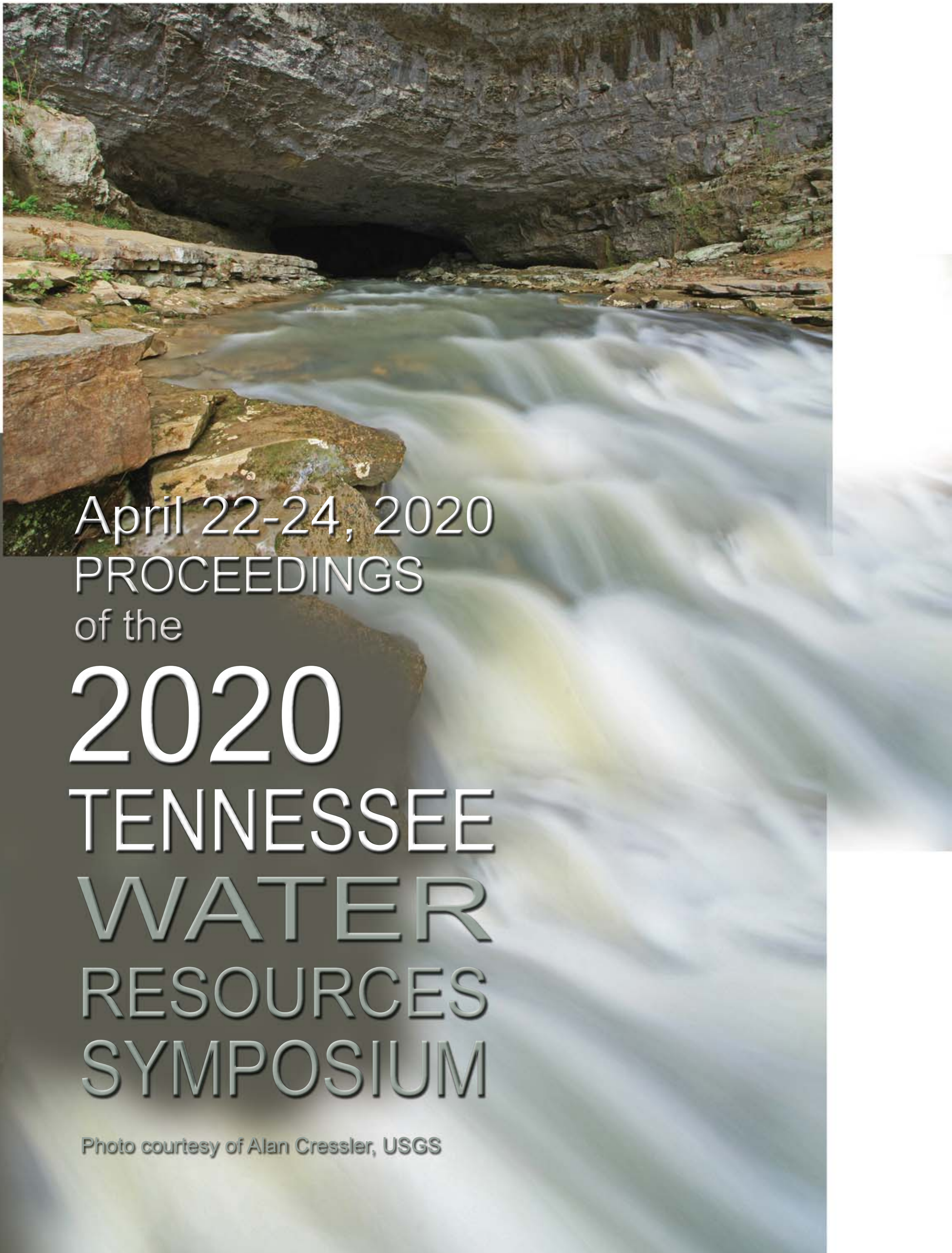

April 22-24, 2020

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Photo courtesy of Alan Cressler, USGS

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12:00 – 1:30 p.m.
Wednesday, April 22
Keynote Address *by* Stephen Ornes, Science Writer and Vanderbilt University, Communication of Science and Technology Program

BEYOND THE WATERSHED: HOW TO REACH A WIDER AUDIENCE FOR YOUR RESEARCH

You've done the work. You've designed the experiment, you've spent hours or days in the field, or in the lab, collecting data. Then you've gone back and collected more data, asked better questions. You've analyzed your data, found the signal in the noise – or *not* found the signal, which might be even more interesting – and drawn some conclusions. You've made recommendations; you've written it up in the strangled jargon that many journals require; you've submitted it for publication; you've shared it with your colleagues.

But how do you expand that reach, not only to far-flung researchers (who might benefit from knowing the questions you asked and seeing the data you collected) but also the general public?

In this talk, award-winning science writer Stephen Ornes (stephenornes.com) will give a brief overview of the state of science communication and the challenges of being heard in an increasingly noisy world. We'll discuss ways to find and reach a target audience, as well as communication tools and strategies that can help researchers connect with a broad audience. From newsletters to social media to Twitter feeds to podcast series, the options can seem simultaneously dizzying and overwhelming, