the Colorado Plateau and Rocky Mountain region (Marshak et al., 2000). Also, Abolins et al. (2015) describes similar structures approx. 20 km to the southwest within the Harpeth River fault zone. The SRFZ is not explicitly shown on published structure contour maps (Moore et al., 1969; Harris, 1975; Rima, 1977) and geophysical maps (Sims et al., 2008), although the Harris (1975) borehole data can be reinterpreted in a way that is consistent with the fault interpretation. The fault was probably overlooked because the main fault plane is underground, and the maximum structural relief across the fault is relatively small (perhaps 40 m).



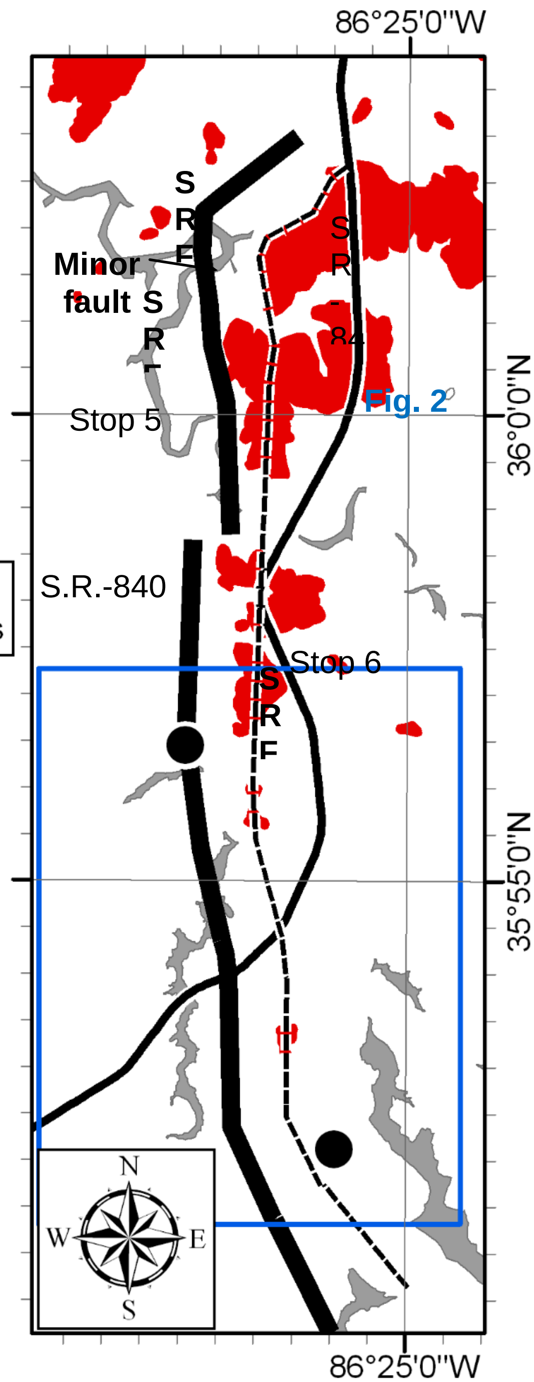


Figure 4. Geology of the Stones River fault zone (SRFZ). Olb is Ordovician Lebanon limestone, Ord is Ordovician Ridley limestone, and Opm is Ordovician Pierce and Murfreesboro limestones. See text for additional explanation and sources of data. Note that the SRFZ is a hypothetical subsurface structure, but is shown as a bold solid line for clarity. Blue rectangle is study area (see Fig. 2).

CONCLUSIONS

Dye traces trending 342-008° are consistent with groundwater flow within the western limb of the Stones River syncline and along the hinge of the syncline. Based on fracture orientation measurements at Stops 5 and 6, the authors think groundwater is flowing north-northwest through a belt of fractures striking approx. 344°. This belt is more than 2.0 km in width, extending at least as far west-southwest as the SRFZ and at least as far east-northeast as Stop 6, 600 m east of the hinge of the Stones River syncline. These findings suggest that, within the syncline, NNW groundwater flow is not confined to the hinge. In light of the likelihood that a subsurface fault underlies the western edge of the syncline and the likelihood that some fractures are fault-related, these findings show that subsurface faults, fault-related fractures, and fault-related folds may be a significant and overlooked control on central Tennessee groundwater flow within some areas.

ACKNOWLEDGEMENTS

Structural research within the study area was supported by NSF grant EAR1263238 to Drs. Mark Abolins and Heather Brown. Geospatial investigations by undergraduate researchers Brandi Bomar and Indya Evans contributed to the map of the northern part of the SRFZ. Joint measurements northeast of Stop 5 could not have been made without logistical support (i.e., canoe assistance) provided by undergraduate Michael Copley. The Fall 2014 Middle Tennessee State University (MTSU) Field Methods in Geology class made fissure orientation measurements at Stop 6, and the Spring 2016 MTSU Field Methods in Geology course checked the measurements. Josh Upham (City of Murfreesboro Water and Sewer Department) participated in many helpful discussions concerning the dye traces. The opinions expressed in this paper are those of the author and do not necessarily reflect the opinions of NSF or persons acknowledged here.

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RECHARGE MECHANISMS TO THE UNCONFINED MEMPHIS AQUIFER, FAYETTE COUNTY, WESTERN TENNESSEE

Dan Larsen[1], John Bursi[1], Brian Waldron[1], Scott Schoefernacker[1], and James Eason[1]

The Memphis aquifer is the most important source of groundwater in western Tennessee, both in regard to quantity of water produced and the number of water users. Although the rate of production of municipal water from this aquifer is monitored, the rates and mechanisms of recharge to the Memphis aquifer are poorly constrained. Previous studies indicate that recharge occurs primarily in the outcrop and subcrop region of the Eocene Memphis Sand, an 800-ft thick Coastal plain sand unit in the northern Mississippi Embayment. Recent studies at the Pinecrest facility in Fayette County included monitoring of soil moisture, groundwater levels, stream flow, and climatic conditions in an upland watershed to test hypotheses regarding heterogeneous recharge pathways and rates to the Memphis aquifer. The chemistry of precipitation, soil water, and both surface and subsurface waters, and environmental tracers provide additional and critical information regarding recharge process.

Analytical data and water levels indicate that most of the yearly change in groundwater levels beneath the upland surfaces is attributed to wet season infiltration of stream waters where they flow directly over sandy alluvium overlying the Memphis Sand subcrop. Tensiometer and lysimeter soil-water data along an upland hillslope transect suggest that some recharge is contributed along upland hillslopes; however, little recharge occurs beneath upland surfaces or valley floors with silty alluvial fill. Upland surfaces are mantled by loess and one or more paleosols which act to limit vertical recharge. Silty alluvial fill of upland valleys likely retards recharge to a similar degree although the rates and processes are not well constrained at present.

Streams flowing over sandy alluvium overlying Memphis Sand subcrop lose discharge to the underlying aquifer and cause localized wet-season mounding of the water table. Tritium and sulfur hexafluoride data suggest piston-like lateral groundwater flow from water-table mounding along the upland margins toward the upland interiors. According to this model, rates of effective recharge from lateral groundwater flow decrease with distance from the upland margins or areas of direct infiltration to the Memphis Sand. Estimated recharge in the largely loess-covered and alluviated upland valley based on water balance is 0.08 cm/yr; however, recharge based on change in groundwater levels for the upland wells is 6 – 7 cm/yr. These estimates suggest that the bulk of the recharge occurs by lateral flow of groundwater rather than directly infiltration beneath the loess-covered and alluviated upland valley. The recharge estimates are also consistent with the results of a nitrate mixing model in largely loess-covered and alluviated upland valley that suggests that less than 10% of the recharge originates from hillslope recharge with the remaining 90% originating from lateral groundwater flow.

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HISTORICAL TRENDS OF THE WATER-TABLE AQUIFER IN SHELBY COUNTY, TENNESSEE

B. Tanner Ogletree[1] and Scott Schoefernacker[1]

Groundwater from the Memphis aquifer is the primary source of drinking water in Shelby County, Tennessee. The Memphis aquifer is overlain and confined by the Jackson-upper Claiborne confining unit, which separates the shallow and Memphis aquifers throughout most of the county. However, there are areas where the confining unit is thin or absent creating windows that allow water to flow from the shallow aquifer into the Memphis aquifer as recharge.

A water-table map of the shallow aquifer and the unconfined portion of the Memphis aquifer in Shelby County was created using water-level data collected during October 2015 including groundwater elevations from 115 wells, surface water elevations from 56 bridge crossings, and historical groundwater elevations from 130 wells measured within the last five years (2010-2015). The water-table map was developed using GIS tools and contouring methods and compared to previous maps completed in 1988 and 2005. Comparison of the current and previous maps included changes in water-table elevations as well as anomalous depressions in the water table that would signify absence of the confining unit and a potential window location.

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SESSION 2A

WASTEWATER
8:30 a.m. – 10:00 a.m.

Total Dissolved Solids Toxicity – The Science, Challenges and Full Scale
Richard Lockwood and Scott Hall

Integrating Site Specific Bioassessment Data into Future Permits as Controlling Criteria
Darren Gore, John Strickland, Steve Tate, Mike Bernard, Kenny Diehl, John Michael Corn, Nick Carmean, and Mike Corn

Temperature Control Challenges for Aerobic Biological Treatment of High Strength Wastewater
Charles J. Robinson

WATER FOR AGRICULTURE I
10:30 a.m. – 12:00 p.m.

Water for Agriculture: How Will Climate Change Affect Tennessee?
Forbes Walker

Assessing Water Availability in the Hiwassee River Basin Using a Hydrologic Bucket
Thanos Papanicolaou, et al.

Investigating the Performance of One- and Two-Dimensional Flood Models in a Channelized River Network: A Case Study of Obion River System
Tigstu Tsige Dullo, Alfred Kalyanapu, and Shawn A. Hawkins

WATER FOR AGRICULTURE II
1:30 p.m. – 3:00 p.m.

Analysis of Groundwater Availability for Agricultural Sustainability in Select Watersheds in Western Tennessee
Brian Waldron

Estimating an Economic Value of Water in Tennessee
C. Clark

More Floods and Droughts: University of Tennessee Extension Approaches to Adapting to Climate Change in Tennessee
Forbes Walker

WATER FOR AGRICULTURE III
3:30 p.m. – 5:00 p.m.

Educational Enhancements at UT Martin Associated with the Joint Water for Agriculture Project
Paula M. Gale and Gregory H. Nail

Educational Curriculum for Youth-Water Quality and Quantity
Lena Beth Reynolds

An Assessment of the Effectiveness of Winter Wheat Cover Crops for Nutrient Load Reduction in the Red and Obion River Watersheds
S. Hawkins

TOTAL DISSOLVED SOLIDS TOXICITY – THE SCIENCE, CHALLENGES, AND FULL SCALE

Scott Hall[1] and Richard Lockwood[1]

With the exception of chloride, the "major ions" that primarily contribute to the specific conductance (conductivity) and total dissolved solids (TDS) content of water have been largely unregulated with regards to protection of aquatic life. Some state regulatory agencies have general use TDS standards for water (i.e., for industrial use or drinking water), but chloride is the only major ion for which federal aquatic life criteria are available. The progressing science on factors dictating TDS and major ion toxicity has indicated that individual ion toxicity is often a function of the concentrations of other major ions, and in many cases increased water hardness or better balanced ionic solutions decrease the toxicity of such ions. Some states such as Illinois and Iowa have aquatic life standards for sulfate and chloride, respectively, that are hardness-dependent. These standards are also a function of the associated chloride concentration (in the case of sulfate) or sulfate concentration (in the case of chloride). The United States Environmental Protection Agency (USEPA) is re-deriving chloride aquatic life criteria that may also be hardness-based. Many state regulatory agencies address aquatic life protection for major ions and TDS through whole effluent toxicity (WET) limits. Because of the relatively low toxicity of major ions relative to many constituents, their low acute to chronic ratio and lack of bioaccumulative potential, increased dispersion via engineered diffusers is often used to protect aquatic life.

Waste water treatment has become increasingly efficient for many constituents due to technological improvements. However, TDS removal is difficult and expensive, and a recent emphasis on water conservation has increased TDS concentrations and WET in some discharges. This is less common in the south eastern U.S. where water conservation has not been a critical issue due to the wide availability of economically obtainable water, but corporate policies driving water conservation are increasingly putting and emphasis on re-visiting this topic. In areas of reduced rainfall or at times of drought, TDS concentrations of shallow groundwater basins and surface waters can become elevated. This is particularly a concern if relatively toxic ions such as potassium or bicarbonate predominate in the effluent discharge.

An array of regulatory and technological solutions are available to protect aquatic ecosystems from the effects of elevated TDS. As will be discussed and illustrated during this presentation, cost-effective solutions generally require a multi-disciplinary approach and one or more of the following approaches or technologies:

- Enhanced effluent dispersion via multi-port diffusers. Due to the conservative nature of TDS and the well-established dispersion models (e.g., CORMIX) used in regulatory programs, dispersion estimates can be accurately modelled and field-documented.

[1] Ramboll Environ, Brentwood, Tennessee

- Salinity Toxicity Relationship (STR) modelling is also useful in conjunction with dispersion modeling to insure protection of aquatic life.

- Flow augmentation

- Ion balancing to reduce toxicity (e.g., increased hardness)

- Ion exchange

- Reverse osmosis, and advanced nano-technology methods

- Sulfate-reducing bacteria (SRB) reactors

- Lime softening

This presentation will also overview the TDS and conductivity sensitivity and toxic ranges of various TDS mixtures to *Ceriodaphnia dubia*, *Daphnia magna*, and the fathead minnow.

INTEGRATING SITE SPECIFIC BIOASSESSMENT DATA INTO FUTURE PERMITS AS CONTROLLING CRITERIA

Darren Gore[1], John Strickland[1], Steve Tate[1], Mike Bernard[2], Kenny Diehl[2], John Michael Corn[3], Nick Carmean[3] and Mike Corn[3]

INTRODUCTION

Urban and suburban areas are currently expanding at a rate that has outpaced the capacity of the current infrastructure of many cities. The City of Murfreesboro, Tennessee is currently experiencing these issues as the current population is expected to double over the next 20 years. The POTW's receiving body, the West Fork Stones River, is listed on the Tennessee Department of Environment and Conservation (TDEC) 303(d) list, which limits its potential assimilative capacity for treated effluents. Biological, water quality and hydrologic studies were conducted over three years to assess the health of the West Fork Stones River in an effort to "ground truth" the reference-stream derived conclusion which led to the 303(d) listing. If the West Fork Stones River is meeting its biological designated uses when the "Tennessee-derived" water quality parameters are greater than the Ecoregion values, then those values are not valid for causation on the 303(d) list. The project team conducted a full assessment of macrobenthos, fisheries, algae (including speciation and total chlorophylls and accessory pigments), and water quality parameters, including ammonia, nitrite+-nitrate, TKN, total phosphorus, alkalinity, total suspended solids, orthophosphates and silica. Additionally, habitat assessments and comparison with other streams in the ecoregion that meet the TDEC ecoregion guidance for comparison were used. Additionally, all data collected were used in this analysis.

APPROACH

In order to assess the TDEC 303(d) listing of this segment, as well as, the impact of the POTW on the receiving waterbody, a study was designed to incorporate benthic macroinvertebrate assessments as a good indicator of stream health. Seven locations along the receiving body were selected as sampling locations and were sampled in two consecutive years. Two of these locations were selected upstream from the outfall location and five downstream from the outfall. Locations in the second year were altered slightly to focus on the particular segment in question where TDEC had listed as impaired. Sampling was conducted using the field collection techniques for semi-quantitative single habitats samples as outlined in the State of Tennessee SOP for macroinvertebrate stream surveys. This SOP generally follows the USEPA SOP for Rapid Bioassessment. Once samples had been collected and identified, the Tennessee Macroinvertebrate Index (TMI) was used as the scoring metric for the communities. Coupled

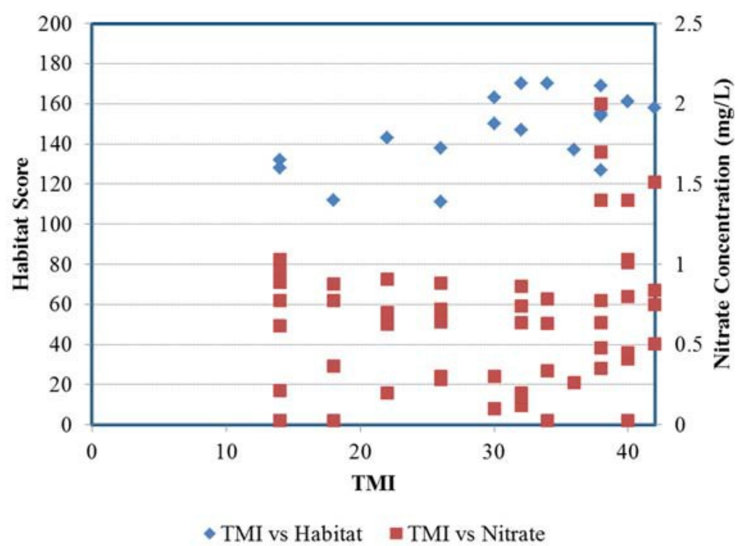
[1] City of Murfreesboro
[2] Smith Seckman Reid, Inc.
[3] AquAeTer, Inc.

with the water quality and discharge measurements, the macroinvertebrates were used to analyze the biological health of the stream. The TMI scores were also compared to the water quality parameters to see if any effects could be determined, as well as, other biological indicators, such as, fisheries and algae/chlorophyll and pigments, suitable habitat, and hydrologic conditions during the surveys, as well as, during past surveys.

RESULTS AND DISCUSSION

Once field work was completed and analyses conducted, the results for sites along the West Fork Stones River were used to assess the true health of the biological communities within the river. Using the water-quality results, it was determined that the segment of the stream immediately downstream from the POTW had a slightly higher nitrate+nitrite nitrogen concentrations than the segment upstream from the POTW. Nitrate+nitrite nitrogen concentrations had been specified by TDEC to be the cause of the original impairment. Both levels were still below the EPA standards for drinking water. The West Fork Stones River segment "2000," which is immediately downstream from the POTW, is currently listed on the 303(d) list as impaired for nitrates. This impairment was implemented due to what was conceived as a diminished aquatic macroinvertebrate community; however, our data show that there is no correlation between TMI and nitrate levels. We have determined that TMI is more aptly correlated to habitat and that the habitat assessment scores should be the first thing to determine whether it is even appropriate to use macrobenthos in some reaches to determine impairment, as shown in Figure 1. In addition, data show that there is no impact to downstream aquatic communities. For two consecutive years, the locations sampled downstream from the discharge point achieved TMI scores equal to, or better than all samples taken upstream. In particular, the sites downstream from the POTW outfall achieved a TMI score of 38, 40 and 42, out of a possible 42. In this ecoregion, the reference-stream-derived guidance threshold for an impaired stream is a score of 32. Therefore, this is confirmation that nitrogen at these low concentrations is not the decisive factor in a stream's biological health, except for the fact it is an essential nutrient for overall biological health.

Figure 1. Nitrate Levels and Habitat Scores Compared to TMI Scores.



In addition to the macroinvertebrate collection and grab samples for water quality, a set of time-series BOD analyses were conducted on locations upstream and downstream from the POTW, as well as, on the effluent collected from the compliance point at the POTW. This analysis showed that there is no significant difference in oxygen demand between the effluent sample and the upstream samples collected within the West Fork Stones River. These analyses also demonstrated that approximately 50% of the organic nitrogen was recalcitrant and would not be converted into ammonia. The nitrogen which remains in the system will likely be used by algae within the river, and serve as an important base of the food chain (i.e., algae to support fisheries). For a healthy aquatic community to thrive, nitrogen is needed at concentrations that will maintain the aquatic food web. The complete removal of nitrogen and phosphorus from a waterway would result in the collapse of the food web, starting with algae and then working its way through the rest of the aquatic environment.

Many factors can affect a macroinvertebrate community, especially discharge and non-point source pollution caused by surface runoff. The time in which a sample is collected is very important. A spike in flow may change a community in an instant, and in order to truly determine if a community is stabilized, macroinvertebrates should be sampled multiple times in a given year or at times when destabilizing natural events could have impacted the sites. While this approach may not be feasible for a government agency to complete, POTWs and other permitted dischargers would potentially be able to provide this information as an indication that biological communities either are, or are not, being impacted. It is also important to recognize that habitat is an essential part of a healthy macrobenthos population and this cannot be ignored.

By incorporating ongoing biological assessments and associated biological criteria in a discharge permit, the true impact of point source discharges can be monitored directly. This approach of using real world data, rather than reference-derived limits, could allow for needed POTW expansion while maintaining water quality standards.

TEMPERTURE CONTROL CHALLENGES FOR AEROBIC BIOLOGICAL TREATMENT OF HIGH STRENGTH WASTEWATER

Charles J. Robinson[1]

Aerobic biological treatment of high strength wastewater presents unique problems for treatment system designers, such as the heat generated by the biological degradation of the wastewater. Aerobic biodegradation of chemical oxygen demand (COD) generates approximately 3,000 calories of heat per pound of COD while ammonia-nitrogen (NH_3-N) biodegradation generates approximately 6,000 calories of heat per pound of NH_3-N. As a result, high strength wastewaters can generate considerable amounts of heat that needs to be managed. Depending on levels of COD and NH_3-N, aerobic bioreactors may be designed for either the mesophilic or thermophilic temperature range. In order to provide effective treatment, a temperature control strategy is required.

The temperature control strategies considered included direct and indirect cooling methods and were evaluated using a predictive model developed by Y. Argaman and C. E. Adams, Jr.[2] The model simulated and compared direct cooling methods like cooling towers, chillers, and convection cooling using surface aerators and indirect methods including cooling towers and chillers in conjunction with shell and tube, plate and frame, and spiral heat exchangers.

This paper focuses on the challenges associated with temperature control strategies and how they were overcome for a landfill leachate pretreatment plant treating 250,000 gallons per day (gpd) of high total dissolved solids (TDS) wastewater containing a high chloride and sulfate concentration.

There were a number of constraints associated with applying either direct or indirect temperature control for the treatment plant in this study. The high chloride content (3,000-5,000 mg/l) dictated that all wetted parts use austenitic stainless steel (duplex, SMO-254 or super duplex). The sulfite (30,000 mg/l) and calcium (6,000 mg/L) concentrations raised concerns about calcium sulfate fouling which would result in reduced wastewater flow, lower heat transfer efficiency, and increased cleaning costs. Air pollution issues in the surrounding community resulted in the elimination of some control strategies.

The selected operating temperature control strategy for the pretreatment plant included maintaining a mesophilic temperature range through the use of indirect cooling by recirculating potable water cooled in a forced air cooling tower and heat exchangers.

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[1] P.E., BCEE, Civil & Environmental Consultants, Inc., 325 Seaboard Lane, Suite 170, Franklin, TN 37067

[2] "Comprehensive Temperature Model for Aerated Biological Systems," Y. Argaman and C. E. Adams, Jr., Progressive Water Technology, Vol. 9, pp. 397-409, Pergamon Press, 1977

WATER FOR AGRICULTURE: HOW WILL CLIMATE CHANGE AFFECT TENNESSEE?

Forbes Walker[1]

More droughts and more flooding are some of the anticipated impacts that climate change will have in Tennessee. It is important to develop tools and models that can help us predict how these effects might impact Tennessee agriculture and the agricultural economy. Farmers and landowners will have to develop strategies to adapt to these predicted changes that may include changes to cropping and livestock systems. It is also important that we educate our current and future workforce to deal with the opportunities and challenges that climate change in Tennessee will result in. The University of Tennessee in collaboration with Tennessee Technological University, University of Memphis, Middle Tennessee State University and the University of Tennessee at Martin was recently awarded a USDA NIFA grant to study the effects that climate change may have on agricultural production in the Tennessee and Cumberland River Basins in the coming decades. This is a multi-year, multi-disciplinary, integrated research, extension and education project. This presentation will summarize the overall objectives of the project: 1) How will changes in climate (temperature, droughts, flooding), land use and industrial and consumer demand affect the quantity, quality, and availability of water for agricultural use in Tennessee?; 2) How can agriculture in the Tennessee and Cumberland River Basins adapt to these changes?; and 3) What policy, institutional, or technological changes will help ensure that water is available to meet needs in Tennessee?

[1] University of Tennessee

ASSESSING WATER AVAILABILITY IN THE HIWASSEE RIVER BASIN USING A HYDROLOGIC BUDGET

Thanos Papanicolaou[1] et al.

The water budget of an agroecosystem not only drives crop and microbial dynamics, but also maintains soil biogeochemical parameters that dictate the system's productivity and sustainability. However, frequent shifts between extensive flooding and deep droughts, coupled with competing demands from encroaching urban areas into formerly agricultural landscapes make it difficult to maintain an optimal balance of the hydrologic stores and fluxes.

As part of a statewide, multi-institutional, water availability study, we are developing hydrologic budgets for five major watersheds in Tennessee. We are using a modeling framework complemented with historical streamflow measurements from the U.S. Geological Survey and Tennessee Valley Authority, as well as new sensors installed in the watersheds. The framework incorporates the Variable Infiltration Capacity hydrologic model to partition precipitation between infiltration, runoff, and evapotranspiration fluxes, which is then coupled with the HEC-RAS hydraulic model for routing the resultant streamflow.

Herein, we present on-going analyses and challenges for one of the watersheds, the 5250-km^2 Hiwassee River basin in southeast Tennessee. Dominant land-uses in the watershed consist of forests and grasslands for cattle and dairy farms, with some row crop and urban areas present. The biggest challenge to quantifying accurately the hydrologic budget is that one-third of the watershed is underlain with Karst geology, which affects surface-subsurface flow partitioning. However, preliminary model calibration/ validation results for monthly streamflows suggest good agreement with the observed data producing Nash-Sutcliff efficiency values between 0.75-0.85. Future work includes simulating alternative practices appropriate for the watershed to better equip it for handling climate extremes.

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INVESTIGATING THE PERFORMANCE OF ONE- AND TWO-DIMENSIONAL FLOOD MODELS IN A CHANNELIZED RIVER NETWORK: A CASE STUDY OF OBION RIVER SYSTEM

Tigstu Tsige Dullo*, Alfred Kalyanapu, and Shawn A. Hawkins

INTRODUCTION

Obion River, is located in the northwestern Tennessee region, and discharges into the Mississippi River. In the past, the river system was largely channelized for agricultural purposes that resulted in increased erosion and downstream flood risks (Shankman and Samson, 1991). These impacts are now being slowly reversed mainly due to wetland restoration. The river system is characterized by a large network of “loops” around the main channels that hold water either from excess flows or due to flow diversions. In some segments along the river, the natural channel has been altered and rerouted by the farmers for their irrigation purposes. Satellite imagery can aid in identifying these features, but its spatial coverage is temporally sparse. All the alterations that have been done to the watershed make it difficult to develop hydraulic models, which could predict flooding and droughts. This is especially true when building one-dimensional (1D) hydraulic models compared to two-dimensional (2D) models, as the former cannot adequately simulate lateral flows and water surface values in the floodplain and in complex terrains (Merwade et al., 2008). The objective of this study therefore is to investigate the performance of 1D and 2D flood models in this complex river system, evaluate the limitations of 1D models and highlight the advantages of 2D models. The study presents the application of HEC-RAS and HEC-2D models developed by the Hydrologic Engineering Center (HEC), a division of the US Army Corps of Engineers (USACE). The broader impacts of this study is the development of best practices for developing flood models in channelized river systems and in agricultural watersheds.

APPROACH

The HEC-RAS and HEC-2D models for the Obion River Watershed was developed for the northern and southern part of the Obion and Deer rivers. Major rivers and tributaries with observed data sets were included in the modeling. HEC-GeoRAS software was used for pre- and post-processing of GIS data and HEC-RAS results while preparing the flood inundation mapping. The three major steps in this study included model preparation, model comparison and performance analysis. During the model preparation step, input flow and/or stage values were obtained from the U.S. Geological Survey (USGS) and USACE, Memphis District gage stations. We were able to get four active gage stations from USGS inside Obion River Watershed. While, the remaining sixteen active gage stations were obtained from USACE, Memphis district. We used 1m Light Detection and Ranging (LiDAR) Digital Elevation model (DEM) values to represent the bare earth elevation values for the entire study area. Spatially distributed Manning’s roughness coefficients were estimated based on the land use and land cover data sets. The HEC-RAS 4.10 and the beta version of the HEC-2D models were used to perform the 1D- and 2D-simulations, respectively. Finally, model to model comparisons were done for water surface elevation and maximum flood inundation extent results.

RESULTS AND DISCUSSION

The WSE comparisons, from the preliminary results, were performed for two sections (one in North Fork Obion River and the other in Obion River). The results from the comparisons showed good agreement for the peak stage values in both sections. However, for both sections, the results from the HEC-2D model showed lag in the hydrographs time to peak. Flood inundation extent comparison for the entire study area revealed a slight under estimation from the HEC-RAS when compared to the HEC-2D model. Similarly, the flood map results at a selected river bend showed a good agreement with a slight underestimation by HEC-RAS model. Though further detailed investigations are required, both HEC-RAS and HEC-2D model preliminary results revealed similar performance. In the remaining period, first we will correct the thalweg values for the entire river basin. Then, we will calibrate and validate the model using observed data sets. Finally, we will repeat the model comparisons for the entire study area using improved results. The final model set up will be integrated with VIC model from University of Tennessee, Knoxville (UT) at subwatershed scale for further analysis.

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Shankman, D., and Samson, S. A., 1991, Channelization effects on Obion River Flooding, Western Tennessee: Water Resource Bulletin, American Water Resources Association, 2(2), 247-254.

ANALYSIS OF GROUNDWATER AVAILABILITY FOR AGRICULTURAL SUSTAINABILITY IN SELECT WATERSHEDS IN WESTERN TENNESSEE

Brian Waldron[1]

Through a USDA NIFA grant, the University of Memphis, as part of a larger effort with other Tennessee universities and with the University of Tennessee at Knoxville as lead institution, is conducting a groundwater analysis of water usage and availability to support agricultural practices in Tennessee. Water resource quality and availability continues to be exceedingly important as we anticipate increases in water use. We can be proactive to anticipated events by creating models to reflect potential future conditions and institute sustainability initiatives.

In areas such as West Tennessee, groundwater is a large contributor to ever growing agricultural needs, driven by a recent boom in row crops and the use of center-pivot irrigation.

Using a regional, multi-state groundwater model establish by Clark and Hart in 2009 as a guide, it is possible to construct a local groundwater model for the watersheds of interest: the North Fork and South Fork Obion River watersheds. By using the geologic layering structure from Clark and Hart's (2009) model to define the aquifer and aquitard boundaries, a finite-difference groundwater model was created using Aquaveo's Groundwater Modeling System (GMS) and MODLOW modeling tool. Topography has been added as an upper boundary in an attempt to model the shallow aquifer, a source for some agricultural irrigation waters. After incorporating the climatic and shallow water models from the other academic partnering institutions, the model will aim to evaluate local groundwater availability and conditions through 2050 for increasing agricultural demands.

[1] CAESER, University of Memphis

ESTIMATING AN ECONOMIC VALUE OF WATER IN TENNESSEE

C. Clark

The effects of climate change on water availability could impact many economic sectors in the southeast, perhaps none more than agriculture. The regional sustainability of agriculture will depend on individual and community adaptation to changes in water availability and the duration and intensity of extreme weather events. Cost-effectively adapting to these changes will require a better understanding of what climate change has in store for the water resources on which our communities depend; which production practices might increase the resiliency of an agricultural sector under climate stress; and what factors influence our willingness to invest the time and resources needed to adapt current production practices in anticipation of an uncertain future. Our research focuses on determining the economic value of water for agriculture, and more generally for the economic sectors important to the regional economies of the southeastern US. We utilize estimates of water availability generated by peer researchers using predictive water balance models and develop an understanding of water use and demand using three sources of data: a) primary and secondary farm-level data, b) regional economic-sectoral data, and c) cost-of-production data for crops commonly produced in the region. We derive so-called “shadow prices” of water by adjusting the hydrological output with the marginal productivity value of farm and non-farm activities. Findings should provide a framework for developing an assessment of our economies’ water footprint, and potential options for stakeholders and policy makers in the medium to long run.

MORE FLOODS AND DROUGHTS: UNIVERSITY OF TENNESSEE EXTENSION APPROACHES TO ADAPTING TO CLIMATE CHANGE IN TENNESSEE

Forbes Walker, University of Tennessee

It is anticipated that Tennessee will experience more floods and more droughts in the future. This will affect agriculture in the state in different ways. University of Tennessee (UT) Extension personnel are working closely with landowners and producers to provide practical and cost-effective strategies for managing and coping with changes in climate patterns especially during periods of rainfall deficient and droughts. This presentation will summarize the on-going applied research and extension efforts of UT Extension to provide livestock with adequate forages during the summer months, as well as extend the grazing season and improve irrigation efficiency for row-crop and nursery crop agriculture. This work is in part supported by a USDA NIFA Water for Agriculture grant awarded to the University of Tennessee in collaboration with Tennessee Technological University, University of Memphis, Middle Tennessee State University and the University of Tennessee at Martin to study the effects that climate change may have on agricultural production in the Tennessee and Cumberland River Basins in the coming decades.

EDUCATIONAL ENHANCEMENTS AT UT MARTIN ASSOCIATED WITH THE JOINT WATER FOR AGRICULTURE PROJECT

Paula M. Gale[1] and Gregory H. Nail[1]

As part of the Water for Agriculture project "Increasing the Resilience of Agriculture Production in the Tennessee and Cumberland River Basins through more Efficient Water Resource Use" the University of Tennessee at Martin is developing new and improving existing courses in agriculture and engineering. Students in courses such as soil and water conservation and environmental regulation have enhanced opportunities outside of the classroom through field work and site visits. In engineering a new course is being developed in Computational Hydraulic and Computational Hydrologic Modeling. We will discuss how these project enhance the student experience.

[1] University of Tennessee at Martin

EDUCATIONAL CURRICULUM FOR YOUTH – WATER QUALITY AND QUANTITY

Lena Beth Reynolds[1]

A component of the USDA NIFA grant, is to develop educational materials to be used with the Extension youth audience, which is 4-H. The goal is for this to become a TN 4-H Project. These materials are to be age appropriate, by level, for fifth grade through high school.

Initial efforts were to study youth water curriculum currently available across the US. Many books, websites, videos, demonstrations, and activities were found. However, most of these were designed for "youth" and were not divided into grade level, as TN 4-H is organized.

McMinn County 4-H has piloted curriculum materials from various sources during the 2015 – 2016 school year, in three groups of teenagers. They studied topography, watersheds, maps, area streams, land use, water use, contaminants, filtering, and role-played a situation as a Water Manager who takes input from various stakeholders and makes a decision. In April 2016, 4-H Honor Club members who have been involved all year, have completed assignments, and pay a fee, will travel to the Georgia 4-H Camp on Tybee Island, near Savannah, GA for a 4 day/3 night study of water at the ocean. Students unable to travel, were invited to The Lost Sea Adventure Wild Tour.

The pilot program used pre-test, post-test, and survey of students with measured responses and open-end questions to gain insight into the success of this series of lessons and activities.

[1] UT Extension

AN ASSESSMENT OF THE EFFECTIVENESS OF WINTER WHEAT COVER CROPS FOR NUTRIENT LOAD REDUCTION IN THE RED AND OBION RIVER WATERSHEDS

S. Hawkins

Water quality models have been developed to evaluate the nutrient load reduction effectiveness of winter wheat cover crops in the Red River and South Fork of the Obion River watersheds. The Soil and Water Assessment Tool, a physically based, watershed-scale, continuous time simulation model was used to comprehensively link hydrology and nutrient cycling with crop growth in these agricultural watersheds. Model inputs included DEM data, the Croplands Data Layer, and the STATSGO soils database. Rainfall inputs were from a new Next Generation Radar database developed for Tennessee. Flow data for calibration were from the Port Royal and Greenfield USGS stations. Crop management schedules (planting, fertilizer applications, harvesting) were established in consultation with corn and soybean producers. Field management parameters (USLE_P, USLE_C, and OV_N) were changed to reflect the adoption of contour and no-till planting without the use of a cover crop. The models were flow calibrated using the Sequential Uncertainty Fitting program following 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 reductions 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.

SESSION 2B

ACID ROCK DRAINAGE INVESTIGATION I
8:30 a.m. – 10:00 a.m.

Potentially Acid Producing Rock (APR) on TDOT Highway Construction Projects
Jeff Hoilman and Jim Ozment

Acid-Rock Drainage from Seeps and Springs at Road Cuts in Middle and East Tennessee
Michael Bradley, Scott Worland, and Tom Byl

Characterization of Runoff Water Quality from Highway Cut Slopes Through Pyrite Geology
John S. Schwartz, Cory Julien, Qiang He, and Angel Palomino

ACID ROCK DRAINAGE INVESTIGATION II
10:30 a.m. – 12:00 p.m.

Attenuation of Acid Rock Drainage with a Sequential Injection of Compounds to Reverse Biologically Mediated Pyrite Oxidation
Thomas D. Byl, Ronald Oniszczak, Diarra Fall, Petra K. Byl, and Michael Bradley

Streamside Salamanders as Indicators of Environmental Stress: Impacts of Acid Rock Drainage on Headwater Stream Integrity
Brittaney Hogan, Calandrea Williams, Tom Byl, De'Etra Young, and William Sutton

ENVIRONMENTAL MICROBIOLOGY I
1:30 p.m. – 3:00 p.m.

Potential Utility of Microbiome Analysis in Microbial Source Tracking
Kristen Wyckoff, Si Chen, Andrew Steinman, and Qiang He

Impact of Process Configuration on Nitrifying Populations in Wastewater Treatment
Si Chen and Qiang He

An Investigation of Microbial Communities in Wastewater Treatment Facilities Undergoing Optimization for Nutrient Removal
Grace McClellan, Rachel Stewart, Tania Datta, and Kevin Young

ENVIRONMENTAL MICROBIOLOGY II
3:30 p.m. – 5:00 p.m.

The Potential of Using Wastewater for Algal Biofuel Production
Teresa Mathews and Shovon Mandal

A Review of Bioremediation in Karst Aquifers
Thomas Byl and Roger Painter

Microbial Interactions in Methanogenic Treatment Processes
Qiang He and Si Chen

POTENTIALLY ACID PRODUCING ROCK (APR) ON TDOT HIGHWAY CONSTRUCTION PROJECTS

Jeff Hoilman[1] and Jim Ozment[2]

The Tennessee Department of Transportation (TDOT) has on certain projects been involved in the, detection, testing, and mitigation of rock materials containing minerals that, under certain conditions, are capable of producing acidic runoff known as acid rock drainage (ARD). Regulatory issues associated with ARD include water quality impacts (e.g. lower pH, elevated metals), surface or groundwater impacts, cave impacts, and public concern. As such TDOT understands that early identification of acid producing rock (APR) materials is a must and that the responsibility is shared across all TDOT Divisions for the proper management of the APR materials. Additionally, TDOT understands from an economic standpoint there is a cost associated with the disposal of APR materials and long term management of ARD. From a public view, there is also a cost of "Loss of Credibility" for not doing the right thing to protect the natural environment. Therefore guidelines, policies and protocols including the TDOT Construction Division Special Provision 107L (policy) and a "*Guideline for Acid Producing Rock Investigation, Testing, Monitoring, and Mitigation*" have been established to deal with the challenges of encountering APR which can lead to ARD. These documents have been written to provide consistent guiding principles that are to be applied to TDOT projects for investigation, prevention, and mitigation of potential ARD and have been produced in cooperation with the Tennessee Department of Environment and Conservation (TDEC). The initial primary focus of these documents was ARD prevention and disposal but recent in recent years is now including a secondary focus of ARD monitoring and treatment. Adaptive Management Plans (AMP) have also been created on certain construction projects that contain APR materials in response to regulatory concerns. The objectives of an AMP include:

- Identify potential localized water quality impacts due to APR exposure and runoff caused by the roadway construction.
- Establish a process to address unanticipated adverse local water quality impacts.
- Keep TDOT Construction, the prime contractor, and TDEC informed of impacts attributed to the roadway construction.

This presentation provides an overview on TDOT's guidance and project examples on APR including:

- Project Screening and Site Assessment
- Sampling and Testing
- Triggers and Thresholds
- Disposal and Mitigation Options
- Adaptive Management Plan for Monitoring

[1] PE, CPESC, Arcadis U.S., Inc., Chattanooga, TN
[2] TDOT Environmental Division Director, Nashville, TN

REFERENCES

Tennessee Department of Transportation Construction Division Special Provision 107L, March 2006

Guideline for Acid Producing Rock Investigation, Testing, Monitoring, and Mitigation, Golder Associates, Inc., October 2007

Tennessee Department of Transportation Adaptive Management Plan and APR Water Quality Monitoring Plan for SR-29 (US-27) From SR-61 Near Harriman in Roane County to South of Whetstone Road in Morgan County; PIN 101411.04; Project No. 65001-3266-14, 73008-3243-14, Arcadis U.S., Inc. June 2014

ACID-ROCK DRAINAGE FROM SEEPS AND SPRINGS AT ROAD CUTS IN MIDDLE AND EAST TENNESSEE

Michael Bradley[1]*, Scott Worland[1], and Tom Byl[1]

Pyrite and other minerals containing sulfur and trace metals are present in several rock formations throughout Middle and East Tennessee. When pyrite-bearing formations are exposed in a road cut or waste pile, there is the potential for acidic runoff containing elevated levels of iron and other metals as the minerals decomposition due to exposure to oxygen and water. The basic modes of acid-rock drainage (ARD) from road cuts are:

1. Seeps and springs from pyrite-bearing formations and
2. Runoff over the face of a road cut in a pyrite-bearing formation.

The U.S Geological Survey, in cooperation with the Tennessee Department of Transportation, is conducting an investigation to better understand the geologic, hydrologic, and biogeochemical controls for acid-rock drainage from seeps and springs at road projects. Acid-rock drainage from seeps and springs at road cuts represents a potential long-term source of acidity and metals to nearby streams. Pyrite-bearing formations in Middle and East Tennessee include the Chattanooga Shale, the Fentress Formation, and the Anakeesta Formation and similar Precambrian rocks.

Six sites were selected in Middle and East Tennessee (figure 1) where the pyrite-bearing formations are exposed in road cuts. The road cuts included in the investigation are located in Hickman and Williamson Counties (Chattanooga Shale), Fentress County (coal-bearing Fentress Formation), Polk and Monroe Counties (Anakeesta Formation), and Unicoi County (Mt. Rogers Group). Water samples from springs and seeps and rock samples were collected during 2014 and 2015 to determine water quality and rock composition. Elevated trace metal concentrations occurred in water from seeps issuing from the pyrite-bearing formations and also due to runoff over exposed secondary sulfide minerals.

The weathering and interaction of the acid on the rocks and other minerals at road cuts can result in drainage with low pH and high concentrations of trace metals. Most of the sites had seeps or springs issuing from the formation or near the base of the road cut. The Hickman County site has seeps that issue from the Chattanooga Shale and also has extensive deposits of secondary sulfate minerals (SSM) occurring below the Chattanooga Shale. The SSM have the potential to accumulate trace metals during the dry season and “wash-out” or contribute high concentrations of trace metals to surface water during rainfall events.

The pH and selected trace metal concentrations for water samples from the road cuts are summarized in table 1. The pH was measured in the field and the water-quality analysis for the filtered constituent and metals were conducted at the USGS National Water-quality Laboratory.

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Understanding the factors that control ARD formation and transport are key to addressing the problems associated with the movement of ARD from the road cuts to surface water. The investigation will provide the Tennessee Department of Transportation with a regional characterization of ARD and provide insights into the geochemical and biochemical attributes for the control and remediation of ARD from road cuts.

Table 1. Range of pH and selected trace metal concentrations during 2014 – 2015 from seeps and springs at select road projects. [mg/L, milligrams per liter; µg/L, micrograms per liter]

County	Formation	Number of Samples	pH	Dissolved solids, in mg/L	Sulfate in mg/L	Copper, in ug/L	Zinc, in ug/L	Aluminum, in ug/L
Hickman	Secondary sulfate mineral	1	2.6	1,890	1,260	387	1,690	30,500
Williamson	Chattanooga Shale	3	3.3 to 5.2	877 to 1,170	594 to 1,190	14.3 to 114	262 to 1,080	1,160 to 19,800
Monroe	Anakeesta Formation	1	4.6	23	13.6	< 0.8	28.4	90
Unicoi	Mt. Rogers Group	2	5.0 to 7.3	43 to 94	12.2 to 30	3.2 to 7.2	9.6 to 13.9	490 to 1,100
Fentress	Fentress Formation	6	3.1 to 6.9	1,040 to 1,870	712 to 1,150	< 2.4 to 39.7	9.3 to 664	< 20 to 33,500
Polk	Anakeesta Formation	7	2.6 to 3.9	44 to 974	21 to 650	1.4 to 176	39 to 262	250 to 24,300

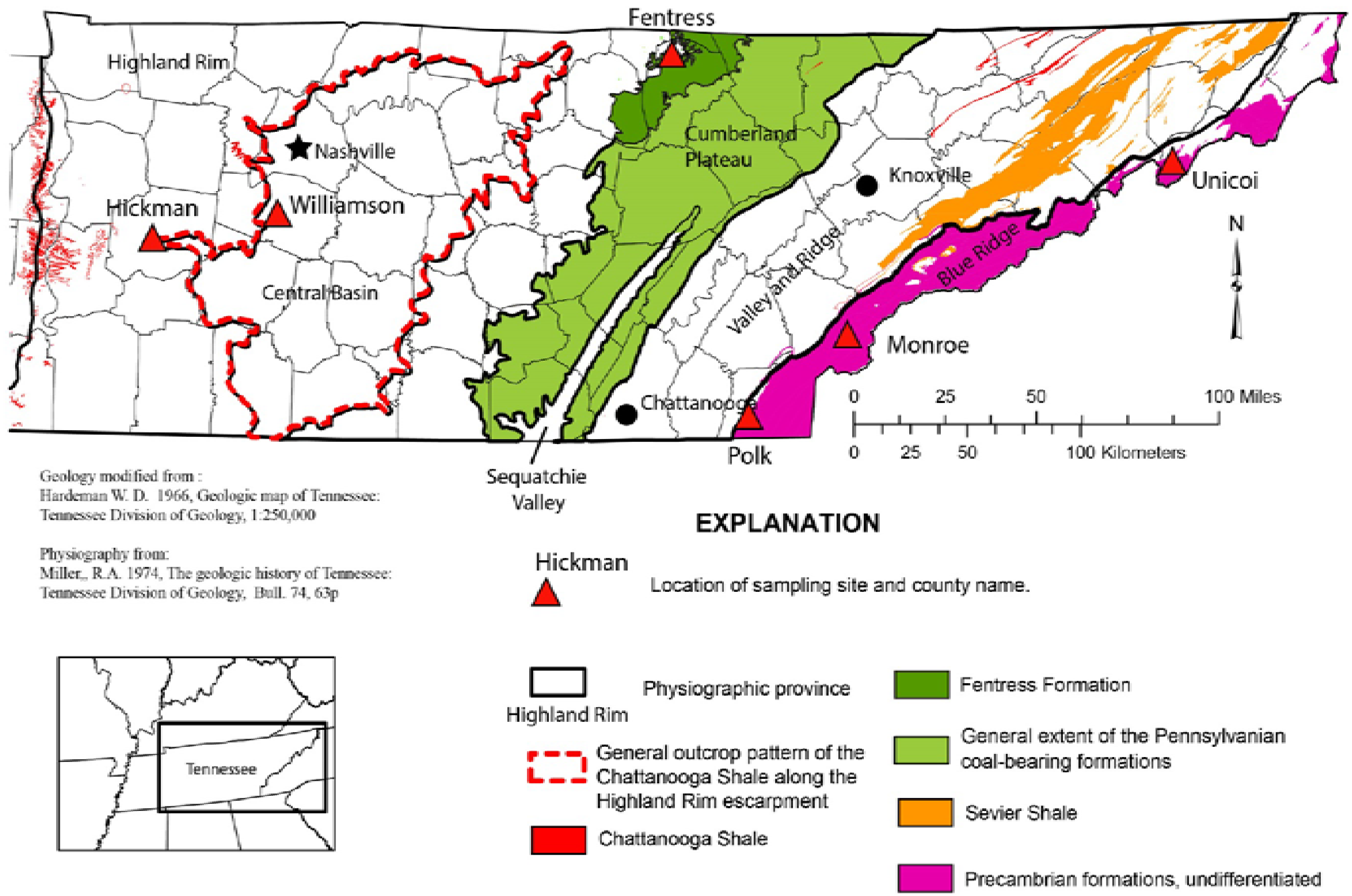

Figure 1. -- Location of sampling sites and pyrite-bearing formations in Tennessee with the potential for acid-rock drainage.

CHARACTERIZATION OF RUNOFF WATER QUALITY FROM HIGHWAY CUT SLOPES THROUGH PYRITE GEOLOGY

John S. Schwartz[1], Cory Julien[1], Qiang He[1], and Angel Palomino[1]

Exposed pyrite geology (acid-producing rock or APR) combined with rainfall (water) generates sulfuric acid and can be transported as runoff. Runoff from these cut slopes may enter nearby streams, in which if acidified can potentially harm aquatic life. TDOT has encountered APR on several projects in the past decade, prompting the preparation of a guidance manual in 2007 for addressing APR at highway projects. TDOT routinely uses these manual design and construction protocols for proper handling of APR spoils from project sites, consisting of removal, disposal, blending, capping, and/or encapsulating APR materials. This approach to environmental mitigation is expensive, thus driving the need to better understand the extent of the environmental problems, and examine alternatives for engineering design, construction, and near-site passive treatment. Although much is known about acid mine drainage, little is known about the water quality generated from road cuts through APR, and what hydrogeological conditions may produce harmful levels of acidic waters containing sulfates and dissolved metals. Many environmental variables potentially can influence water chemistry changes from a road-cut source to a stream, i.e., such a hydrological retention and neutralization from geochemical processes and vegetation. One component of this study characterizes runoff chemistry from exposed road-cuts with APR so that adequate information can be generated for engineering design of passive on-site treatment systems (i.e., wetlands, retention ponds). A second study component based on an experiment design utilizing field-collected pyrite rock and simulated rainfall will be conducted to quantify pollutant yields. Pinson sampling devices were used to collect runoff water from ten sites: Jamestown (3) sites, Nashville (2) sites, Ocoee (3) sites, Grainger site, and Sevierville site. Samples were collected from all four seasons. Preliminary results have found pH ranging from 3.85 to 7.43 among the ten sites. Conductivity widely ranged from 94 to 5,567 μS/cm. Dissolved aluminum ranged from non-detect to 15.7 mg/L. Water quality results vary widely based on site condition and biogeochemical controls on runoff chemistries. The second part of our study quantifies weathering rates of various ions and dissolved metals from the Anakeesta formation.

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ATTENUATION OF ACID ROCK DRAINAGE WITH A SEQUENTIAL INJECTION OF COMPOUNDS TO REVERSE BIOLOGICALLY MEDIATED PYRITE OXIDATION

Thomas D. Byl[1,2], Ronald Oniszczak[2], Diarra Fall[2], Petra K. Byl[3], Michael Bradley[1]

Iron-sulfide minerals such as pyrite found in shale formations are stable under anaerobic conditions. However, in the presence of oxygen and water, acid-loving chemolithotrophic bacteria can transform the iron-sulfide minerals into a toxic solution of sulfuric acid, dissolved iron and other trace metals known as acid rock drainage (ARD). The objective of this study was to disrupt chemolithotrophic bacteria responsible for ARD using chemical treatments and to foster an environment favorable for competing microorganisms to attenuate the biologically-induced ARD. Chemical treatments were injected into flow-through microcosms consisting of 501 grams of pyrite-rich shale pieces inoculated with ARD bacteria. Treatments included a sodium hydroxide-bleach mix, a sodium lactate solution, a sodium lactate-soy infant formula mix--each treatment with or without phosphate buffer, or injected sequentially with sodium hydroxide. The effectiveness of the treatments was assessed by monitoring pH, dissolved iron, and other geochemical properties in the discharge waters. The optimal treatment was a sequential injection of 1.5 grams sodium hydroxide, followed by 0.75 gram lactate and 1.5 grams soy formula dissolved in 20 milliliters of water. The pH of the discharge water rose to 6.0 within 10 days, dissolved iron concentrations dropped below 1 milligram per liter, the median alkalinity increased to 98 milligrams per liter $CaCO_3$, and sulfur-reducing and slime-producing bacteria populations were stimulated and exhibited an increase in the estimated population counts. The ARD attenuating benefits of this treatment were still evident after 33 weeks. Other treatments provided a number of ARD attenuating effects but were tempered by problems such as high phosphate concentrations, short longevity, or other shortcomings.

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STREAMSIDE SALAMANDERS AS INDICATORS OF ENVIRONMENTAL STRESS: IMPACTS OF ACID-ROCK DRAINAGE ON HEADWATER STREAM INTEGRITY

Brittaney Hogan[1*], Calandrea Williams[1*], Tom Byl[1], De'Etra Young[1], and William Sutton[1]

Globally, amphibian populations are declining at alarming rates. Multiple factors, including pathogens, environmental pollution, climate change, and habitat destruction play major roles in these declines. Environmental pollution in the form of acid runoff through road construction (i.e., Acid Rock Drainage [ARD), serves as an important, but understudied threat to stream integrity. We completed streamside salamander surveys on two streams (Carter's Creek Tributary and Wolf Creek tributary) impacted by ARD in middle Tennessee (Williamson and Fentress Counties). We monitored streamside habitats upstream and downstream of ARD disturbances via two $1m^2$ quadrats and one 15m X 3m transect at each sampling location. We used a combination of rock turning and dipnet surveys to capture adult and larval salamanders. Collectively, these data can be used as a proxy of stream quality and conservation in the face of rapid urbanization and habitat alteration.

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POTENTIAL UTILITY OF MICROBIOME ANALYSIS IN MICROBIAL SOURCE TRACKING

Kristen Wyckoff[1], Si Chen[1], Andrew Steinman[1], and Qiang He[1]

Accurate identification of the sources of microbial contaminants in stormwater, stream water, and wastewater is of great importance in the development of targeted mitigation strategies to prevent water pollution and to protect public health. Traditional microbial indicator enumeration methods for water quality assessment are incapable of determining the origins of microbial contamination. Molecular techniques targeting particular microbial populations also suffer from limitations of specificity and coverage. Microbiome analysis aided by high-throughput sequencing technology has emerged as a potential tool for microbial source tracking. With the ability to profile the majority of microbial populations in a water sample, microbiome analysis makes targeting multiple microbial populations as potential indicator organisms for source tracking possible. In this study, analyses of microbiomes in stormwater samples, which tested positive for fecal contamination by traditional microbial indicator enumeration, were performed in addition to wastewater samples from sewage treatment facilities. Since wastewater microbiomes are known to contain and represent human fecal contamination, comparisons of the microbiomes between wastewater and stormwater could provide insight into the origins of microbial populations in stormwater runoff. While similar bacterial genera could be found in both stormwater and wastewater, potentially pathogenic organisms including but not limited to *Mycobacterium*, *Legionella*, *Moraxella*, *Actinobacteria*, and *Escherichia* may not all be from fecal sources. Ongoing efforts are further assessing the utility of microbiome analysis for microbial source tracking.

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IMPACT OF PROCESS CONFIGURATION ON NITRIFYING POPULATIONS IN WASTEWATER TREATMENT

Si Chen and Qiang He

Nitrification is an important microbial process in wastewater treatment converting harmful ammonium/ammonia-nitrogen to less harmful nitrate. Various microbial populations have been identified to be involved in nitrification. Optimization of the management and control of nitrification processes requires the systematic understanding of the ecophysiology of individual nitrifying populations, which remains to be elucidated. An important factor that could influence the selection and adaptation of nitrifying microbial populations in wastewater treatment is process configuration, such as the conventional oxidation ditch process and membrane bioreactor configuration. It could be hypothesized that the nitrifying microbial populations might differ considerably given the vastly different solids retention times typically practiced in oxidation ditch vs membrane bioreactors. To eliminate other process parameters that could potentially influence microbial community composition, oxidation ditch and membrane bioreactor process trains located in the same facility treating the same wastewater were selected for this study. The mixed liquor samples from both process configurations were characterized by next-generation sequencing. Our results show that sequences of *Nitrospira* was the most abundant nitrifying population in both oxidation ditch and membrane bioreactor configurations, accounting for 2.2% of the total microbial abundance. The relative abundance of sequences belonging to the phylum *Planctomycetes* reached 5.2% and 7.2% in oxidation ditch and membrane bioreactor process trains, respectively. Since bacterial populations carrying out the Anammox process are known to belong to the phylum *Planctomycetes*, ongoing efforts are investigating the importance of Anammox in nitrogen removal in these treatment processes. The surprising lack of impact of process configuration on the nitrifying microbial populations suggests the robustness of *Nitrospira* in nitrogen removal and potential applications of these nitrifying populations in improving process stability for nitrogen removal.

AN INVESTIGATION OF MICROBIAL COMMUNITIES IN WASTEWATER TREATMENT FACILITIES UNDERGOING OPTIMIZATION FOR NUTRIENT REMOVAL

Grace McClellan[1], Rachel Stewart[2], Tania Datta[3], and Kevin Young[4]

Excess runoff and discharge of nitrogen (N) and phosphorus (P) from wastewater, urban areas, and agricultural farms is a major threat to aquatic ecosystems worldwide (Woodward et al., 2012). Such discharges stimulate the growth of algae and cyanobacteria, causing significant water quality degradation and impacting aquatic biodiversity. The consequences are well documented for the Chesapeake Bay, Mississippi River Delta, Gulf of Mexico and several other watersheds within the United States (Boesch et al., 2001; Alexander et al., 2007). Federal and state regulatory agencies are therefore implementing stringent numeric standards for N and P discharges, especially from point sources, such as wastewater treatment facilities (WWTFs).

Upgrading WWTFs to meet these stringent standards can be cost intensive, especially for smaller municipalities that treat less than 10 million gallons of wastewater per day. This is because, conventionally, N and P removal is accomplished through nitrification, denitrification and enhanced biological phosphorus removal processes. These processes require separate anaerobic, anoxic and aerobic reactors to enable the creation of specific ecological niches for different types of microorganisms to carry out their function. High upgrade and expansion costs often translate to higher user rates, which is one of the primary barriers to widespread implementation of N and P discharge standards. As the protection of water quality is of utmost importance, a balance must be created between economic and environmental benefits through exploration of innovative technologies that can be easily retrofitted within existing WWTFs.

One such possible technology is simultaneous N and P removal that utilizes a single reactor, instead of three, and has much less energy demand compared to the conventional designs. Recently, a few studies have shown that nitrification and denitrification can occur concurrently in one reactor under aerobic conditions with low dissolved oxygen, through the so-called "simultaneous nitrification and denitrification process" (Liu et al., 2010). In addition, it has been found that denitrification can be accomplished by denitrifying polyphosphate accumulating organisms in anaerobic–anoxic systems, allowing simultaneous nitrate/nitrite reduction and P uptake (Zeng et al., 2003). Such studies challenge the traditional school of thought on biological N and P removal and indicate that microorganisms responsible for these processes may be phylogenetically and functionally more diverse than currently understood.

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With this background, the overarching goal of the study is to conduct a preliminary investigation of simultaneous biological N and P removal in full scale anoxic-aerobic systems at two WWTFs by correlating macroscale data (such as wastewater characteristics) to microscale data (such as microbial community structure and function). More specifically, the investigator will (a) study historical wastewater charactistics and operations of two WWTFs (Cookeville and Livingston, TN), operating secondary treatment systems that can easily be converted to anoxic-aerobic systems; (b) evaluate if operational changes, such as altered dissolved oxygen concentration or increase in organics in the anoxic phase can result in improved biological N and P removal; and (c) assess and correlate wastewater characteristics and operational data with results from metagenomics that can monitor shifts in microbial community structure and function.

Preliminary results from this study will be presented at the conference.

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THE POTENTIAL OF USING WASTEWATER FOR ALGAL BIOFUEL PRODUCTION

Teresa Mathews and Shovon Mandal

Algae hold much promise as a viable feedstock for biofuels but there is still much discussion over how to make production more cost effective. High biomass and lipid yields are achievable from algae cultured under controlled laboratory conditions at the bench scale or in incubators. However, cultivation in outdoor pond facilities may be the only cost-effective way to produce algal biomass at the scales needed for the biofuel industry. To date, the algal biofuel industry has focused on selecting for (or genetically modifying) algal strains that have rapid growth rates or high lipid contents in order to maximize lipid yields. While this strategy can be effective at smaller scales and in the short term, shifting production from the laboratory to outdoor ponds raises a number of ecological challenges. Further, scaling up algal biomass production will put increasing demands on our nation's already strained water and nutrient supplies.

While the algal biofuel industry has focused on cultivating monocultural crops, monocultures are exceedingly difficult to maintain in outdoor settings because they are easily contaminated through aerial colonization by wild algal strains, grazers, and pathogens. Ecological theory predicts that increasing the species diversity of algal crops could lead to both higher productivity and crop stability, but laboratory experiments have shown that algal assemblages, or polycultures, do not often outperform the most productive species in the consortium. We hypothesize that heterogeneous environments could provide niche differentiation that could allow strains with different traits to utilize resources more efficiently, increasing the possibility for overyielding. While conventional algal growth media used in laboratory experiments typically contains only nitrate as a source for nitrogen, natural or waste waters may contain heterogeneous mixtures of nitrogen species (i.e. ammonium, nitrate, urea). In the present study, we examined the performance of 13 algal strains from diverse taxonomic groups in a mixed nitrogen environment. Our results demonstrate up to 3-fold differences in growth of a given algal strain under different nutrient conditions. Further, the different strains showed different media preferences, suggesting the possibility for significant overyielding in polycultures. Our results show promising indications that algal polycultures grown in recycled or waste waters could lead to significant cost reductions for the biofuel industry.

A REVIEW OF BIOREMEDIATION IN KARST AQUIFERS

Thomas Byl[1],[2] and Roger Painter[3]

The carbonate aquifers of central Tennessee and Kentucky are vulnerable to dissolved and non-aqueous phase contamination due to contaminant transport through sinkholes, fractures, and other karst features. The complexity of local karst hydrology often prevents the efficient removal of contaminants through the use of traditional pump-and-treat methods. Bioremediation, in some instances, is a viable remediation option, with suitable hydrological, geochemical and microbial site conditions. Bacteria indigenous to Tennessee and Kentucky karst terranes are well adapted to a variety of metabolic capabilities and aquifer conditions. Supplement injections into karst aquifers have been used to stimulate specific bacterial types in the aquifer and foster geochemical conditions which enhance biodegradation or immobilize the contaminants. Tracer studies are essential for characterizing site hydrology and estimating residence times. Sample collection and evaluation of the geochemical conditions and existing bacterial types are critical as part of the site evaluation. Non-traditional groundwater models that incorporate residence time distribution and decay rates are useful tools in the remediation decision-making process.

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MICROBIAL INTERACTIONS IN METHANOGENIC TREATMENT PROCESSES

Qiang He[1] and Si Chen[1]

Methane is a clean fuel that can be generated from renewable sources. Yet methane is also a potent greenhouse gas contributing to climate change. Therefore, effective control of methane production, i.e. methanogenesis, is of great significance. Methanogenic treatment processes such as anaerobic digestion have long been established as a sustainable technology for the treatment of organic waste and production of methane as a renewable energy source. The broader application of this technology requires improvement in process efficiency and stability to further enhance its technical and economic feasibility. Methanogenesis is a predominantly microbial process, which requires interactions between diverse populations of bacteria and archaea. While progress has been made to profiling the microbial community composition in methanogenic processes, it remains a challenge to understand the interactions between microbial populations, which is critical for developing strategies for the control of methanogenic processes. Examples of these interactions will be provided based on interpretations from the linkages between population dynamics and process performance in methanogenic treatment processes.

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SESSION 2C

CASE STUDIES
8:30 a.m. – 10:00 a.m.

Wolf Creek Dam Rehabilitation and Environmental Considerations
Tim Higgs

Mercury Monitoring and Research in Oak Ridge, Tennessee
M. Peterson

Stream Restoration: Myth, Mystery or Fact?
Gary Moody

WATER RESOURCES
10:30 a.m. – 12:00 p.m.

Examination of Algal Assemblages in Rivers of Middle Tennessee: A Project Supported by the Tennessee Healthy Watershed Initiative
Jefferson G. Lebkuecher, Molly R. Grimmett, and Arianna L. Ackerman

Application of the High Definition Stream Survey on Choccolocco and Turkey Creek
Brett Connell

High Definition Stream and Fish Surveys: Integrating Fish Habitat, Channel Geomorphology, Water Quality, Water Quantity, and Infrastructure Surveys
James E. Parham

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

Reclamation of the Lower North Potato Creek Watershed
T. McComb

Conception, Design, and Construction of a Regenerative Stream Restoration in Knoxville, Tennessee
William K. Barry, David McGinley, John Wisinger, and Patrick McMahon

Phase I Restoration of Beaver Creek, Bristol TN/VA
Ingrid Luffman, Gary Barrigar, and Phil Scheuerman

STREAM RESTORATION II
3:30 p.m. – 6:00 p.m.

Hatchery Creek Stream Restoration Project — A Unique Opportunity to Enhance Sport Fishing
Oakes Routt

Nashville Zoo Stormwater Retrofit: Applying Level Spreader and Check Dam Design Principles to Restore Riparian Area and Protect Receiving Stream
Steve Casey

Dam Removal in Tennessee: An Alternate Form of Stream Mitigation Credit?
Adam Spiller

Ecological Effectiveness of Channel Restoration in the Coastal Plains
Jeffrey D. Fore and Thomas Blanchard

WOLF CREEK DAM REHABILITATION AND ENVIRONMENTAL CONSIDERATIONS

Tim Higgs[1]

INTRODUCTION

Recently, Wolf Creek Dam, which forms Lake Cumberland, required extensive upgrades to lower the risk of dam failure. During 2007, Lake Cumberland was lowered to a flat target elevation of 680 feet to reduce the risk of failure while repairs were being made to the dam. With the lower reservoir elevation approximately 10 river miles of the Big South Fork (BSF) of the Cumberland River were allowed to temporarily revert to natural free flowing conditions.

Prior to returning to normal reservoir operations, the U.S. Army Corps of Engineers (Corps) was required to conduct surveys for federally listed aquatic species within areas of the Big South Fork River (BSF) that would be inundated under a return to normal operations. The Corps committed to conduct these surveys during a 2008 EIS addressing the dam rehabilitation. Surveys were conducted in fall of 2013 and the federally endangered duskytail darter (*Etheostoma percnurum*) was observed in 8 of 15 exposed riffle sites. Figure 1 shows typical seasonal pool operations.

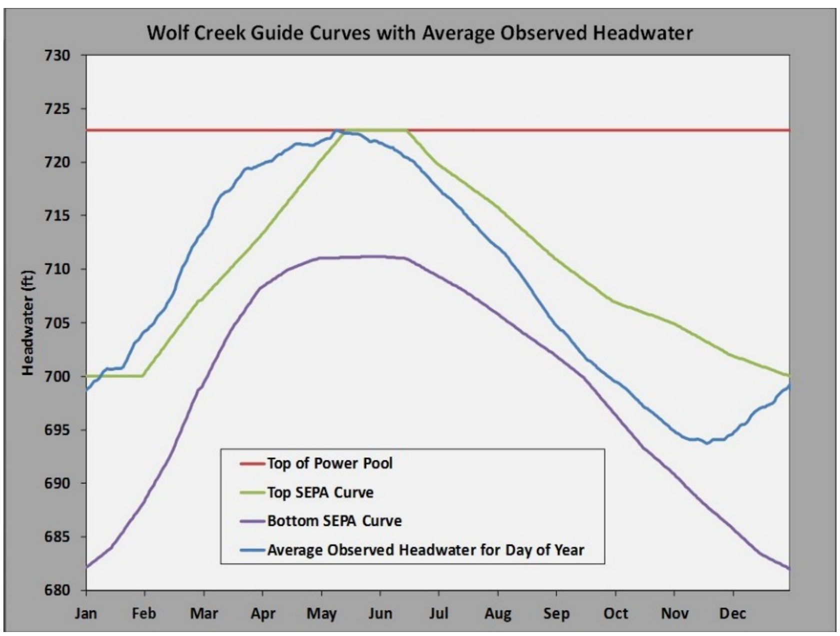

Figure 1 – Guide Curves for Wolf Creek Reservoir Operations and Average Observed Headwater During Historical Operations.

[1] U.S. Army Corps of Engineers, 110 9th Ave South, Room A-405, Nashville, TN 37203, timothy.a.higgs@usace.army.mil

As the dam rehabilitation was nearing completion, surveys were conducted in the Big South Fork of the Cumberland River (BSF) from approximately river mile 45.1 to 34.4 (areas affected by backwater from historical dam operations) in 2013 by TVA, under contract with the Corps. The survey targeted 15 shoals where mussels were likely to be found as mussels were the primary focus of the survey. No listed mussel were found, however, the survey documented the federally endangered duskytail darter (*Etheostoma percnurum*) at sites 1 - 8 of the 15 survey sites.

Once the seepage repairs were completed in late 2013, the Corps proposed to return Wolf Creek to historical operations in 2014 (in reality by the spring filling cycle). With the finding of the endangered fish, a Biological Assessment (BA) was required to be submitted to the U.S. Fish and Wildlife Service (FWS) to address the effects of returning Wolf Creek Dam to historical operations (proposed action) on the duskytail darter. The FWS would respond with a Biological Opinion to provide Endangered Species Act (ESA) compliance prior to a decision to return to historical lake operations. In order to do this in 2014, an extremely short timeline for ESA Consultation would be required.

The duskytail darter is a small fish endemic to the Cumberland and Tennessee River drainages and was listed as an endangered species in 1993. It was known to exist only in the BSF in 13 sites from Station Camp Creek downstream to Blue Heron and just upstream of Station Camp Creek at Rough Shoals. TVA's 2013 survey revealed the occurrence of the duskytail darter at an additional 7 sites in the BSF from Site 2 (Blue Heron BSF mile 44.5) to Site 8 (Yamacraw, KY Highway 92 BSF mile 40.1). The survey found between 1-15 individuals at each of the seven sites in habitat similar to what has previously been described (Simmons and Shaffer 2013).

The timing and duration of the top of Lake Cumberland Reservoir pool has effects on stream mechanics in the BSF action area due to backwater effects from the higher pool elevations. Increases in water depth, duration of those increases, and reduction in stream velocities all influence the amount of sediment deposits in substrate. A detailed analysis was performed for the proposed action in regards to these stream mechanic characteristics. Three basic questions were addressed in the analysis: 1) Where do the impacts occur, 2) What magnitude of impacts occur, and 3) When do impacts occur? The analysis used graphs, of reservoir operation and USGS stream gauge data, termed depth hydrographs (see Figure 3) to answer all three of the questions listed above.

Figure is a depth hydrograph of various summer target pool operations, including historical operations (summer pool target el. 723) and their relationship to natural stream depths estimated from the upstream Stearns Gauge data (Stearns Gauge data is the dark blue line, presented as relative depths) at Site 7. The depth hydrographs show that, if Lake Cumberland is managed at a target summer pool elevation of 723, there would be on average an increase of depth (up to 5 feet) on Site 7 (BSF mile 40.6) for approximately 81 days. Similar graphs for other sites show that the return to historical pool operations would cause no depth changes at Sites 1 – 3 (BSF miles 45.1 – 44.1) and minimal depth increases for Sites 4 – 6 (BSF miles 43.7 – 41.9). To summarize, the depth hydrographs as a whole, demonstrate that the proposed action would have minor to no effects on Sites 1 - 6 and moderate impacts to depths on Sites 7 and 8.

In addition to the physical change of water depth and duration of depth as they relate to duskytail darter habitat, another concern is the possibility of increased sedimentation of darter habitat as a byproduct of these depth and durations of depth changes associated with historical operations.

As stated above, the 2013 TVA survey indicates there is little sediment deposition present in the substrate of the shoal complexes found at sites 1 – 9 (BSF miles 45.1 – 39.1). Also, sediment deposition became noticeable in Site 10 (BSF mile 38.2) and increased steadily in a downstream direction to Site 15 (BSF mile 34.4). Similar observations were made by the Corps in 2008, when sediment deposits were documented in BSF from mile 39.8 (Site 8) through the sites downstream. Based on the similarities of habitat observations in both surveys, it may be deduced that sedimentation of shoal complexes would be a minor effect from the proposed action at Sites 1 – 8 (BSF miles 45.1 – 40.1). Sediment deposition would likely increase due to the

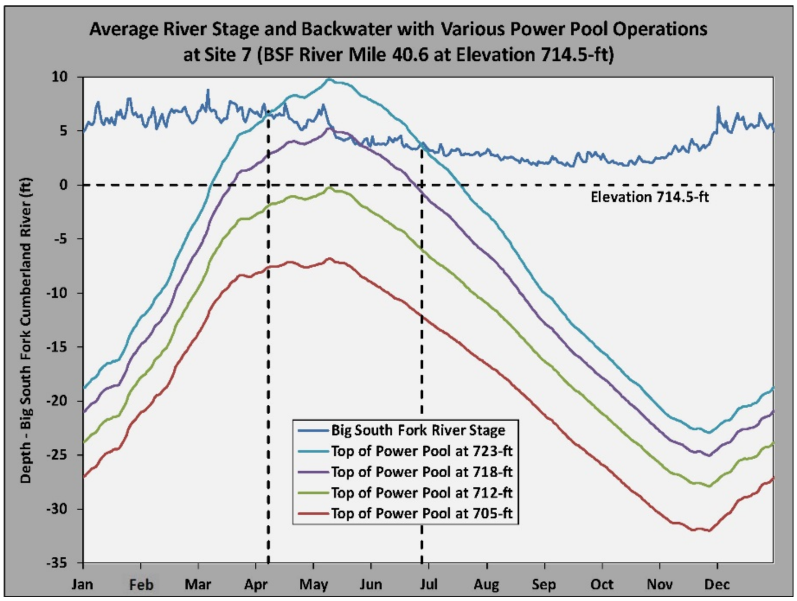

Figure 2 - Average River Stage and Backwater with Various Power Pool Operations at Site 7 (BSF River Mile 40.6 at Elevation 714.5-ft)

effects of the proposed action at Site 9 and continue to increase in shoal complexes further downstream. TVA will characterize sedimentation of shoal as part of the five years of monitoring.

RESULTS OF THE ESA CONSULTATION

The Corps' BA was submitted in February 2014 with the following ESA determination: 1) The proposed action to operate Wolf Creek Dam in accordance with the historical summer pool target elevation of 723, is **not likely to adversely affect** the duskytail darter at Sites 1- 6 (BSF miles 45.1 – 41.9) and it is **likely to adversely affect** the duskytail darter located in two shoal complexes (Sites 7 and 8) at approximately BSF mile 40.6 and mile 40.1. A Biological Opinion was issued by the FWS in March 2014. The FWS issued a Biological Opinion in March 2014 which included the following commitments:

A. Interim Pool Adjustment. In an effort to minimize the depth and velocity impacts to the duskytail darter habitat, an interim dam operation adjustment was committed to by the Corps as summarized below. This interim adjustment would be used until the three Water Quality/Habitat Improvements actions (described later) are functioning. As seen in Figure 1, the Corps has historically kept the lake well above the upper SEPA band during the late winter and early spring fill cycle of the lake when weather conditions allowed. This alternative adjusts the operation of the dam such that the lake levels more closely follow the upper SEPA band. Doing so minimizes increased depth and velocity impacts to the duskytail darter habitat as caused by the proposed action, as well as the duration of impacts, mainly at Sites 7 and 8.

B. Water Quality/Habitat Improvements. The Corps is to implement two water quality improvement and one sediment abatement remediation projects at sites within the BSF. Discussions were held with the National Park Service and FWS on potential conservation measures that could improve habitat conditions in the BSF for the duskytail darter. The intent is to improve habitat within the river reach potential utilized by the darter. Several sites upstream of the Blue Heron area were recommended NPS due to impacts of historic coal mining activities, including mine spoil disposal. These sites were screened to an array of three sites with planning and design being finalized this year. The goal is to construct these remediation sites in fall of 2016. Monitoring of the sits will be required to demonstrate their effectiveness in reducing sediment and providing water quality improvements (raised pH, lowered metals) by reducing stream and spoil interactions.

C. Conduct Annual Monitoring in Sites 1-8 for five years. The Corps has funded TVA to perform monitoring during low flow season to further define impacts of Lake Cumberland operations on sites with duskytail darters.

D. Capture and Hold Conservation Measure. The Corps has funded for a limited number (about 30) of darters to be captured and maintained at Conservation Fisheries Incorporated. These fish would be breed to maintain a stable number for reintroduction into suitable sites at a future date. Genetic testing was conducted to determine if genetic diversity was maintained. Ideally, if monitoring shows Sites 1-8 are not impacted by lake operations, they would be reintroduced in these sites. If the sites are degraded, other locations with the BSF basin would be located.

CONCLUSION

With the completion of the ESA consultation in an extremely short time frame of 45 days, the Corps was able to return Lake Cumberland to historic operations in 2014. This allowed the project to provide suitable pool levels for lake recreational uses and commercial marinas, as well as provide hydropower benefits for the region.

MERCURY MONITORING AND RESEARCH IN OAK RIDGE, TENNESSEE

M. Peterson[1]

INTRODUCTION

Mercury is a global pollutant that can pose health risks to humans and wildlife primarily through fish consumption. Although widespread mercury contamination of aquatic environments is most often associated with atmospheric deposition, localized mercury contamination from industrial point sources affects many rivers and streams in the U.S. Mercury dynamics in these flowing systems are complex - flashy conditions, sediment movement, and in-stream chemistry can favor the conversion of inorganic mercury to the more toxic methylmercury, making the remediation of flowing systems especially challenging.

APPROACH

East Fork Poplar Creek (EFPC) in Oak Ridge, Tennessee provides a useful case study of mercury fate and transport, speciation, and bioaccumulation processes in flowing systems. Since the early 1980s, EFPC has been one of the most well-studied mercury-impacted streams in the U.S., with thirty years of in-stream spatial and temporal bioaccumulation trending data and dozens of more short-term studies of environmental media. EFPC is a 3rd order stream that received large quantities of mercury from an industrial facility in the 1950s and 1960s (Figure 1). Long-term monitoring has revealed significant decreases in waterborne mercury concentrations from the facility, but fish concentrations have not responded commensurately highlighting that source reduction alone may not achieve downstream remediation goals (Mathews et al. 2012, Southworth et al. 2011). A phased, adaptive management approach to mercury remediation has been developed in Oak Ridge that includes source reduction at the facility coupled with investigations of potential in-stream remediation strategies. A new Mercury Remediation Technology Development Program is underway that is providing new insights on mercury processes in EFPC, including the role of storm flow and erosion on mercury flux, the importance of mercury forms and their respective bioavailability, and the role of invertebrate and fish community structure on fish mercury bioaccumulation (Peterson et al. 2015).

RESULTS AND DISCUSSION

Current research is investigating the use of physical, chemical, and biological manipulations to decrease the primary regulatory concerns in LEFPC: mercury flux, concentration, and bioaccumulation. The research strategy centers on development of remedial technologies that could potentially positively impact the three key factors that determine the level of mercury contamination in fish: the amount of inorganic mercury available to an ecosystem, the conversion of inorganic mercury to methylmercury, and the bioaccumulation of methylmercury through the food web (Wentz 2014). Consequently, three research tasks were developed:

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Task 1 - Soil and Groundwater Source Control, focuses on addressing downstream mercury sources to the creek (especially floodplain and bank soils) and groundwater,

Task 2 - Sediment and Water Chemistry Manipulation, centers on potential manipulation of in-stream processes, including the many water and sediment chemistry factors that affect mercury methylation, and

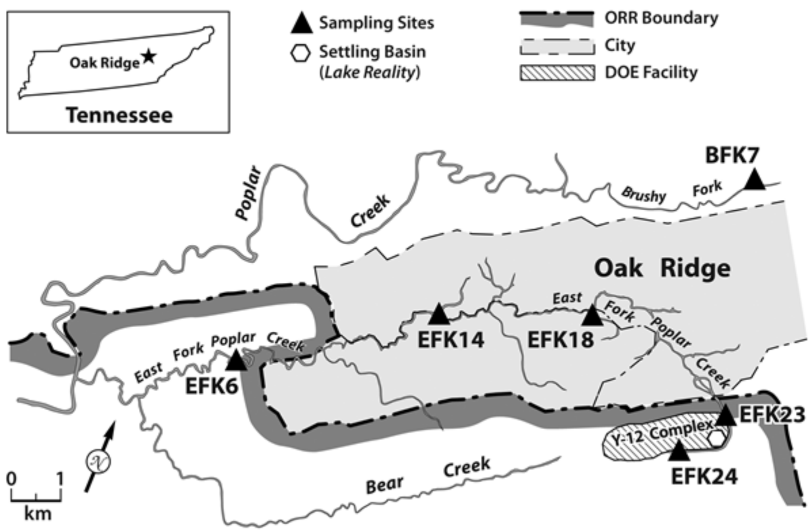

Figure 1. Map of the East Fork Poplar Creek watershed showing major sampling sites.

Task 3 - Ecological Manipulation, investigates methods to manipulate the food chain at both lower and higher levels of organization to decrease mercury concentrations in fish.

Together, the three study tasks focus on manipulating the key factors that affect mercury concentrations in fish in the downstream environment1 (Fig. 2). Because the physical, chemical, and biological factors that affect mercury processes in the creek are interdependent and interrelated as well as complex, the current research approach focuses on obtaining a watershed-scale understanding of the system. A longer-term goal of this research is to inform our national-level understanding of mercury cycling in flowing systems and design targeted solutions to reduce mercury-associated risks in the environment.

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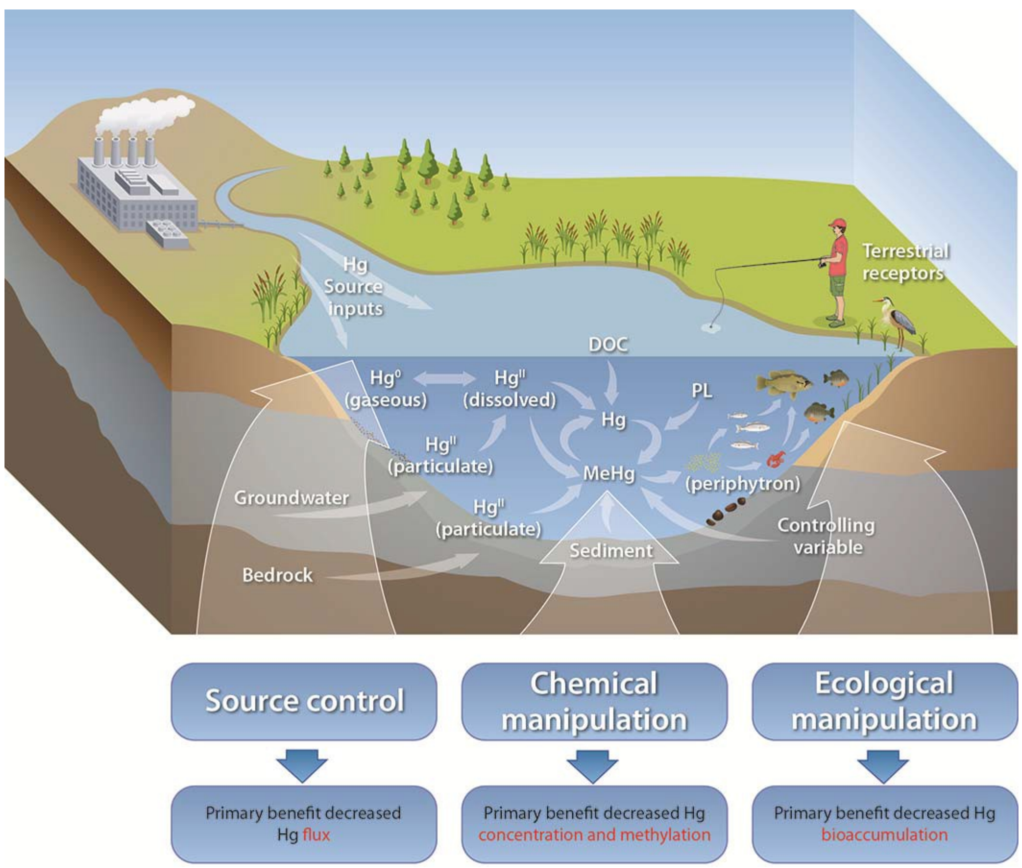

Figure 2. Conceptual model highlighting targeted technology development approaches under development to address the major factors controlling mercury in fish.

STREAM RESTORATION: MYTH, MYSTERY OR FACT?

We will seek to answer The Big Question; Are Streams better off today than they were last year , 2014, 2013, 2012?

Gary Moody[1]*

Is the premise for streams consistent with the sentiments echoed in the 80's Wendy's commercial "***parts is parts***"?

.... ***RIGHT*** well it bears consideration here…..today!

There are 26,988,160 total Acres in TN. At any one time over the last 10 years, an average of 24,000 acres required a General Permit. The disturbed acres have actually gone down from an incredible high in 2006. Overall, this doesn't seem like much, yet there is equipment near water everywhere you look.

Year	Total Acres
2006	57,951
2007	49,111
2008	30,985
2009	18,460
2010	13,712
2011	12,846
2012	13,465
2013	14,916
2014	14,156
2015	16,182

Provided by TDEC

[1] WISE Hydrology 145 Old Shackle Island Rd Hendersonville TN 37075

My Start Date in streams was 1989… "the good ole days", when government intervention was a necessity only if a structure (asset) was jeopardized, or where the rate of, and/or the potential for, erosion could threaten future planned improvements. Most applications required confinement utilizing hard armor.

Where are we today after 27 + years of bioengineering, stream-bank stabilization, Mitigation (permittee-responsible compensatory mitigation), Mitigation, (bank or in lieu), and finally, Natural Channel Design?

Changes are occurring in our watersheds that affect water quality, habitat, riparian zones, and consequently upstream, downstream, and adjacent property....... "even as we speak".

So, who is in charge? Who owns the waters of the state? Are there conflicts? Who determines if a stream is qualified to be a stream? Who initiates the work? If someone initiates the work, do they own and therefore control the work and that section of stream?

Are streams suffering the bastardized version of "Frog in a Well" syndrome where a situation exists that for every attempt to make progress in a task, an actual retrograde performance is achieved? "One step forward, two steps back...."

RESULTS AND DISCUSSION

Let's look at where we are today, how we got there, and the direction we're going. Let's consider if streams have rights. Does stormwater have more rights than surface water?

Does stream design and construction require a steep learning curve? Is that present?

If we're in an enlightened, scientific era, is there reason to suspect foul play? Or, is the current direction possibly better classified as opportunity…"low hanging fruit"?

The final BIG QUESTION may be; What does the promised land look like for streams? Is it ruled by developers, farmers, and road-builders? Is it ruled by regulators and environmental enthusiasts?

Is nature, not human nature, a part of the N.W.O. (New World Order) for streams?

There are four short case studies that will illustrate and define stream's rights: Adairville KY, Middlefork Creek, Kyles Ford and the Clinch River, and Little Dry Creek.
It will be up to you to decide; Myth, Mystery, or Fact.

References: Paul Davis, "Can I use…working its ass off"?
Dan Eagar, "Do bugs know GPS"?

EXAMINATION OF ALGAL ASSEMBLAGES IN RIVERS OF MIDDLE TENNESSEE: A PROJECT SUPPORTED BY THE TENNESSE HEALTHY WATERSHED INITIATIVE

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

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. The initiative's primary goal is to maintain and improve water resources across the state. Funding by the THWI for the evaluation of algal assemblages in Tennessee rivers is providing base-line data needed to monitor ecological integrity. Samples of soft algae (algae other than diatoms) and water for determinations of nutrient concentrations were collected at six stream reaches in five different watersheds during the spring and summer of 2015. Sampling of additional streams will continue in 2016. Percent composition for each soft-algae species in each stream reach is being compiled. The Algae Trophic Index will be calculated for each stream reach to demonstrate the impact of nutrient concentration on the structure of algal assemblages. Preliminary results suggest the structure of an algal assemblage is an accurate indicator of the trophic state of a stream reach and that the data will be useful for monitoring changes in ecological integrity.

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APPLICATION OF THE HIGH DEFINITION STREAM SURVEY ON CHOCCOLOCCO AND TURKEY CREEK

Brett Connell[1]

Traditional stream survey methods are often spatially limited due to access, time consuming measurements, and large manpower needs. The results are also limited due to the chosen set of predefined parameters measured in the field and the lack of documenting for future assessments. The High Definition Stream Survey (HDSS) approach was created to rapidly gather continuous geo-referenced data in a single pass on 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.

To highlight some of the applications and benefits of HDSS, we will use examples from recent projects. In just three and a half days, over 60 miles of Choccolocco Creek and 8 miles of Cheaha Creek were surveyed using the HDSS sampling method to gather current, geo-referenced video and to develop spatially continuous maps of bank and stream conditions. This was part of a court

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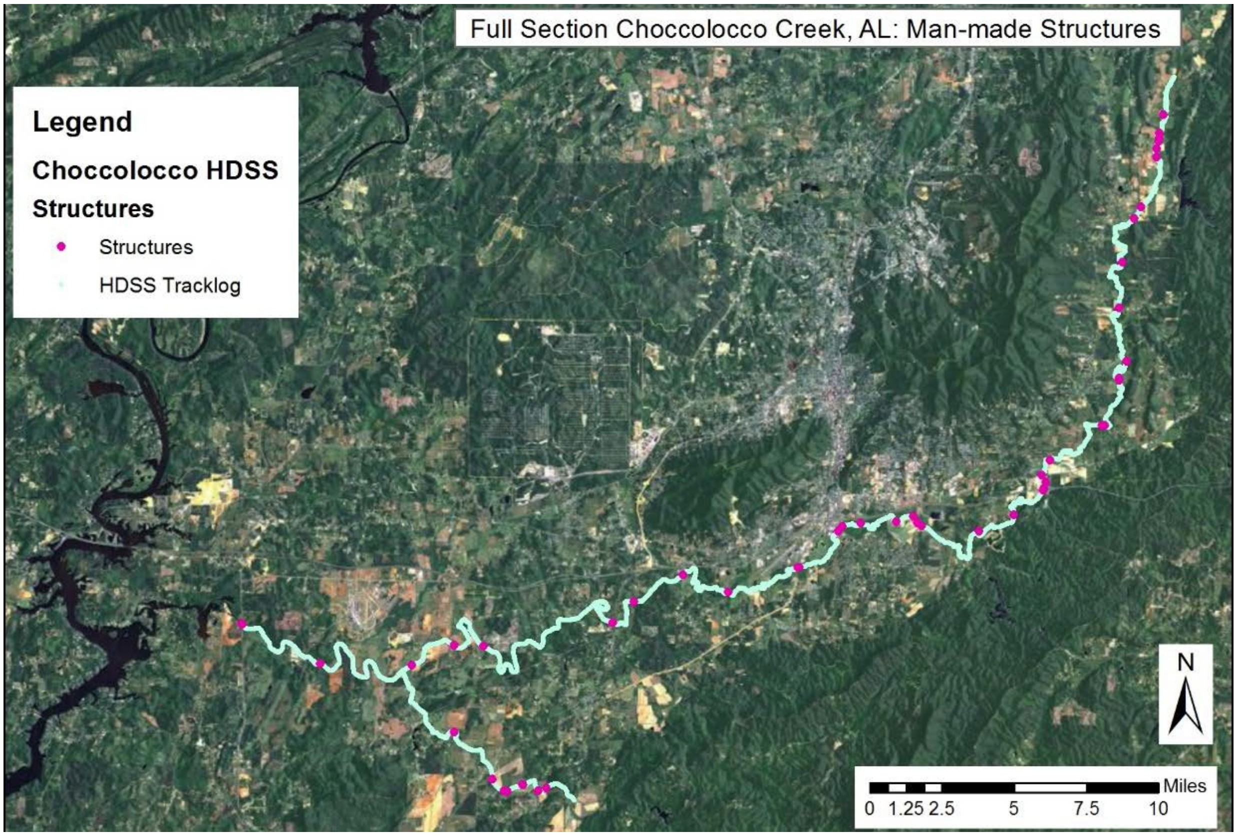
settlement where baseline conditions in 2014 needed to be documented and archived as well as used in identifying optimal mitigation locations. In another example, HDSS is being used to assess the impact of a large highway project on Turkey Creek, Alabama and determine potential mitigation options. We collected continuous information on 15 miles of stream in a single day enabling us to determine optimum habitat locations for T&E darters and determine locations which will provide the greatest benefit from shoreline stabilization.



HIGH DEFINITION STREAM AND FISH SURVEYS: INTEGRATING FISH HABITAT, CHANNEL GEOMORPHOLOGY, WATER QUALITY, WATER QUANTITY, AND INFRASTRUCTURE SURVEYS

James E. Parham[1]

Traditionally, stream fish habitat, channel geomorphology, water quality, water quantity, infrastructure survey methods are based on detailed descriptions of short (several 100m) stream segments which are intended to characterize the stream as a whole. The different surveys methods measure different stream characteristics and different sites of interest. As a result, we end up with multiple survey methods collecting inconsistent information spread haphazardly throughout a stream system. Integrating the results of the different survey approaches is difficult and accurately determining the worst problems and defining the best solutions are imprecise at best. High Definition Stream Survey (HDSS) is a stream survey system that integrates GPS, video, depth, and other sensors to allow many miles of stream to be surveyed in a single day with data collected approximately every meter. By using this multi-attribute data collection technique, we move from broad extrapolations about the condition of the study area based on short survey sites to continuous high-resolution maps of the stream and stream channel.

High Definition Fish Survey (HDFS) provides a method to rapidly survey fish and fish habitat use over long distances in clear water streams and rivers. The HDFS uses geo-referenced, high-definition underwater video to replace snorkelers doing visual surveys. The big advantages of the HDSS and HDFS approaches over traditional surveys include faster data collection, reviewable survey footage, less disturbance to the fish, a wider range of sampling conditions, lower cost, and broad applicability to a wide range of stream management issues. An overview of the process of field data collection, data management, classification, mapping, and analysis will be shown from a number of recent studies. These projects address issues associated with instream flow documentation, understanding mitigation needs, and assessing habitat distribution for fish species (Figures 1 and 2). These case studies show the range of data collected and its utility in GIS mapping, fish habitat identification, and overall stream health applications.

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Figure 1. High Definition Stream Surveys and High Definition Fish Surveys integrate together easily to provide habitat availability and habitat use information.

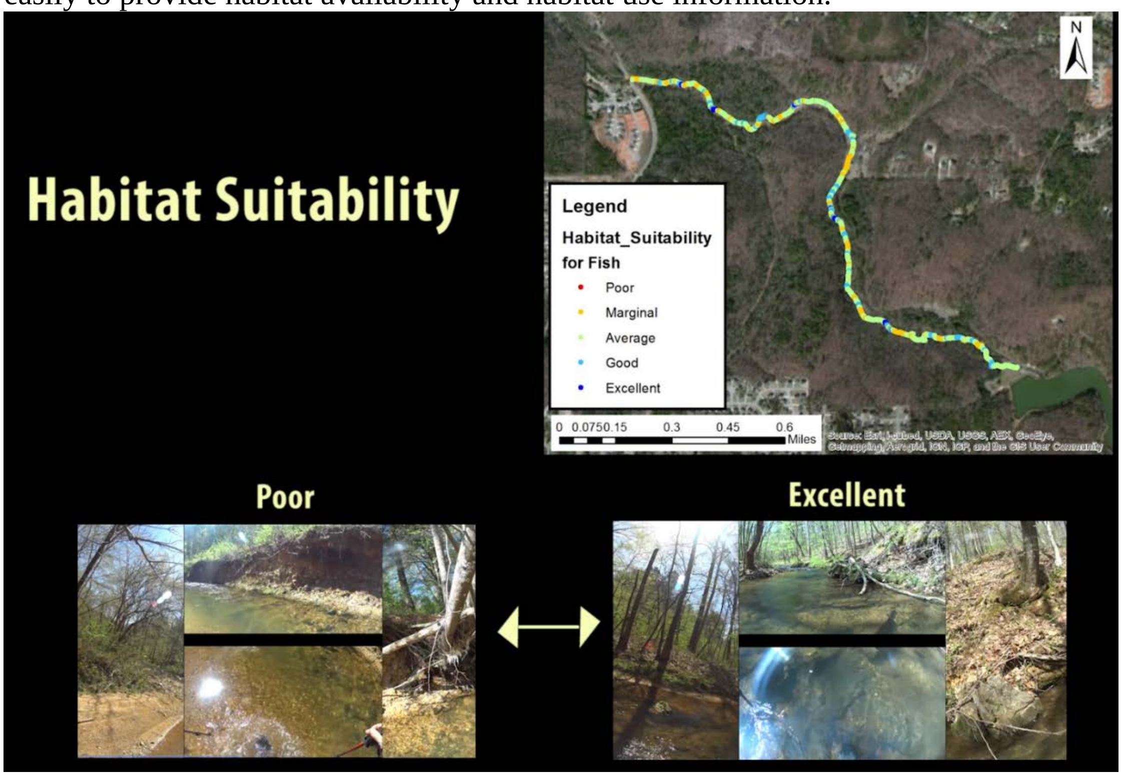

Figure 2. Habitat Suitability and other metrics of habitat or stream channel conditions can be developed for long stretches of streams rapidly and with a fully reviewable data archive.

RECLAMATION OF THE LOWER NORTH POTATO CREEK WATERSHED

T. McComb

The Lower North Potato Creek Watershed is a 4,000 acre site located between Ducktown and Copperhill, Tennessee in the southeastern corner of the state. Historic copper, iron, and zinc mining, mineral beneficiation, and the resulting acid-mine drainage left this watershed devegetated, severely eroded, and unable to support aquatic life. The Lower North Potato Creek Watershed is an example of a mining megasite – a site with multiple mines, tailings ponds, ore storage areas, and processing facilities. In the EPA National Conference on Mining-Influenced Waters in 2014, the EPA stated that the typical assessment of a mining megasite can take over 20 years. The Lower North Potato Creek Watershed project has progressed from the initial investigations, through remediation to long-term monitoring in approximately 15 years.

The key to the success of the reclamation of the Lower North Potato Creek Watershed has been the use of adaptive management techniques combined with the use of biological performance goals in place of water quality goals for the reclamation activities.
The adaptive management process included:

- Construction and operation of an interim water treatment plant to reduce metal loading and acid mine drainage from North Potato Creek to the Ocoee River
- Initial inventories to identify source materials
- Ranking source material by potential impact to the streams
- Phased remedial actions

During all phases of the project, biological monitoring was conducted focusing on macroinvertebrate communities and in-stream and riparian habitat quality at selected locations in North Potato Creek and its major tributaries. The value of the biological monitoring included measuring the impact of the remedial actions on the biological communities to determine which areas would recover and which areas required additional remedial actions.

Today the aquatic macroinvertebrate communities in Lower North Potato Creek and its tributaries are recovering and fish and amphibians have returned to the streams. Additionally, the metals and acid loading in North Potato Creek has been reduced to the point where the stream flows directly to the Ocoee River without requiring treatment.

CONCEPTION, DESIGN, AND CONSTRUCTION OF A REGENERATIVE STREAM RESTORATION IN KNOXVILLE, TENNESSEE

William K. Barry[1], David McGinley[2], John Wisinger,[3] and Patrick McMahon[4]

Abstract: Organizations that must administer a Municipal Separate Storm Sewer System (MS4) permit face the challenge of addressing impairments to water quality in the streams in their jurisdiction. MS4 managers have a variety of tools and approaches to utilize in this work, including stream restoration. A growing body of research into the effectiveness of stream restoration techniques and philosophies indicates greater water quality and aquatic habitat improvement can be achieved by addressing the following:

(1) locating the restoration reach in upstream/headwater portions of the watershed,
(2) allow the floodplain to be in more frequent contact with flood waters relative to the historical recommendation, and
(3) if the restoration reach is in urban areas, implement measures to enhance the pollutant removal effectiveness of the restored reach.

The Banks Avenue project started with the desire of the City of Knoxville to remove a deteriorated storm drain pipe from an approximately 200-foot reach of an un-named headwater tributary of Second Creek. A straight-forward pipe removal and conventional stream restoration would have met that initial goal and met the first of the criteria for enhancing improvements resulting from stream restoration. To obtain a greater benefit from the project an approach called "Regenerative Stream Restoration" was applied to this project. Regenerative stream restoration can enhance the second and third criteria listed previously. This presentation will review the historical and current conditions at the project site, present the theory behind Regenerative Stream Restoration, describe the approach used to design the restoration reach and surrounding floodplain area, present issues identified during construction and the completed project, and discuss the future of the Regenerative Stream Restoration approach.

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PHASE I RESTORATION OF BEAVER CREEK, BRISTOL TN/VA

Ingrid Luffman[1], Gary Barrigar[2], and Phil Scheuerman[3]

Beaver Creek in Sullivan County, TN and Washington County, VA, is water quality impaired and does not support its intended use for recreation. It has a water contact advisory for *Escherichia coli (E.coli)*, nitrates, and a loss of biological integrity due to siltation (US Environmental Protection Agency, 2014). The 282 km^2 (109 mi^2) watershed straddles the VA/TN state line, which can present some issues for planning and implementation of restoration projects. Tennessee has existing TMDLs for *E. coli* (Tennessee Department of Environment and Conservation, 2006a) and sediment (Tennessee Department of Environment and Conservation, 2006b). The Tennessee portion of the stream (approx. 52% of the watershed area) begins in downtown Bristol, TN/VA, and land use transitions from commercial urban, to residential and to rural land uses downstream.

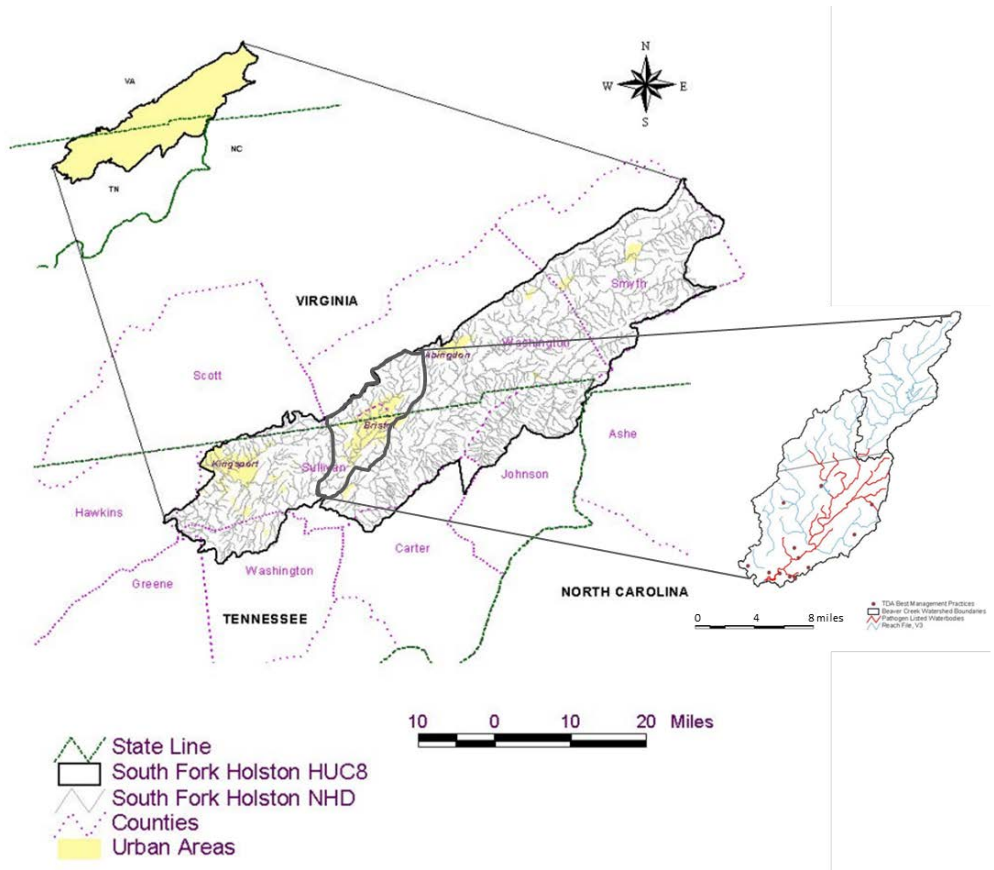

Figure 1. Beaver Creek Watershed location (modified from Tennessee Department of Environment and Conservation, 2006a)

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In 2007, the Virginia Department of Conservation and Recreation published a Water Quality Implementation Plan for Bacteria and Sediment TMDLs on the portions of Beaver Creek and Little Creek in Virginia (Virginia Department of Conservation and Recreation, 2007). The plan outlines Best Management Practices (BMPs) to address bacterial impairment. Execution of the implementation plan began shortly thereafter; however, the Virginia restoration work stopped at the state line and Tennessee had yet to develop an implementation plan.

In 2008, two year-long studies were begun on Beaver Creek (both TN and VA portions) to 1) assess land use and 2) monitor water quality. Fourteen sampling sites were selected above and below changes in land use, tributary confluences, and potential pollution sources. Grab samples were collected monthly in triplicate for six months beginning in June 2008, and then quarterly for a further 18 months. Water samples were analyzed at the East Tennessee State University Environmental Health Sciences Laboratory for total coliform bacteria, fecal coliform bacteria, Nitrate-N, orthophosphates (as PO_4^{3-}), BOD, alkalinity (as $CaCO_3$), and hardness (as $CaCO_3$). The primary objectives of the water quality monitoring were to determine the spatial and temporal distribution of fecal coliform bacteria in the creek, and identify potential sources of contamination.

In conjunction with the water sampling, monthly land use surveys were conducted by the East Tennessee State University Department of Geosciences from September 2008 through August 2009 to estimate population and spatial distribution of livestock and domestic animals, and to identify potential sites of illicit discharge. Agricultural land acreage was surveyed in spring and fall, and a one-time door-to-door septic survey was conducted for residences within a 10 m (35 ft) buffer of Beaver Creek. The purpose of the land use surveys was to quantify land use in the watershed as a factor in water quality and to identify potential sites for BMP installation.

SURVEY RESULTS

Indicator bacteria were elevated at all sites during at least part of the year (Figure 2). Although some sites periodically experienced peaks higher than upstream and downstream sites, no single location or region was consistently higher than other sites in Beaver Creek. Similar results were seen for other chemical and biological parameters.

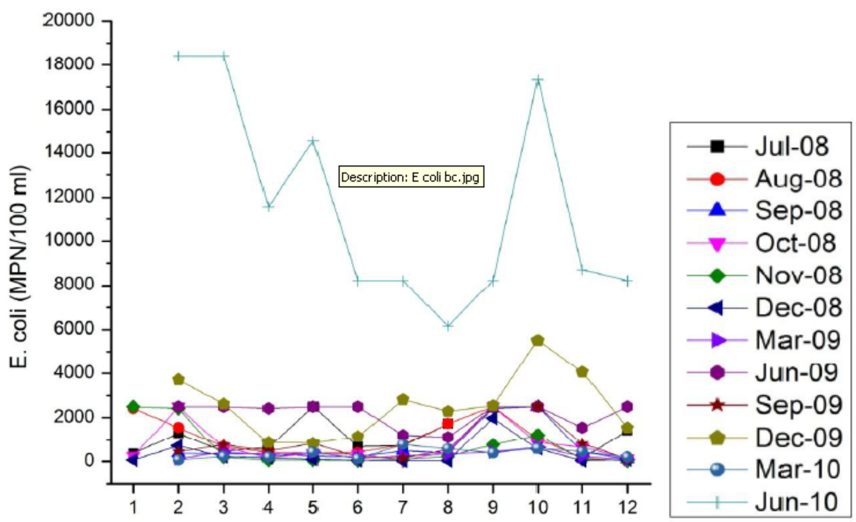

Figure 2. *E. coli* in water samples at twelve sites on Beaver Creek, VA/TN (Barrigar et al., 2011).

Wildlife along Beaver Creek consists of primarily geese and ducks, which typically congregate at a few locations: stream mile 16.1 (Pals Restaurant near Exit 7), stream mile 13.1 (Memorial Park in downtown Bristol, VA) and stream mile 12.0 (Hwy 11E at Weaver Pike) (Figure 3). Within Tennessee, livestock are consistently found along Back Creek and Whitetop Creek, both tributaries to Beaver Creek (Figure 4). Results from these studies and other stream surveys formed the foundation for the TMDL Implementation Plan (Barrigar et al., 2011) developed by the Boone Watershed Partnership in conjunction with East Tennessee State University Departments of Environmental Health and Geosciences. The plan presents the results of the two studies and outlines restoration plans for the Tennessee portion of the watershed.

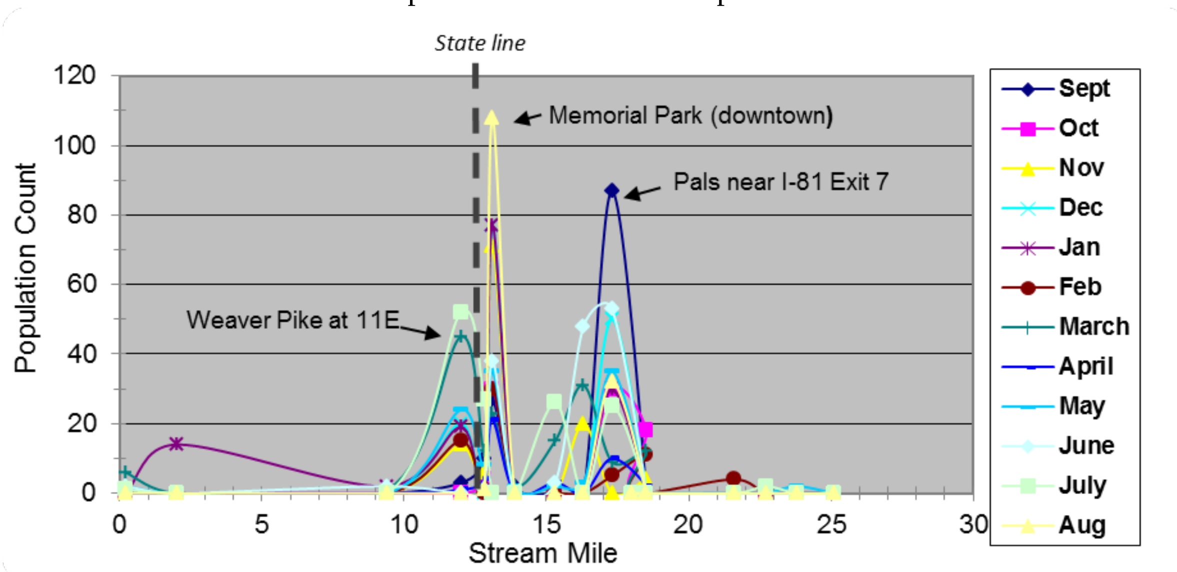

Figure 3. Monthly wildlife sightings on Beaver Creek, TN/VA (September 2008 – August 2009).

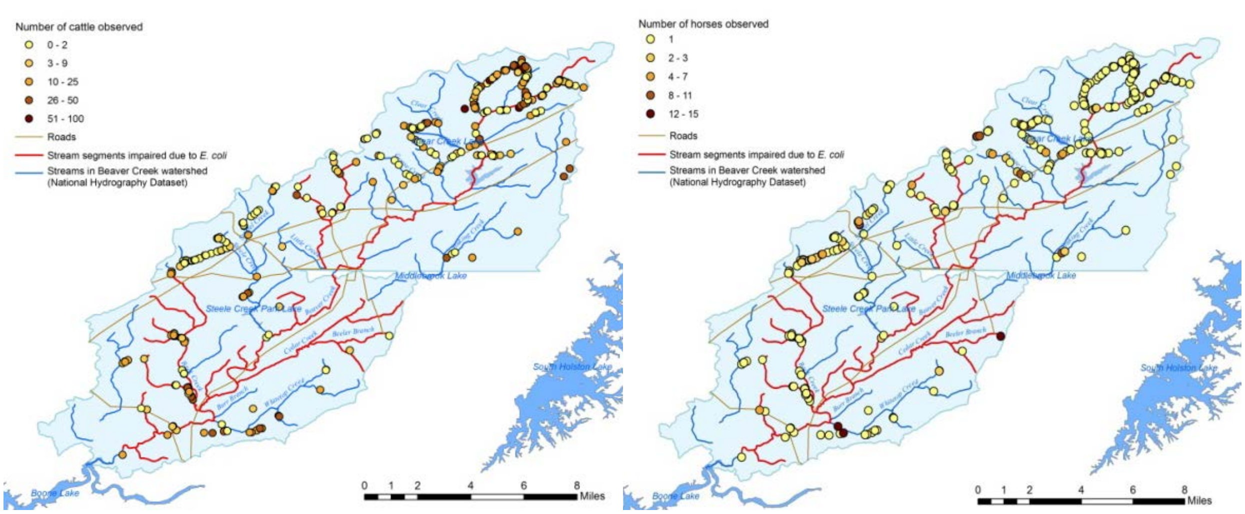

Figure 4. Summative distribution of cattle (left) and horse (right) populations, September 2008 – August 2009. Each dot represents an observation event; the darker the shading, the higher the count. Streams colored red are 303(d) listed for *E. coli*.

RESTORATION PROJECTS

Restoration work was divided into multiple phases, with Phase I to implement best management practices at the most pressing sites in partnership with forward thinking land owners. Because the water quality analyses did not pinpoint specific pollution sources for pathogens, Phase 1 concentrated on stream bank stabilization to address sediment impairment. Phase 1, nearing completion, was funded through the EPA 319 program administered through the TN Department of Agriculture. Since 2013, six restoration projects have been implemented at seven sites along the TN portion of Beaver Creek (21.6 miles in length).

Rain garden. In partnership with the City of Bristol, TN, a 27 x 3 m (90 x 10 ft) rain garden was installed in the municipal parking lot downtown (Figure 5). The purpose of the raingarden was two-fold: intercept parking lot runoff which, prior to construction, flowed directly into Beaver Creek; and serve as a demonstration project and opportunity to educate the public about stormwater runoff and benefits of raingardens. Over 53% of the $51K project cost was covered by matching funds from the city and other partners.

Figure 5. Before (left) and after (right) installation of raingarden. Parking lot runoff is intercepted and pollutants are trapped. Educational signage explains the process.

Streambank restoration. Two streambank restoration projects were constructed at Earhart Campground, adjacent to Bristol Motor Speedway in 2014 (Figure 6). Bank stabilization projects were completed on a 186 m (610 ft.) section of the stream where cut banks were severely eroding at two meanders. Large 1x1m (3x3 ft) foundation rocks were installed to support ~10 root wads which improved bank stability and created habitat. The eroded area was backfilled, the bank was reshaped, and grass, trees, and live stakes were planted overtop.

Bank Stabilization. Three rock vanes were constructed in 2014 along 58 m (190 ft.) of streambank at a residential property to armor the bank and divert flow toward the center of the channel (Figure 7). Grass was sown immediately after construction, which was followed several months later by tree planting. Two additional projects on 20 m (65 ft) and 60 m (200 ft) reaches in the downtown corridor stabilized steep banks in 2014 and 2015 using bare root trees and live stakes where the use of herbicides and weed-eating had killed vegetation and set the stage for subsequent erosion.

Figure 6. Before restoration (left) stream bank was eroding at a cut bank at Earhart Campground. After (right), root wads and foundation rocks support the stream bank.

Figure 7. Before restoration (left) stream bank was eroding at this residential property. New rock vanes protect the bank and divert water back toward the center of the channel.

POST-RESTORATION MONITORING

Monitoring of Beaver Creek *E. coli* levels was reestablished in 2015 at the TN/VA state line and near the mouth of Beaver Creek. Early results indicate a downward trend in *E. coli* concentration at the state line, likely due to earlier BMP implementation in the Virginia. In Tennessee, mean *E. coli* concentration is lower, but statistical significance cannot be established with limited data available. Beaver Creek is scheduled for water quality monitoring (per TDEC's five year Watershed Management Cycle) in 2017-2018 which coincides with the need for post–restoration assessments to follow completion of Phase 1.

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HATCHERY CREEK STREAM RESTORATION PROJECT – A UNIQUE OPPORTUNITY TO ENHANCE SPORT FISHING

Oakes Routt[1], Kevin Rexroat[2], Rob Lewis[2], George Athanasakes[3], Eric Dawalt[4], and Jim Hanssen[5]

The Hatchery Creek Stream Restoration project is a unique opportunity to utilize the latest stream restoration techniques to maximize trout habitat, create recreational opportunities for the citizens of Kentucky, and provide mitigation credits. The project is located immediately downstream of the Wolf Creek Dam US Fish & Wildlife National Trout Hatchery near Lake Cumberland in Jamestown, Kentucky. In an effort to maximize habitat and recreational opportunities, the project is being designed to provide a variety of habitat for all life stages of trout and will include a variety of stream types including A, B, C and DA channels.

This talk will focus on unique sport fishing aspects of the project. The Hatchery Creek Stream Restoration project is a relatively high profile project for the state and is highly anticipated by a number of local trout fishing clubs. Prior to restoration the existing 400-foot long channel was already a very popular fishing spot. The new 6,000 foot long channel was designed and constructed to promote a self-sustaining trout stream while accommodating sport fishing and different zones of fishing restrictions. Specific design aspects to maximize trout habitat and accommodate the different fishing restrictions will be discussed. In addition, the permitting of the project will be discussed including the combining of stream and wetland credits for the project as well as the unique aspects of permitting a DA stream type. As part of the project a braid calculator was developed to quantify additional habitat provided by DA stream types in light of mitigation credit generation.

About the Speaker: **Oakes Routt, P.E. is a stream restoration design engineer/project manager for Stantec Consulting Services Inc. He has a broad range of experience in stream restoration and has been involved in stream restoration designs throughout the United States for Stantec. Oakes' holds Bachelor's of Science and Master's of Engineering Degrees from the University of Kentucky.**

About the Co-Speaker: Eric Dawalt, P.E. serves as the Project Manager for the EcoGro/Ridgewater Team, which designs/builds projects to solve stream and stormwater problems. He is a Professional Engineer with over 16 years of experience in the design, construction, monitoring, and research of stream and wetlands restoration projects. Eric holds Bachelor's of Science and Master's of Engineering Degrees from the University of Kentucky.

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NASHVILLE ZOO STORMWATER RETROFIT: APPLYING LEVEL SPREADER AND CHECK DAM DESIGN PRINCIPLES TO RESTORE RIPARIAN AREA AND PROTECT RECEIVING STREAM

Steve Casey[1]

INTRODUCTION

Stormwater runoff from a business park was negatively impacting property at the Nashville Zoo, including a small headwater stream that flows through its grounds. The Cumberland River Compact partnered with the Nashville Zoo and secured partial funding for the project via a Clean Water Act 319 grant administered by the Tennessee Department of Agriculture. Civil & Environmental Consultants, Inc. was brought on as the engineering partner of the overall team.

APPROACH

The original intent of the project was to increase the storage capacity of the existing basin; however, the necessary increase would have been prohibitively large and would not have addressed the primary water quality concern which was the detention basin's outlet flow eroding the riparian area between the basin and the stream. Nor would just making the basin larger address another concern, which were floatables and other debris washing through the basin to Cathy Jo Branch. CEC designed a management approach that integrated principles from level spreader and check dam designs to manage inflow and outflow from the basin. Inflow controls to the basin had to be easily maintained and visible to promote regular maintenance and ensure the integrity of the Zoo's perimeter fence. The Zoo wanted the area between the existing detention basin and Cathy Jo Branch to be a future Elk and Bison exhibit, not a wetland. Therefore, this area had to completely drain after a storm event, so the approach to dampening the energy of the basin outflow had to ultimately allow stormwater to drain but to do so in a non-erosive manner.

Another impetus for the chosen approach was the Maryland Protocol's encouragement within its stream corridor assessment methodology to be on the lookout for areas within inadequate stream buffers to create wetlands. While the measures that were constructed are not wetlands, they share a similar feature in that water is temporarily allowed to impound in response to rainfall and slowly drain. The difference being that the area behind the flow control berms fully drains after a storm event.

RESULTS AND DISCUSSION

The inflow controls had to be integrated into the Zoo's perimeter fence. Since flow was already entering the Zoo through the perimeter fence, and, at times, pushing a section of fence over when debris piled up on the chain link, the solution sought to increase the available area of the fence in

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order to reduce the velocity and depth of flow (based upon the continuity equation Flow = Area x Velocity). The inlet control had to be visible to Zoo staff to alert them to maintenance needs; this was easily accomplished by the proximity of the inflow points to an existing Zoo internal access road. The inflow controls had to be easy to clean; therefore, concrete pads were constructed to facilitate a “Bobcat” type piece of equipment entering the control and scooping up accumulated debris including the ability for the scoop to push against a concrete curb.

The outflow controls downgradient of the basin were designed to initially dissipate the energy of the flow from the basin’s 30-inch diameter pipe. This was accomplished by installing a constant elevation TDOT Class B riprap berm around the outlet structure (to which the 30-inch pipe drained) within the basin and a constant elevation Class B riprap berm immediately downgradient of the 30-inch pipe. Downgradient of this Class B riprap berm, two constant elevation, flow control berms were constructed. The berms were constructed primarily of soil. However, each had a section that was comprised of a TDOT Class A riprap core overlain with a cellular confinement system that was backfilled with river gravel. This rock core segment of the berm promoted complete draining (and filtering) of impounded stormwater that did not infiltrate after a storm event. Large storm events that overwhelmed the rock core segment of the flow control berm would overtop the berm similar to a level spreader.

Materials and construction of the basin inflow and outflow flow control measures were readily available and relatively inexpensive. Constructing a true concrete, curb type level spreader was not only infeasible due to the length that would be required, it would have been prohibitively expensive and not compatible with the desired, future use of the area as an Elk and Bison exhibit within a prairie habitat. The primary inflow control material used was chain link fence – the same material used for the Zoo’s perimeter fence.

Though the innovative project is nearing the final stages, there already has been marked improvement in the health of the water and habitats. “It is absolutely amazing how quickly a stream can recuperate thanks to a good erosion control and infiltration project,” said Dale McGinnity, the Nashville Zoo’s Ectotherm Curator. “This stream segment had always been comprised of a strictly brown silt substrate. Now there are rocks and gravel evident, and it has the appearance of a healthy streambed that can support macroinvertebrates and biodiversity. I really did not expect the character of the stream to change so dramatically, so quickly.”

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DAM REMOVAL IN TENNESSEE: AN ALTERNATE FORM OF STREAM MITIGATION CREDIT?

Adam Spiller[1], CPESC[1]

Stream mitigation in Tennessee has generally followed a set formula for the past 10 years or so. Over the past couple of years Tennessee and other states have been putting an emphasis on stream function as a component of stream mitigation. At the same time there has been a growing interest in dam removal throughout the state and the southeast in general. With this emphasis on stream function, is it feasible to use dam removal projects to generate mitigation credit? This presentation will discuss examples of how other states have used alternate forms of stream mitigation, including dam removal. Also, an example dam removal project will be used to examine how these projects address stream function and an example credit generation strategy will be given. This will be followed by a general discussion of the constraints that dam removal projects face for use in mitigation, and how these projects could be successful in spite of these constraints.

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ECOLOGICAL EFFECTIVENESS OF CHANNEL RESTORATION IN THE COASTAL PLAINS

Jeffrey D. Fore[1] and Thomas Blanchard[2]

Channel restoration projects have been implemented in West Tennessee to reverse stream channelization, reestablish channels through valley-plugged systems, and reduce localized flooding issues. The ecological effects of these projects are poorly understood and our goal was to assess the ecological effects of channel restoration and to provide potential recommendations for restoration improvements. We assessed how fish assemblage composition differed among reference, restored, and channelized streams as related to physical instream habitats. A control/impact sampling design was used to inventory instream physical habitat and collect fish assemblage data at four restoration sites, four channelized sites, and three reference sites. Relative abundance of each reproductive guild (number of individuals in guild/total number of individuals in sample) was calculated for each site. Non-metric multidimensional scaling was used to assess reproductive guild composition among sites and treatments. The envfit function was used to assess how habitat factors varied among sites. Guild composition of reference streams was characterized by high abundance of pelagophils, lithophils, and speleophils. These sites were characterized by a higher number of mesohabitats, coarser substrate, and higher amounts large woody debris. Community composition was variable among restoration and channelized sites but was often dominated by generalist reproductive strategies (e.g., polyphils) and greater parental investment (e.g., guarding behaviors). Sites with generalist and high investment strategies were generally dominated by pool habitats and high water temperature. Restoration practitioners should, in the near-term, utilize restoration techniques that maximize mesohabitat types, minimize temperature increases (from loss of riparian zones), and increase large woody debris recruitment.

[1] West Tennessee Program Director, Tennessee Chapter of The Nature Conservancy
[2] Professor; Director, Reelfoot Lake Environmental Field Station, University of Tennessee at Martin

SESSION 3A

EPA
8:30 a.m. – 10:00 a.m.

Low Cost Opportunities for Energy and Nutrient Reductions at WWTPs
Bob Freeman and Brendan Held

National Aquatic Resource Survey
David Melgaard

BETTER OUTCOMES FOR NATURAL RESOURCES MANAGEMENT: ALIGNING FOR SUCCESS!
10:30 a.m. – 12:00 P.m.

Speakers: S. Gain, U.S. Geological Survey; T. Calabrese Benton, TDEC; and S. Kniazewycz, TDOT No Abstracts Available

LOW COST OPPORTUNITIES FOR ENERGY AND NUTRIENT REDUCTIONS AT WWTPS

Bob Freeman[1] and Brendan Held[1]

TDEC and EPA Region 4 began an Energy Management Initiative for public Wastewater Treatment Plants (WWTPs) in 2011 which has demonstrated that opportunities to achieve significant energy savings through operational optimization exists at almost all WWTPs. These changes can be implemented with little to no cost to the utility and significant nutrient reductions can also be achieved at many facilities as part of energy optimization changes. Twenty TN WWTPs have participated to date in this effort with over 11 million kWh/year energy saving opportunities identified, over $800,000 cost reduction opportunities identified, over 10,000 tons CO2 emission reduction/year identified, and over 500,000 lbs of nitrogen discharge reduction opportunities identified. Approximately 40% of those savings have been implemented and documented; approx. 25% more has been implemented and documentation is being collected, and we are working with the WWTPs to implement the remaining savings. All of these savings have come from operational optimization with low or no cost to implement. Case Studies for Fayetteville, Columbia, and Franklin WWTPs will be presented and lessons learned discussed. TDEC is expanding this effort to at least 12 more WWTPs over the next two years with the support of a Dept. of Energy grant.

[1] EPA Region 4 Atlanta

NATIONAL AQUATIC RESOURCE SURVEY

David Melgaard[1]

An update of the status of the EPA funded National Aquatic Resource Surveys (NARS) will be presented. These national scale surveys are funded by the U.S.EPA and conducted by the states and other partners. The surveys that will be discussed are the National Rivers and Streams Surveys (NRSA), the National Lakes Assessments (NLA), and the National Wetland Condition Assessments (NWCA). Some of the results of assessments from the surveys will be presented with a focus on the condition of the waterbodies in the southeastern U.S. ecoregions. Information outlining the availability of reports and data and the future schedule of the surveys will also be provided.

[1] U.S.EPA Region 4, Atlanta GA, Water Protection Division, Water Quality Planning Branch

SESSION 3B

FLOODS
8:30 a.m. – 10:00 a.m.

Developing Flood Consequence Correlation Using Global DEMs
N.M. Bhuyian and Alfred Kalyanapu

A Probabilistic Hydrologic Model to Analyze the Uncertainty of the Design Hydrograph Attributes
Ebrahim Ahmadisharaf, Alfred J. Kalyanapu, and Jason Lillywhite

Making Room for Big Creek
Adrian Ward

DEVELOPING FLOOD CONSEQUENCE CORRELATION USING GLOBAL DEMS

MD N M Bhuyian[1]* and Alfred Kalyanapu[2]

ABSTRACT

Flood modeling and damage assessment require extensive surveyed data, which often are cost prohibitive and time consuming. Digital Elevation Model (DEM) is usually used as a substitute for surveyed topographic data. DEM (i.e. SRTM, ASTER, NED, and LiDAR) varies by source, acquisition technique, and spatial resolution. Selection of suitable DEM and optimum spatial resolution is a key for achieving expected accuracy and simulation time. For most part of the earth, global DEMs (i.e. SRTM, ASTER) are only available source of large extent elevation data for flood modeling. Therefore, it is needed to ascertain the uncertainties derived from these global DEMs and search for possible ways to avoid them. For example, it has been observed that flood damage is strongly correlated with flood extent irrespective of the DEM source. Therefore, it is possible to establish damage vs flood extent correlation using global DEMs, which is comparable to similar correlation, derived from high quality elevation data (i.e.g LiDAR). Therefore, the objective of this study is ***"to develop flood consequence correlation using global DEMs."*** This study compared DEM from different sources (i.e. SRTM, ASTER, NED, and LiDAR) with various spatial resolutions for a 22-mile long stretch of American River downstream of Folsom dam in California. This Flood Consequence Correlation can be helpful to produce gross estimate of flood losses in remote and data poor areas. This would be helpful for areas where flood extents are available from secondary sources (e.g. satellite image, high water marks) but accurate topographic and bathymetric data are limited to global DEMs only.

INTRODUCTION

Elevation data is one of the most important input data for flood modeling (Jung and Jasinsky 2015). According to Bales and Wagner (2009) uncertainty in the flood inundation polygons simulated with a one-dimensional model increases with distance from the main channel. Therefore, it is not only needed to be accurate at river bottoms but also in floodplains for such applications (Brandt and Lim 2012). Engineers and managers are often required select the best elevation data for optimum result. The spatial limitation and vertical accuracy affects the results at different levels of simulations. These elevation uncertainties amplify as they are driven further into the modeling process. Global DEMs have a larger extent of the earth but are very prone to error for localized applications (Wilson et al 2007). This study found that, local DEMs (i.e. NED, LiDAR) manage to depict flood plain better than their global counterparts do. However, for most part of the earth, global DEMs (ASTER, SRTM) are the only source of digital elevation. Therefore, it is needed to look for ways if flood consequences can be estimated more accurately

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using global DEMs only. This can be done if a generic consequence correlation is found that follows a similar pattern irrespective of the DEM source.

The open science question being asked in this study was, ***"is it possible to derive a generic flood consequence correlation with flood magnitude using global DEMs only?"*** Therefore, Objective of this study is ***"to develop flood consequence correlation using global DEMs."*** This study demonstrated that, flood damage is strongly correlated with flood extent irrespective of the DEM source. It considered the scenario with most reliable elevation data (i.e. surveyed bathymetric data and 1/3 arc second LiDAR data for floodplain) as the "*Control*" scenario to carry out the investigation.

METHODOLOGY

This study was comprised of three steps (i) hydrodynamic calibration for *"Control"* scenario (ii) hydrodynamic simulation with test elevation data set (iii) flood consequence assessment for *"Control"* and test scenarios. Figure 1 shows a schematic of the methodology. Two Hydrologic Engineering Center (HEC) products were employed in this study.

To investigate consequence versus magnitude correlation series of flow events were selected via return period analysis for the stretch of river. The peak flow values for corresponding return period (i.e. 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, and 500-yr) were converted into unsteady flow events by finding similar observed flow events or via scaling of actual events. These events are hereafter called as RP flows. A 22-mile HEC-RAS model acquired from the Sacramento Flood Control Agency was used for hydrodynamic simulations. HEC-River Analysis System (HEC-RAS) was used for 1D flow simulation and HEC-Flood Impact Assessment (HEC-FIA) was used for flood consequence assessment.

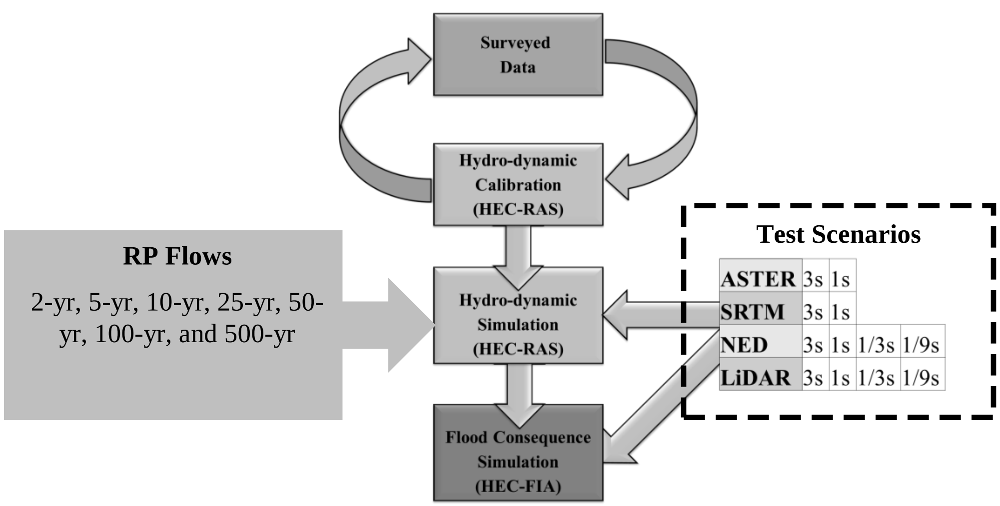

Figure 1: Methodology Flow chart

RESULTS

Uncertainty in DEM produced errors in simulated WSE. It was observed that larger extents being flooded by the *test* cases than the *control* scenario due to over estimation of WSE. This over estimation was product of bathymetric inaccuracy in the DEMs. On the other hand, due to lack of hydraulic connectivity in DEMs over floodplains the flood extents appeared as scattered pools of water. These inaccuracies may arise from missing vector features such as drainage ditches and embankment heights, pits caused by vegetation canopies, subpixel-sized structures, and random radar speckles (Jung and Jasinsky 2015, Schubert et al 2008, Yamakazi et al 2012).

The authors further intended to find if there was any correlation between flood consequence estimates and spatial resolution. Figure 2 shows the correlation of flood consequence against DEM spatial resolution. No significant correlation could be obtained when DEM sources are not separated which indicates DEM fineness is not the only driving factor for reducing errors in consequence assessments. However, strong correlations between consequence and simulated flood extent were observed indicating flood consequences are functions of flood extent and flood depths. It was also noticed that the estimates made using different DEMs do fit within a certain pattern.

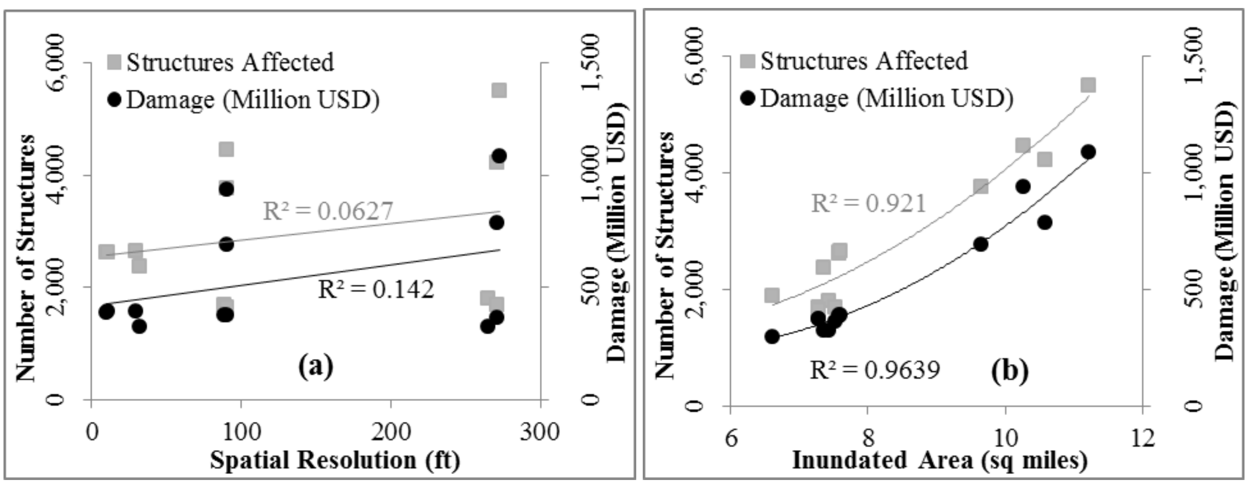

Figure 2: Correlation of flood consequences against (a) DEM spatial resolution and (b) inundated area.

DISCUSSION

Response of a community to a flood event showed consequences could be correlated to flood magnitudes. Flow, WSE and inundated area are well correlated with consequence when reliable elevation data (both bathymetric and topographic). Hence, these correlations can be established using hypothetical flow events for estimation of consequences known flood events. Similar approach can be followed for areas with global DEMs only. Nevertheless, for these areas only inundation extent is the flood magnitude parameter that can be used. In such events, it is recommended to derive flood extents from secondary sources (i.e. satellite imagery, aerial photograph, high water marks etc.). Flood depth can be also be estimated comparing that with a

DEM (Benz et al 2004, Hussein et al 2011). This ***Flood Consequence Correlation*** can be helpful to produce estimate of flood losses in remote areas and during or after a flood event.

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A PROBABILISTIC HYDROLOGIC MODEL TO ANALYZE THE UNCERTAINTY OF THE DESIGN HYDROGRAPH ATTRIBUTES

Ebrahim Ahmadisharaf[1], Alfred J. Kalyanapu[2] and Jason Lillywhite[3]

Reliable flood risk management (FRM) requires that all sources of uncertainty being addressed properly. One of the primary uncertainty sources is design hydrograph. Hydrologic modeling is one of the widely used methods to predict the design hydrograph. As hydrologic models are associated with uncertainty, the predicted hydrographs will be accordingly uncertain. It is therefore critical to understand the uncertainty of design hydrograph. Developing hydrologic models that are capable of incorporating uncertainties is thus emerging. *This study introduces a probabilistic hydrologic model that is capable of presenting the uncertainty of design hydrograph attributes due to multiple uncertainty sources.* The model employs Natural Resources Conservation Service infiltration method for rainfall-runoff transformation, Muskingum technique for channel routing and Latin Hypercube Sampling for uncertainty propagation. Although the uncertainty of hydrograph has been investigated in some previous studies, attention has been often given to a single attribute, peak. Utilizing the presented model, the uncertainty of other hydrograph attributes, including time to peak and volume, due to the uncertainty of design rainfall depth and antecedent moisture conditions can be also presented via probability distributions. The Swannanoa River watershed, which is a part of the Tennessee River basin and is located in the state of North Carolina, is used as the case study. The probabilistic model provides the hydrologists with valuable information on the uncertainty of design hydrographs and hence their place in the FRM.

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MAKING ROOM FOR BIG CREEK

Adrian Ward

BACKGROUND AND STUDY AREA

The Big Creek drainage basin has experienced repeated flooding issues as adjacent areas have been developed. Big Creek has a drainage area of approximately 155 square miles. Both the city of Millington and the U.S. Navy's Naval Support Activity (NSA) facility are located along the north side of Big Creek and are currently protected by an earthen levee. In 2010, Big Creek experienced a historic flood event that exceeded previous records and flooded the city of Millington and the NSA facility.

METHODOLOGY

The methodology for the study was as follows:

- Collect all readily-available data for the Big Creek drainage basin and for the stream itself, including additional field survey data.
- Develop a HEC-HMS hydrologic model of the basin capable of replicating the steady-state flows from the Shelby County Federal Emergency Management Agency (FEMA) Flood Insurance Study for the appropriate theoretical storms. The HEC-HMS model was also developed to be capable of using historic National Oceanic and Atmospheric Administration (NOAA) rainfall data to synthesize the unsteady state flows for the May, 2010 record flood.
- Develop and calibrate a HEC-RAS hydraulic model of the basin capable of modeling both steady state and unsteady state flows to evaluate potential improvement projects for the basin.

Develop and analyze conceptual proposed improvements to provide resiliency against the potential damages from future flooding.

DATA COLLECTION

Historical studies of the Big Creek drainage basin have been performed by various governmental, local, and regional organizations during the past 50 years. Therefore, significant amounts of existing studies exist. Both local and federal government agencies provided existing data and studies to aid in the development of this study. In addition, 73 new channel cross-sections were field surveyed and used with existing FEMA cross-sections to develop a new hydraulic model.

HYDROLOGIC AND HYDRAULIC (H/H) MODELING

This study developed a H/H model to evaluate the current flooding conditions using the most current land use and LIDAR data to model the topography of the drainage area and NEXRAD rainfall data to determine the inflows. Flood inundation mapping was performed and compared to aerial photography for calibration since no gage data was available. Once calibrated, simulations evaluating a variety of flood reduction alternatives were evaluated. These alternatives varied from regional detention facilities, levee improvements, a high flow diversion designed to transfer flow to the adjacent drainage basin and a park that would provide flood capacity necessary to prevent future flooding.

RESULTS AND FUNDING OPTIONS

After various flood simulations and cost estimates were prepared and reviewed it was determined that the park alternative was the most desirable alternative and would benefit the most residents. Benefit-cost ratio (BCR) was developed to support a resiliency grant submittal to the U.S. Department of Housing and Urban Development (HUD) in order to fund the desired flood mitigation project along Big Creek. The BCR documented how the proposed project would reduce flood damage costs, reduce vulnerability to low to moderate income households in the area and provide additional environmental value. After a competitive selection process, the project was selected and funded by HUD.

SESSION 3C

SEDIMENT
8:30 a.m. – 10:00 a.m.

Relationship Between Cohesive Soil Erosion Behavior and the Physical and Geochemical Properties of Soil in Tennessee, USA
Badal Mahalder, John Schwartz, Angelica M. Palomino and Jon Zirkle

GIS Tools to Locate Potential Sediment Sources in Stream-Channel Networks
Jennifer Cartwright

Facing Our Most Challenging Pollutant: Sediment from Unstable Streams. A Look Into Utilizing Stream Restoration as a Best Management Practice to Reduce Pollutant Loads
Adam V. McIntyre

RELATIONSHIP BETWEEN COHESIVE SOIL EROSION BEHAVIOR AND THE PHYSICAL AND GEOCHEMICAL PROPERTIES OF SOIL IN TENNESSEE, USA

Badal Mahalder, John Schwartz, Angelica M. Palomino, and Jon Zirkle

Erosion properties of cohesive soils can be defined with respect to excess shear stress and are dependent on two fundamental properties of soil: a threshold critical shear stress and erodibility coefficient. However, the prediction of cohesive soil erodibility is challenging in that limited advancements have occurred in developing an improved prediction model, especially compared to granular non-cohesive sediments. The inter-particle attraction in cohesive soils is one main reason behind this difficulty since the particle-level interactions are influenced by physical, geochemical and biological properties. In different geological locations, these properties vary spatially along both the stream bank and bed. No empirical approach has been published to date that the engineering community has significant confidence with its predictability. This study was conducted in a geologically diverse region in the United Sates in order to improve our understanding of cohesive soil erodibility phenomena. Field data were collected using the mini jet tester from 21 streams in four geological regions of Tennessee. Soil samples were collected from the jet testing locations for laboratory measurement of physical and geochemical properties. Jet-tester data were analyzed using the Blaisdell (1981) approach for measuring the critical shear stress and erodibility coefficient of the cohesive soils. Finally, multivariate statistical approaches were applied on these data for developing a predictive relationship of cohesive soil erodibility based on different soil properties. The response in different geological formations was analyzed as well. Findings from this research found some interesting and significant relationships among these data.

GIS TOOLS TO LOCATE POTENTIAL SEDIMENT SOURCES IN STREAM-CHANNEL NETWORKS

Jennifer Cartwright[1]

High-resolution digital elevation models (DEMs) derived from Light Detection and Ranging (lidar) provide new opportunities for analysis of stream-channel geomorphology. High-resolution DEMs contain spatially-comprehensive information (unlike conventional survey data) and enable characterization of geomorphic features with greater precision than is possible using lower-resolution elevation data. The U.S. Geological Survey has developed automated GIS tools designed for analysis of high-resolution DEMs that can be used to identify potential sediment sources in stream-channel networks. The tools can be used to modify DEMs using known locations of storm-water infrastructure, derive flow networks at user-specified resolutions, and identify topographic features including steep banks, abrupt changes in channel slope, or areas of rough terrain. These topographic features may indicate sites of geomorphic instability that contribute sediment, such as eroding stream banks, head cuts, and gullies. Field verification of tool outputs identified several tool limitations but also demonstrated their overall usefulness in highlighting likely sediment sources within stream-channel networks. In particular, locations producing consistent results from multiple tools can be used to prioritize field efforts to assess and restore eroding stream reaches.

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FACING OUR MOST CHALLENGING POLLUTANT: SEDIMENTATION FROM UNSTABLE STREAMS. A LOOK INTO UTILIZING STREAM RESTORATION AS A BEST MANAGEMENT PRACTICE TO REDUCE POLLUTANT LOADS

Adam V. McIntyre[1]

It is widely recognized that unstable streams contribute significant sediment to our waters, considered a top pollution priority. These sediments often carry excess nitrogen, phosphorus, heavy metals, and other impurities. Studies have shown that streambank sediments in agricultural areas have significant nitrogen and phosphorus components. In urban areas, other pollutants associated with urban growth get flushed into water supply through stream networks. Traditional approaches and regulations that focus stormwater management quality controls on impervious surfaces may miss opportunities to address a primary source of these pollutants.

In parts of the Southeast, local/regional governments are adopting various innovative stream assessment/watershed management approaches to improving water quality. These programs are being developed to address water quality requirements MS4/TMDL at the watershed level, while also providing opportunities to improve degraded streams. Programs that include stream restoration, channel protection, urban stormwater retrofits, regional stormwater controls and education programs on a watershed level are finding success in the reduction of pollutant loads in our waters. In addition, these practices improve in-stream habitat, providing a resurgence in the diversity and growth of aquatic species.

The presentation provides stream restoration and stormwater retrofit project examples selected and implemented based on the criteria of the stream assessment/watershed management approach. These projects largely focused on the reduction of sedimentation from in-stream bank erosion within significantly modified watersheds. A watershed assessment and geomorphic data collection procedure were developed to determine the most cost-effective restoration approach to enable these funding sources to meet primary goals.

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STUDENT POSTERS

Reclaiming Florida's Freshwater Supply
Jana Archer, Ingrid Luffman, and Andrew Joyner

Prediction of Storm Surge Impacts on Coastal Infrastructure Using AD-CIRC and HEC-FIA Models
John T. Brackins and Alfred J. Kalyanapu

Groundwater Flow in a Karst Watershed: Structural Controls of the Stoney Creek Syncline
Aaron Doyka, Ingrid Luffman, and Michael Whitelaw

Assessing Groundwater Geochemistry and Flow Path Using GIS in Karst Aquifer
Hung-Wai Ho and Danelle Solomon

Suspended Sediment Source Tracking: Review of the Method and Future Developments
Yanchong Huangfu, Shawn Hawkins, Alice Layton, Michael Essington, and Forbes Walker

Stimulation and Inhibition of Seedling Growth by Groundwater Rich in Sulfide
Melanie Kirtland (acknowledgement, Tom Byl)

A Comparative Analysis of the Development Trajectory of Mitigation Wetlands in the Piedmont Region
Anna M. Ledeczi, K. Patel, A. Reside, R. Tennent, and L. Yaseen

Driving Forces of Bioretention Effluent Nutrient Variability in Field Applications
Brandy N. Manka, J.M. Hathaway, R.A. Tirpak, Q. He, and W.F. Hunt

Evaluating Methods for the Comprehensive Characterization of Feedstocks for Anaerobic Codigestion
Juliet Ohemeng-Ntiamoah, Sarah Ramirez, Melissa Moffet, and Tania Datta

Accurately Predicting Botanical Nitrate Concentration to Reduce Nitrogen Leaching Caused by Over-Fertilization
Todd Pirtle and Song Chui

Flood Hazard Zone Development in India
Joseph C. Thornton, Alfred J. Kalyanapu, and Nanduri V. Umamahesh

RECLAIMING FLORIDA'S FRESHWATER SUPPLY

Jana Archer[1], Ingrid Luffman[2], and Andrew Joyner[2]

Florida's freshwater supply is endangered due to increased demand from population expansion and reduced availability associated with saltwater intrusion and drought, both of which are exacerbated by climate change (Jenkins et al., 2004). Human consumption of water has doubled in the United States since the 1940's which places increased pressure on water management systems (Montagna, 2002). By 2025, Florida's current water demand will no longer be sustainable given the depletion of the Floridian aquifer and other groundwater sources (Koch-Rose, 2011). Much of the state relies on aquifers, which are vulnerable to these pressures, and as a result water reuse has been adopted as a way to improve water management and meet future demand. According to Maupin et al. (2010), Florida ranked fourth in the United States for total freshwater use. In 2006, Florida ranked first in the United States for recycled water distribution (FLDEP, 2012) Water reuse is the process of recycling wastewater into effluent discharge to streams and new water products for irrigation (agriculture and golf courses), factory reuse, groundwater recharge, and wetlands reclamation. This study examines the spatial pattern of recycled water use in Florida to find gaps in distribution and identify potential areas for expansion of recycled water production as a way to increase freshwater supply.

METHODS

Publically-Owned Treatment Works (POTWs) using recycled water in Florida were extracted from the 2008 Clean Water Needs Survey (CWNS) database (USEPA, 2010) and combined with Florida's 2008 Reuse Inventory (FLDEP, 2010).

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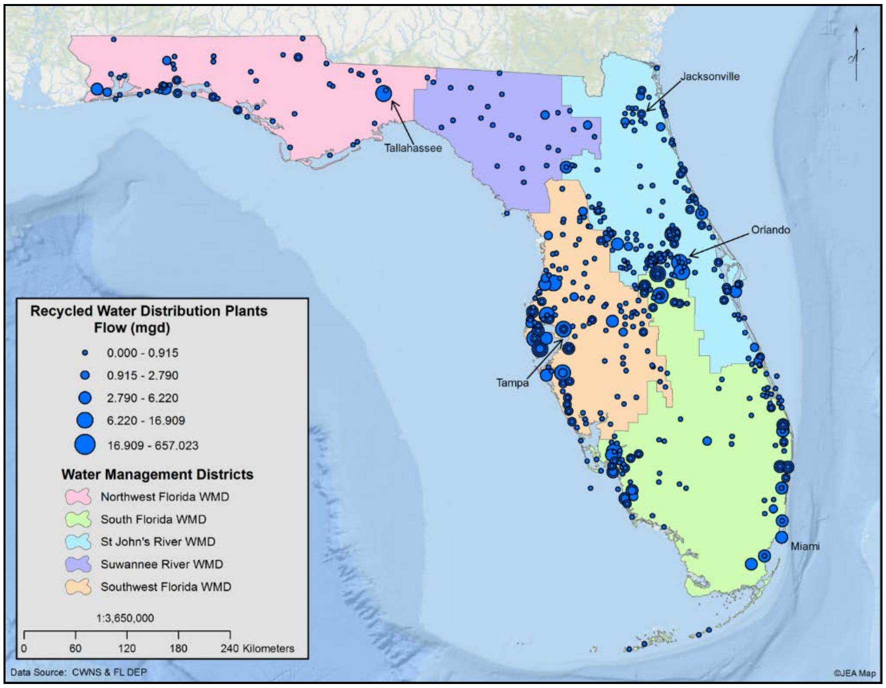

Figure 1: Recycled water distribution plant locations and flow for Florida in 2008

Each POTW was geocoded in ArcGIS 10.3. Of 927 separate recycled water products, 899 were successfully geocoded accounting for 98.5% of the total recycled water flow. The volume of flow in millions of gallons per day (mgd) was mapped for all discharged recycled water products, including groundwater recharge, industrial reuse, irrigation, spray irrigation, overland flow, and outfall to surface waters to show where most production occurred. Recycled water products were compared for each Water Management District (WMD) using SPSS 22.0. Flow data for all WMDs were log-transformed and a one-way ANOVA with Tukey *post-hoc* test were completed.

RESULTS

Of 546 POTWs in Florida, 481 (88%) distribute recycled water (FLDEP, 2010). Most of these are located along the coast and in central Florida, concentrated in the major metropolitan areas around the cities of Orlando, Tampa, and Miami (Figure 1). In 2008, Florida's POTWs produce a total flow of 666.82 mgd, distributed as multiple recycled water products (Figure 2). The most common discharge method associated with recycled water was spray irrigation. Irrigation of public access areas had a total distribution of 368.53 mgd (55% of the state total). Nearly 40% (146.65 mgd) of recycled irrigation water was supplied by POTWs to the South Florida WMD (Figure 3A). Industrial reuse was the next largest recycled water product in the state, with a total of 91.09 mgd (14% of the state total). Nearly 45% (40.86 mgd) of industrial water reuse was distributed by POTWs to users in the Southwest Florida WMD (Figure 3B). Only slightly behind industrial reuse, groundwater recharge had a total state production of 88.78 mgd (13% of the state total) with the largest portion distributed by POTWs to users in the South Florida WMD at 46.12 mgd (52%) (Figure 3C). At the state level, recycled water use for agricultural irrigation totaled 76.74 mgd (12% of the state total), with the largest portion distributed by POTWs to users in the Northwest Florida WMD at 32.49 mgd (42%) (Figure 3D). Last, at the state level, wetlands and other recharge totaled 41.68 mgd (6% of the state total), two-thirds (27.72 mgd) of which was distributed by POTWs to users in the St. John's River WMD (Figure 3E).

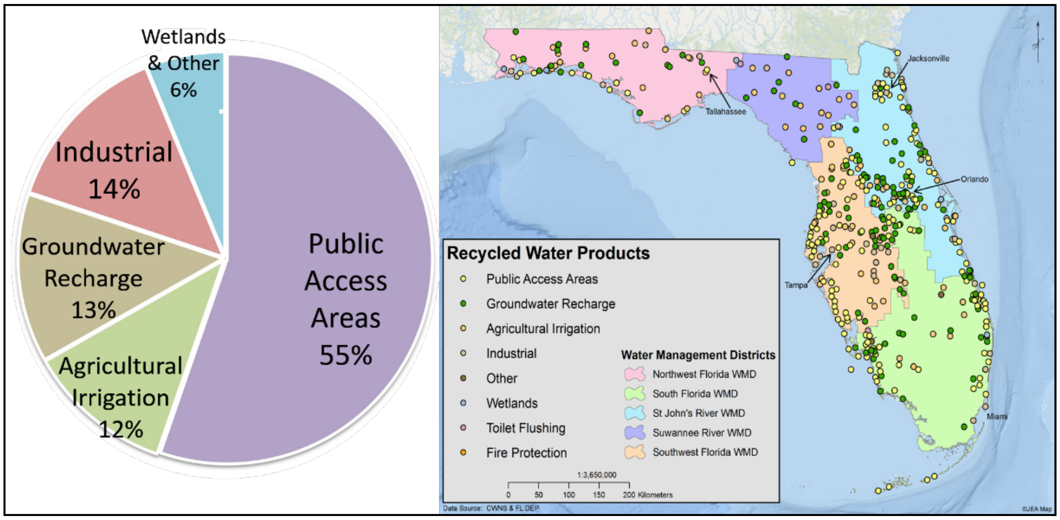

Figure 2: (left) Recycled water production by proportion (FLDEP, 2010) and main recycled water product by individual POTWs

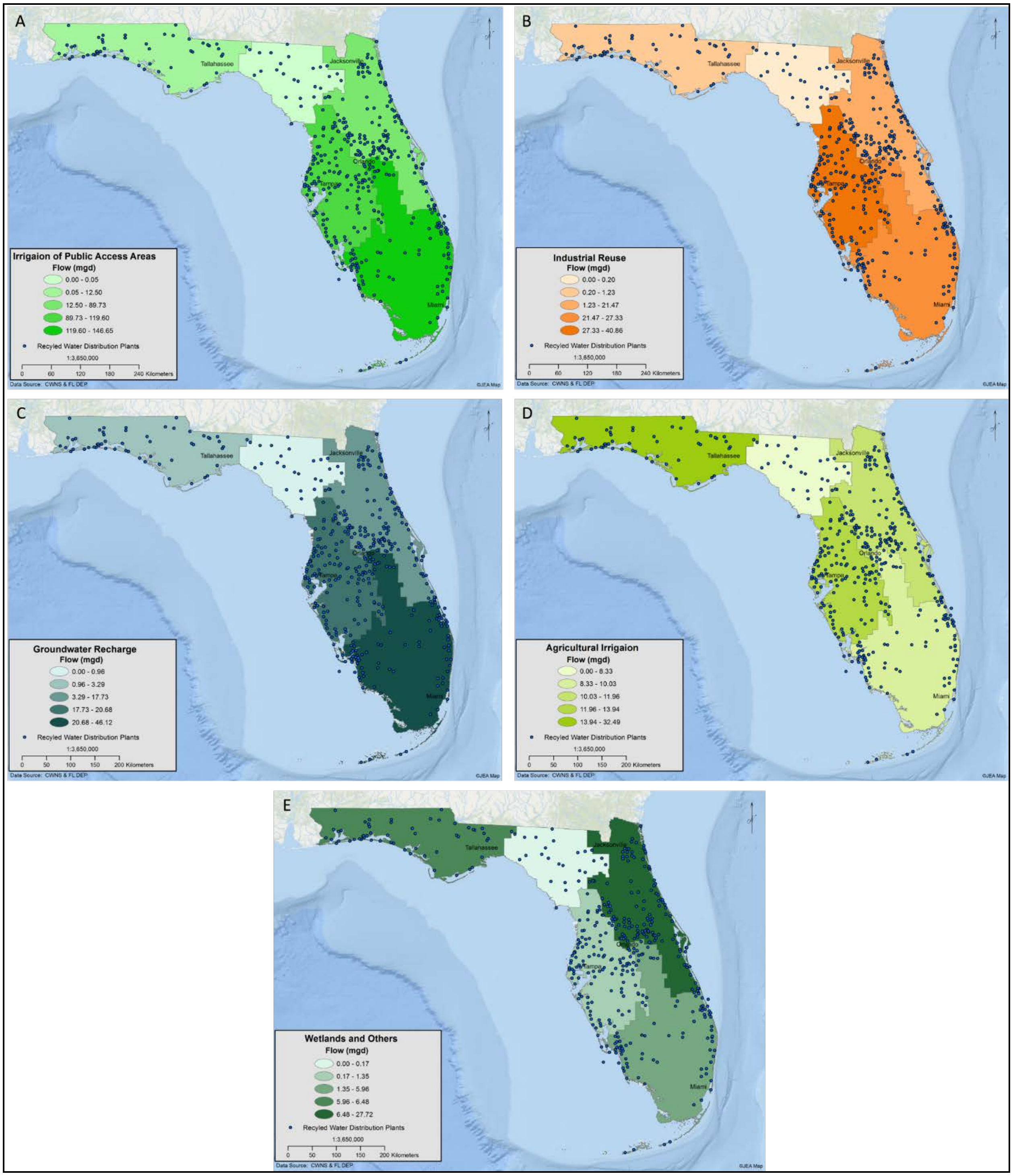

Figure 3: A) Public Access Areas, B) Industrial Reuse, C) Groundwater Recharge, D) Agricultural Irrigation E) Wetlands Recharge and Other

While each district produces recycled water for each category of discharge method, Suwannee River WMD was the lowest-producing district overall with a total production of 9.74 mgd (1.5% of the state total) (Figure 4). *ANOVA* results indicate significant differences in recycled water production between WMDs. *Tukey post-hoc* tests further show significant differences ($p < 0.05$) between South Florida and St. John's River WMDs, and South Florida and Northwest Florida WMDs. The Suwannee River WMD had the lowest mean production at 0.32 mgd (per POTW), but was not significantly different from the other WMDs. Land use in the Suwannee River WMD is primarily agricultural so there is less demand for water from the rural population. In addition, Suwannee River WMD and Northwest Florida WMD receive the bulk of Florida's precipitation, further reducing demand for water reuse products.

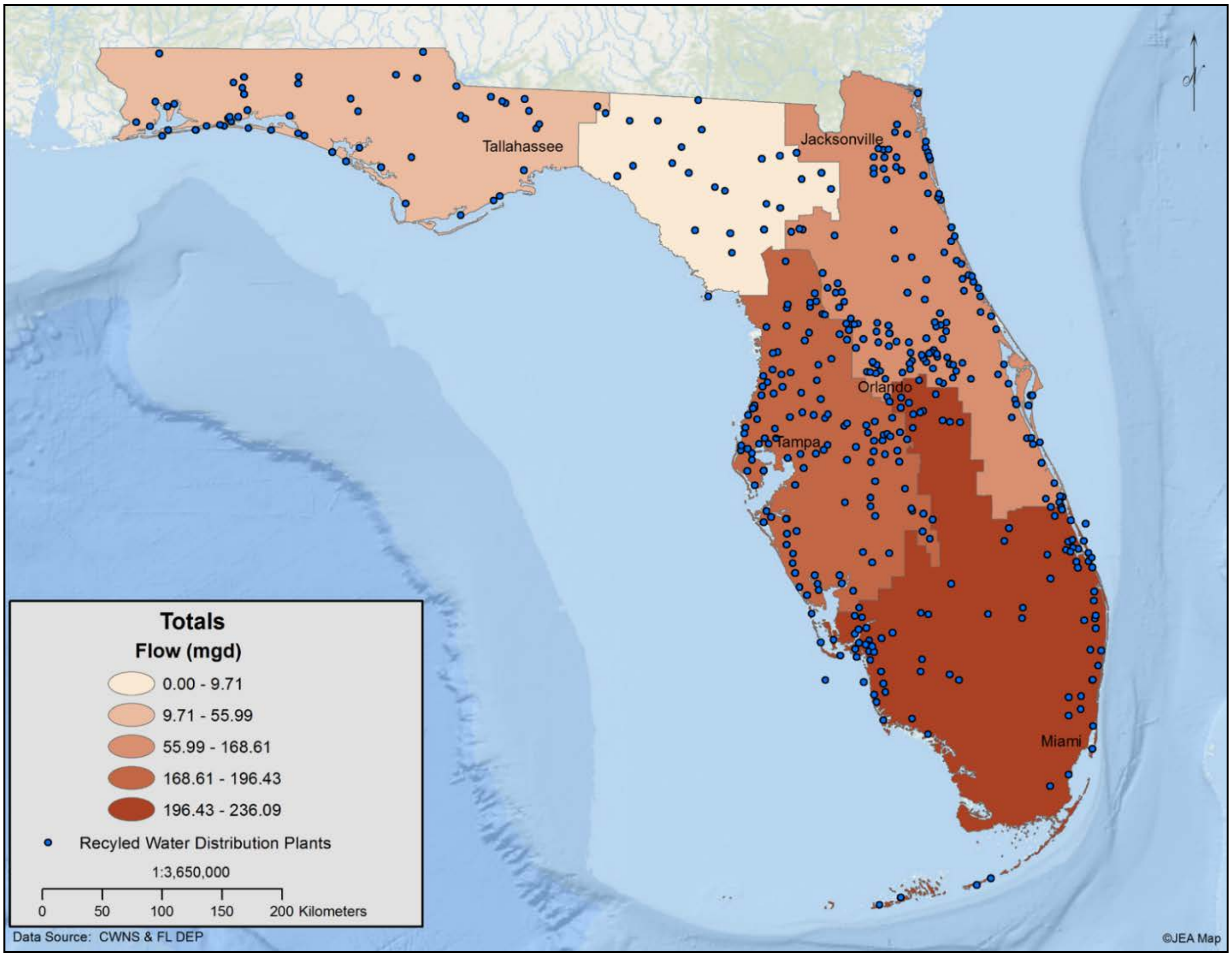

Figure 4: Total flow (mgd) per district

CONCLUSION

A spatial examination of recycled water use in Florida is a first step toward addressing water shortages through expansion of recycled water use. Water reuse is not balanced between districts even after accounting for the number of POTWs per district. Recycled water production is significantly less in the Suwannee River WMD than in the other districts; this may present an opportunity for expansion. Implementation of a recycled water program can enhance ecosystem health by reducing water withdrawal in coastal aquifers, slowing saltwater intrusion, and decreasing nutrient loading in surface streams. Consequently, recycled water use is an essential component of water conservation plans in water-stressed coastal communities.

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PREDICTION OF STORM SURGE IMPACTS ON COASTAL INFRASTRUCTURE USING AD-CIRC AND HEC-FIA MODELS

John T. Brackins[1]*, Alfred J. Kalyanapu[2]

INTRODUCTION

More than one-third of the United States population is at risk of coastal hazards due to hurricanes and nor'easters. A major contributor to this danger is the storm surge due to hurricane-force winds, which inundates coastal infrastructure and damages them due to breaking-wave action. The objective of this study is *to develop a modeling framework that links storm surge models to consequence assessment tools so that flood damages can be estimated*. To achieve this objective, the storm surge impacts on coastal infrastructure in the Cape Fear North Carolina basin under tropical cyclone conditions will be quantified using a combination of the ADvanced-CIRCulation (AD-CIRC) and the Hydrologic Engineering Center's Flood Impact Analysis (HEC-FIA) models. This analysis will serve as a methodology for future prediction of structural damages, as well as aiding in the production of other tools useful for making evacuation decisions for areas under threat of a tropical cyclone.

APPROACH

In order to quantify the effects tropical cyclone storm surge has on infrastructure, an accurate prediction model is required for the magnitude and timing of storm surge itself. This study utilizes the AD-CIRC model, a Fortran-based code that accepts elevation data such as topography and bathymetry as well as meteorological data like tropical cyclone tracks to determine water surface elevations (Luettich and Westerink 2004). Using Aquaveo's™ Surface Modeling System (SMS), a graphical user interface for AD-CIRC, a two-dimensional elevation mesh was created from bathymetric data from the General Bathymetric Chart of the Oceans (GEBCO 2014) and topographic data from the United States Geological Survey (USGS) National Elevation Dataset (NED). In this particular study, a mesh was created for the Cape Fear basin off the coast of North Carolina. Hurricane Floyd struck this area in 1999 as a Category 2 hurricane (NWS 2009), and Floyd's best track data were utilized from the HURDAT database (2012) as well as from a similar hurricane best track re-analysis database maintained by Colorado State University (Demuth et al. 2006). These best track data include Floyd's geographic location every 6 hours, maximum wind speed, radius to maximum winds, minimum central pressure, and the radius to the last closed isobar. Following mesh creation and input of meteorological data, the AD-CIRC model is ready to run.

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*This research is done entirely independently by the first author. Dr. Kalyanapu serves as the research advisor for the project.
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RESULTS AND DISCUSSION

Following the completion of the AD-CIRC run, various datasets become available for use in predicting flood impacts on coastal infrastructure. AD-CIRC calculates time-series datasets of water surface elevation (WSE), water velocities, wind fields, and pressure fields when hurricane parameters are specified. Of particular interest at this juncture is the WSE dataset, as it can be used to determine storm surge inundation above ground level. To obtain this, SMS was used to subtract the elevation mesh from the AD-CIRC WSE results. Once the inundation dataset was calculated, a filter was applied using SMS to determine the arrival time of a given flood threshold (0.5 foot of inundation swas used in this study). Both inundation data and floodwater arrival time are crucial inputs to HEC-FIA for infrastructure impact analysis.

After flood data have been gathered from AD-CIRC, one is ready to begin using HEC-FIA. In addition to flood data from AD-CIRC, the required input data for HEC-FIA include digital elevation models such as those available from the USGS NED, census block and county shapefiles as included in the Federal Emergency Management Agency (FEMA) Hazus model, and a structural inventory of the study area. For preliminary studies, Hazus includes a suitable structural inventory, but for detailed studies, these structural inventories should be created by local emergency management officials. Using these data, HEC-FIA can generate an aggregated structure damage report, an individual structure damage report, a detailed life loss estimation report, and an overall consequence summary report. Overall, these analyses and reports will aid in the planning and design of more flood-resilient infrastructure by identifying areas where current building practices or placements put citizens and infrastructure at risk, allowing examination of planning alternatives that could save lives.

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GROUNDWATER FLOW IN A KARST WATERSHED: STRUCTURAL CONTROLS OF THE STONY CREEK SYNCLINE

Aaron Doyka[1]*, Ingrid Luffman[2], and Michael Whitelaw[2]

INTRODUCTION

The Watauga River Watershed (HUC 06010103) drains 2,113 km^2 (816 mi^2) of east Tennessee and North Carolina; 75% of the watershed (1,590 km^2) lies in Tennessee (TDEC 2002). The study area is two HUC12 level watersheds within the Stony Creek Syncline, Gap Creek-Watauga River Watershed (060101030505) and Buffalo Creek Watershed (060101030502) (Figure 1). Extensive sinkhole and cave formation is present in the underlying carbonate rocks of the Stony Creek Syncline. Studies by Benfield et al. (2005), Gao et al. (2006), and Fridell et al. (2015) have demonstrated that groundwater flow within this area exhibits rapid flow (i.e. >0.001 m/s) characteristic of karst aquifers (ASTM 1995), and that groundwater readily crosses topographic divides. Because these studies have also shown that subsurface flow consistently follows structural controls, we anticipate that surface water from the Gap Creek-Watauga River Watershed enters the karst aquifer of the Stony Creek Syncline and resurges at springs within the Buffalo Creek Watershed. This hydrologic connection, if verified, has important implications for water quality, because both Gap Creek and Buffalo Creek are 303(d) listed for *E. coli* impairment. Implementation of the approved Total Maximum Daily Load (TMDL) (TDEC 2015) for these streams must take into account the potential for surface water-groundwater-surface water connections between watersheds through the karst system.

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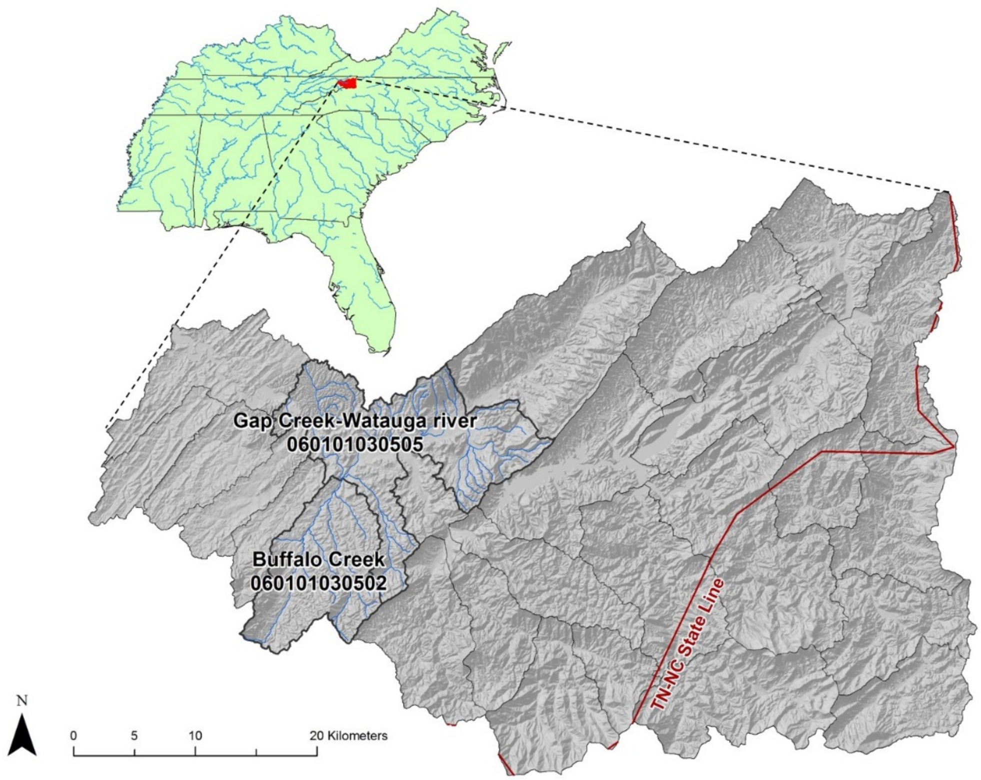

Figure 1. Location of Gap Creek-Watauga and Buffalo Creek watersheds.

GEOLOGIC SETTING

The Stony Creek Syncline (Figure 2) is a major regional fold in the Shady Thrust Sheet. Bounded to the northwest by the Holston Mountain Fault and to the southeast by the Iron Mountain Fault, the syncline extends to the northeast into Virginia and to the southwest disappears under the Buffalo Mountain Thrust Sheet at the Buffalo Mountain Fault (Hardeman 1966). The Stony Creek Syncline contains a complete sequence, with pre-Cambrian basement rocks to the northeast that young to the Ordovician Sevier Formation as the syncline plunges to the southwest (Rodgers 1953). The area of interest for this study is southwest of Elizabethton, in Carter County, TN where shales within the Upper Conasauga Group (Ꞓcu) form a confining layer under approximately 46 km^2 (~18 mi^2) of Knox Group (OꞒk) carbonate rocks. The Tennessee Cave Survey (TCS) 2015 database records 84 caves and accessible sinkholes within approximately 234 km^2 (90 mi^2) of rock units mapped in Carter County as dolostone or limestone (~0.35 features/km^2), 28 of which are within the study area (~0.61 features/km^2). The degree of karst development within the Knox carbonates indicates a complex and extensive subsurface conduit system in the study area.

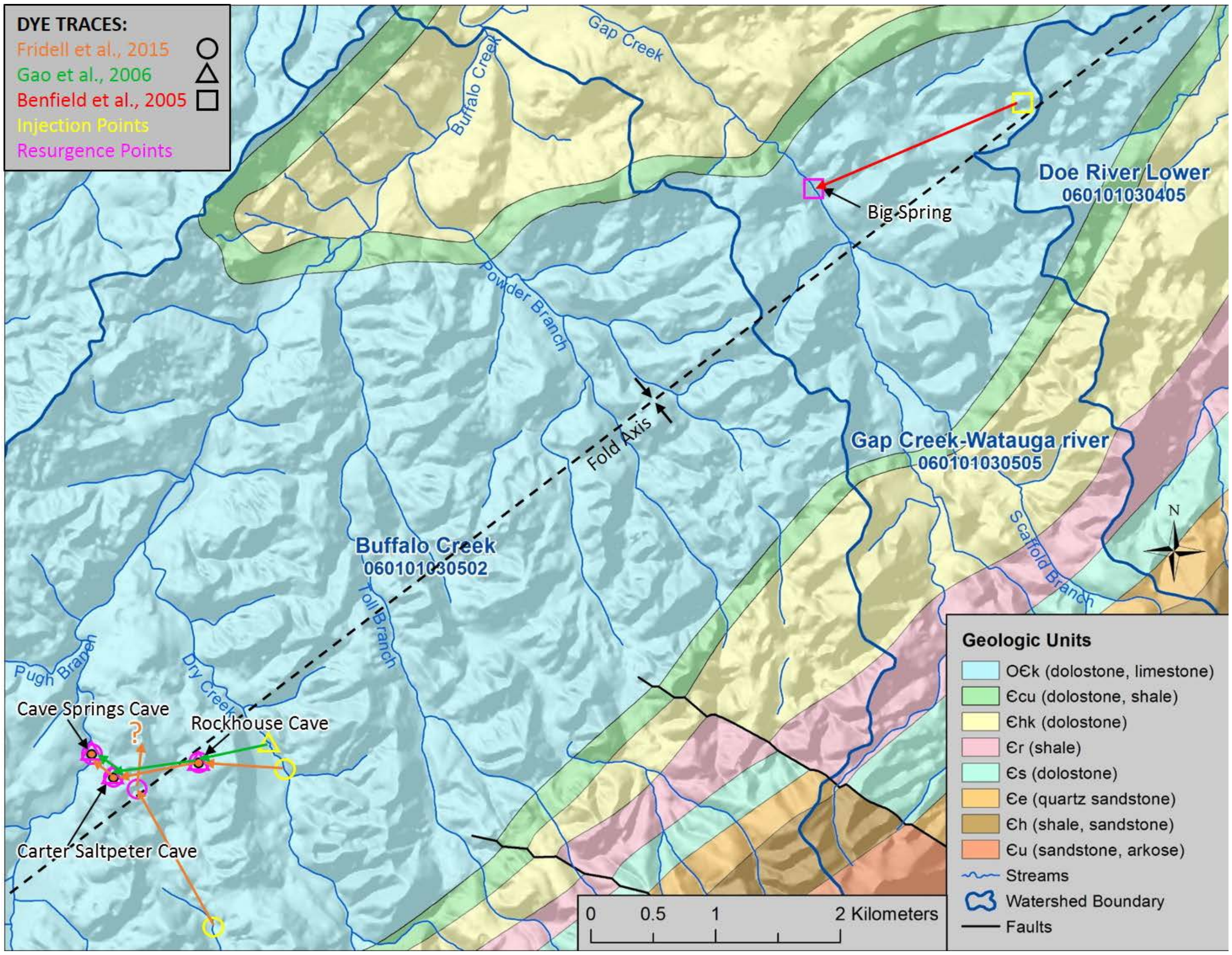

Figure 2. Geologic map of the Stony Creek Syncline showing previous dye trace results.

HYDROLOGY

The Buffalo Creek and Gap Creek-Watauga River watersheds are HUC-12 sub-watersheds dominated by karst topography. Surface water in the study area generally flows to the northwest, yet several studies have shown that subsurface flow tends to follow the structure of the Stony Creek Syncline. Studies by Gao et al. (2006) and Fridell et al. (2015) showed that at least one stream (Dry Creek) loses water through joints in the stream bed, which then flows west through multiple cave systems until resurging into Buffalo Creek. One of these caves, Carter Saltpeter Cave, has a second separate stream which receives source water from the southeast, controlled by joints and bedding in the southeast limb of the syncline (Fridell et al. 2015). At the northeast end of the study area, near Gap Creek, dye tracing of the source water for Big Spring has also shown that subsurface flow trends to the southwest, generally following geologic structure (Benfield et al. 2005).

IMPLICATIONS

Due to repeated demonstration of structural control of groundwater flow and the extensive dissolution of the Knox Group carbonates within the Stony Creek Syncline, the prospect of surface water from the Gap Creek-Watauga River Watershed flowing through subsurface conduits and resurging in the Buffalo Creek Watershed cannot be ignored. Transmission of water from the Gap Creek-Watauga River Watershed into the Buffalo Creek Watershed is significant because both Gap Creek and Buffalo Creek are listed as impaired due to *E. coli* on Tennessee's 2014 303(d) list (TDEC 2014). In addition, Gap Creek is listed for nitrates and habitat alteration due to sediment load. Should the hydrologic connection between these two HUC-12 watersheds be confirmed, TMDL implementation plans for either stream should be developed in concert, recognizing that the watersheds are not distinct, and restoration work in one watershed will have impacts on the watershed downgradient. Similarly, restoration work in the upgradient watershed should be completed first so that its benefits to water quality can be established in the downgradient stream independent of any restoration work in the latter.

RECOMMENDATIONS

A quantitative test using dye tracing is recommended to determine whether surface runoff from Gap Creek crosses watershed boundaries through groundwater flow. Dye should be injected in Gap Creek and detection equipment placed at intervals along Powder Branch, Toll Branch, Dry Creek, and Buffalo Creek, and at all known springs in the study area. Tracing methods should follow guidelines set out in the *Groundwater Tracing Handbook* (Aley 2002), and dye mass should be calculated using tracer mass determination outlined in Worthington and Smart (2003) and results from prior studies in the watersheds. Activated charcoal packets (BUGs) should be placed in target locations (primarily identified springs and stream junctions) and changed out regularly to constrain dye travel time. A second dye trace should be conducted after discharge points are established, with water samples being collected using an ISCO automatic water sampler to further constrain travel time and develop dye breakthrough curves.

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ASSESSING GROUNDWATER GEOCHEMISTRY AND FLOW PATH USING GIS IN KARST AQUIFER

Hung-Wai Ho[1]* and Danelle Solomon[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.

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Suspended Sediment Source Tracking: Review of the Method and Future Developments

Yanchong Huangfu, Shawn Hawkins, Alice Layton, Michael Essington, and Forbes Walker

For controlling the soil erosion and improving the water quality, many different techniques have been developed to track the sources of suspended sediments in the watershed over the past decade. We review these techniques by investigating into the entire procedure for each one, including sampling technique, laboratory work, and data analysis. In general, there are chemical and molecular ways to differentiate the suspended sediments within the streams. In chemical ways, fingerprinting and isotope source tracking are two primary methods to describe the techniques for determining the source of unknown sediment by their elemental properties. In molecular ways, several source tracking methods include pulse-field gel electrophoresis, denaturing-gradient gel electrophoresis, and 16S rRNA sequencing, which can identify the potential sources of suspended sediments by defining the context of microbial communities. All of these methods can investigate and characterize the content of suspended stream sediments on their possible sources. We also highlight some of their advantages and disadvantages for each method here. This review also provides different statistical models for assisting in analyzing the sources of sediment. Finally, future developments of the techniques for suspended sediment source tracking are discussed to incorporate practically the technology into improving the water qualities and controlling soil erosion efficiently.

STIMULATION AND INHIBITION OF SEEDLING GROWTH BY GROUNDWATER RICH IN SULFIDE

Melanie Kirtland[1] (acknowledgement – T.D. Byl[2])

The aqueous geochemistry varies in the irrigation wells on the Tennessee State University (TSU) campus research farm in Nashville, Tennessee. Water in four of the nine wells contains sulfide ranging from low (1.5 mg/L S^{2-}) to high (75 mg/L S^{2-}) concentrations, the sulfide-rich water easily identified by the H_2S odor. The biological effects of sulfide on plants have received increasing attention in recent years. Lab studies found that plants raised in water containing low concentrations of dissolved sulfide grew faster and larger. Those studies used sterile, reconstituted water and not natural waters rich in sulfide. The objective of this research was to determine if natural water collected from two of the TSU wells with sulfide would enhance or reduce plant growth. This was achieved by monitoring the germination and growth of four different seeds and germinating them under four different concentrations of sulfide, 0.0, 0.3, 3.0, 57.0 mg/L S^{2-}. The seeds used in this test were black seed Simpson lettuce (*Latuca sativa*), radish (*Raphanus sativus*), mung bean (*Vigna radiata*) and red bean (*Vigna angularis*). Nine seeds were placed in covered Petri dishes containing a filter paper soaked with 1.5 mL of test water. Germination was evaluated on day 2. Root growth measurements were taken on days 2, 4, 6 and 8. Statistically significant differences were determined using Student T-test with a p-value of 0.05. The sulfide water did not have a significant difference on the rate of germination for lettuce or radish seeds. The germination rate of mung bean seeds was enhanced 44% by 0.3 mg/L S^{2-}, 33% by the 3 mg/L S^{2-}, and 11% by the 57 mg/L S^{2-} as compared to seeds germinating in ultra-pure water. The germination of red bean was inhibited 11-33% by the sulfide waters. The growth of the lettuce roots were significantly enhanced (40% stimulation by day 8 in the 0.3 mg/L S^{2-} treatment). Low concentrations of sulfide significantly stimulated radish root growth (+18%), but high concentrations significantly inhibited radish root growth (-17%). Mung bean roots were significantly stimulated by all concentrations of sulfide, ranging from +80 to 120% longer roots by day 8. Red bean roots were significantly inhibited (approximately 50%) by all the sulfide waters. These results indicate that TSU's natural sulfide waters tend to stimulate growth at low concentrations of sulfide, with the exception of red beans which were inhibited. Ongoing tests are looking at leaf growth and plant biomass.

Additional acknowledgement: The author would like to thank Dr. John Lee, Hume Fogg High School for use of his lab; Dr. Matthew Blair, TSU, College of Agriculture for bean seeds; and Dr. Dafeng Hui TSU, Biology Dept for greenhouse space.

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A COMPARATIVE ANALYSIS OF THE DEVELOPMENT TRAJECTORY OF MITIGATION WETLANDS IN THE PIEDMONT REGION

Anna M. Ledeczi, K. Patel, A. Reside, R. Tennent, and L. Yaseen

Wetlands act as natural buffers against urban and agricultural runoff, filtering water before it reaches rivers and streams. Under Tennessee Department of Environmental and Conservation policy, mitigation wetlands are created using the standard “bath-tub” method to offset natural wetlands destroyed by infrastructure construction. Current estimates suggest that it takes 12-15 years for a wetland to fully develop. The soil properties and water retention abilities of a mature natural wetland and four mitigation wetlands in the Cumberland River floodplain were examined to compare their developmental trajectories. As both the natural and mitigation wetlands developed, the standard wetland water cycles became more established as indicated by changes in soil color, nodule presence, and the perched water retention after precipitation events. The water retention and soil characteristics analyzed in this study reveal that the two developing wetlands are becoming more similar to the natural wetland, indicating that the mitigation wetlands involved in this study are following the desired development trajectory and should become fully functional within the allotted time interval.

DRIVING FORCES OF BIORETENTION EFFLUENT NUTRIENT VARIABILITY IN FIELD APPLICATIONS

B.N. Manka[1], J.M. Hathaway[1], R.A. Tirpak[1], Q. He[1], and W.F. Hunt[2]

The purpose of this study is to build upon our understanding of nutrient variability in bioretention effluent by translating laboratory observations to field installations. Nutrient variability is explored in eight bioretention cells in North Carolina, USA and two in Nashville, Tennessee, USA, to determine how environmental conditions such as temperature and soil moisture affect nutrient effluent concentrations. Analytes for the samples included nitrate (NO_3-N), ammonium (NH_4-N), total nitrogen (TN), orthophosphate (PO_4), and total phosphorus (TP). Variables identified to affect nutrient and microbial dynamics included temperature, antecedent rainfall totals, and relative humidity. The effect of these variables was tested at multiple antecedent time periods to account for varied temporal effects. Average temperature, total rainfall, and average relative humidity were calculated for the 2, 7, and 28 days preceding a given storm. Additionally, the rainfall depths of each storm event were utilized as an additional explanatory variable. Non-parametric statistical analyses were performed in order to determine seasonal variance trends across sites and correlations between environmental parameters and effluent nutrient concentrations. The largest and most consistent relationships were identified for NO_3-N and TN, where both antecedent precipitation depth and temperature were found to be significantly correlated to effluent concentrations for over half of the sites. For PO_4, TP, and NH_4-N no relationships were consistent across more than five of the 12 sites. Inter-event nutrient removal variability appears to be influenced by seasonal temperature and precipitation changes, consistent with findings from laboratory studies.

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EVALUATING METHODS FOR THE COMPREHENSIVE CHARACTERIZATION OF FEEDSTOCKS FOR ANAEROBIC CO-DIGESTION

Juliet Ohemeng-Ntiamoah[1], Sarah Ramirez, Melissa Moffet, and Tania Datta

Anaerobic co-digestion is the process of adding supplemental feedstocks to an anaerobic digestion system to augment biogas production. Although co-digestion results in higher biogas yields, complex and variable feedstock characteristics often inhibit key microbial communities from functioning effectively, resulting in operational problems. It is therefore important to thoroughly analyze various feedstocks to be used in an anaerobic co-digestion process. Very few studies have looked into a more detailed characterization of feedstocks for anaerobic co-digestion. However, in order to design and operate efficient anaerobic co-digestion systems, a detailed feedstock characterization of lipids, carbohydrates and proteins is important. Also, there is not enough literature on the methodologies for comprehensively characterizing feedstock for anaerobic co-digestion. This paper seeks to address these gaps by evaluating and standardizing methods for a more comprehensive characterization of wastewater sludge, foodwaste and animal manure as anaerobic feedstocks in order to gain knowledge for optimizing the anaerobic co-digestion process. In this study, Bligh & Dyer method and anthrone method were used to determine the %lipid and total carbohydrate respectively. Protein content was estimated as containing 16% nitrogen. The next phase of the study will evaluate a matrix effect by running the above methods on a mixture of wastewater sludge spiked with standard solutions. Finally, the methods will be repeated on a mixture sample containing wastewater sludge, foodwaste and animal manure at different proportions. Biomethane Potential (BMP) test and Anaerobic Toxicity Assay (ATA) of feedstocks will be conducted and correlations between the bioassays and the feedstock characteristics will be developed.

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ACCURATELY PREDICTING BOTANICAL NITRATE CONCENTRATION TO REDUCE NITROGEN LEACHING CAUSED BY OVER-FERTILIZATION

Todd Pirtle[1*] and Song Cui[1]

INTRODUCTION

Nitrogen is the most important nutrient in biomass feedstock crop production such as native warm-season grasses (NWSG), yet one of the most difficult to manage (Cui et al., 2013). Insufficient N application can cause low biomass production and reduce economic profitability. Inversely, excessive N application can cause severe nitrate contamination to ground and low hydrocarbon yield during the thermochemical processes for biofuel production. Thus, compiling a rapid and accurate method for estimating botanical nitrate concentration is of paramount importance.

APPROACH

This study used remote sensing-based instruments and regression-based mathematical models to estimate nitrate concentration of two NWSG, including Alamo Switchgrass and Cheyenne Indiangrass. Urea fertilizer was applied in four levels. Foliar chlorophyll concentration and spectral reflectance were measured weekly using a SPAD 502 Plus Chlorophyll meter and ASD FieldSpec4 spectroradiometer, respectively. Botanical nitrate concentration was measured using a TL-2800 Ammonia Analyzer and all spectral data were analyzed using machine learning algorithms implemented using the Matlab Programming Language.

RESULTS AND DISCUSSION

Our algorithm successfully recognized the spectral patterns and accurately predicted the nitrate concentration across two NWSG (R^2 = 0.71 and RMSE = 0.84).

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FLOOD HAZARD ZONE DEVELOPMENT IN INDIA

Joseph C. Thornton*, Alfred J. Kalyanapu, and Nanduri V. Umamahesh

On average, India has more lost Gross Domestic Product and people affected by river flooding annually than any other country. Future population growth will increase losses unless preparations are made for future flood events. A precaution practiced in other countries is flood hazard zoning (FHZ). The National Water Policy of India states that FHZ is a non-structural measure taken to minimize loss of life, property and the recurring expenditure of flood relief. Even though it is federal policy, it has not been practiced due to opposition at the state level. This study aims to answer the question, "How can the benefits of FHZ implementation and enforcement be measured and leveraged as evidence supporting FHZ formation?" A case will be developed using hydraulic modeling of five probability flood events. The resulting inundation maps will be used to demarcate zones with varying flood risks, and high-risk areas will be restricted as no development zones. After the FHZs are established, current land use patterns will be assessed to see if development presently in place violates the established FHZs. Using a GIS-based approach, development in the FHZs will be assigned socioeconomic values based on potential lives affected/lost and monetary loss. Future land use projections will be used to estimate future benefits of FHZs. A comparison will be made between a scenario where the FHZs are being enforced with no future development of the floodplain and a scenario without FHZs where development is unregulated. The results will be used to convey the benefits of FHZs.

EXHIBITORS and SPONSORS

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At Amec Foster Wheeler, our combination of local expertise and global reach allows our Clients to feel secure doing business with us. By integrating the latest technologies into our stormwater data collection processes, we have helped reduce our Client's data collection costs by 50%. With offices in Nashville, Knoxville, and Chattanooga, our multi-disciplined team can help ease the pain of surface water management.

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OTT Hydromet
5600 Lindbergh Drive
Loveland, CO 80539
512-528-9775
970-232-8594 cell
Contact: Bill Harrington
Email: bharring@otthydromet.com
www.ott.com

OTT Hydromet, a member of Hach Company, 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.

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

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Trutta Consulting
415 Stonecrest Drive
Birmingham, AL 35242
Contact: Brett Connell
Phone: (419) 215-7897
Email: truttaconsulting@gmail.com
http://www.truttaconsulting.com/

Trutta Consulting provides aquatic habitat surveying and assessment services. We have developed and use the High Definition Stream Survey (HDSS) which 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.

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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: 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.

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ASCE Tennessee Section/Environmental and Water Resources Institute
Contact: Thomas B. Lawrence, P.E., M.ASCE
TN ASCE President
Phone: (901) 237-4819
Contact: Alvin Cook, P.E., M.ASCE
TN EWRI Chair
Phone: (423) 892-1810

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
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Phone: (615) 252-4329
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Contact: Adrian Ward, P.E.
Senior Project Engineer, Environment and Water Resources
Email: Adrian.Ward@bwsc.net
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Barge, Waggoner, Sumner & Cannon, Inc. is a professional services firm in Nashville, Tennessee, with offices in Ohio, Tennessee, Alabama and Georgia. The staff of BWSC offers a wide range of water resource services, focused on water supply and treatment, groundwater, storm water, municipal and industrial wastewater, utility management, feasibility studies, watershed management and rehabilitation, natural channel design, in-system mitigation, and river and impoundment hydrology and hydraulics.

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://memphis.edu/caeser

The University of Memphis' Ground Water Institute and Center for Partnerships in GIS combined their expertise to form the Center for Applied Earth Science and Engineering Research (CAESER) in 2015. This new center will continue the efforts of its former institutes, while broadening its areas of expertise to help build smarter, stronger communities through research and education.

Center for the Management, Utilization and Protection of Water Resources
Tennessee Technological University
P.O. Box 5033
Cookeville, TN 38505
Phone: (931) 372-3507
http://www.tntech.edu/research/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

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Civil & Environmental Consultants, Inc.
325 Seaboard Lane, Suite 170
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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.

Neel-Schaffer, Inc.
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KCI TECHNOLOGIES

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 stream and wetland restoration, 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.

Exhibitors

Eureka Water Probes
2113 Wells Branch Pkwy, Suite 4400
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Contact: Jonathan Evans
Phone: (678) 765-7118
Email: jevans@waterprobes.com
Contact: Gary Miller
Phone: (512) 302-4333
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http://www.waterprobes.com

Eureka Water Probes is a designer and manufacturer of water quality instrumentation used to monitor our world's fragile water supplies. Eureka's Manta2 multiparameter sondes, software, and data collection platforms, are used to monitor surface and ground water quality for a wide variety of applications.

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HydroLogics
30 Orchard View
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Contact: Steven Nebiker
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HydroLogics has over 30 years of experience in modeling and managing water resources. The firm's OASIS software is used to support water allocation decisions, develop drought management plans, and evaluate the benefits of water efficiency and conservation measures.

HydroTech ZS Consulting
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Suntree Technologies Inc.
798 Clearlake Road, Suite 2
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Suntree Technologies Inc. offers a wide range of engineered stormwater treatment devices for environmental compliance. Suntree's Nutrient Separating Baffle Box is the ONLY system with Hydro-Variant Technology: enabling superior performance on line without the headloss commonly associated with other treatment devices. Suntree is the licensed national distributor of Bold and Gold media, proven to remove nitrogen, phosphorus and TSS from stormwater runoff. Contact our approved area distributor, Jen Hill Construction Materials (800) 452-4435 or (321)637-7552 for information.

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

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Water & Land Solutions (WLS) is a hybrid mitigation solutions and land management firm that incorporates expertise in mitigation banking, environmental finance, environmental consulting, land use applications, and regulatory permitting. We use our experience and expertise to ensure land owners can maximize yield while complying with current environmental regulations. As mitigation experts, our approach is to eliminate inefficiencies in the mitigation marketplace to maximize the value added for the individuals and/or entities involved in each project.

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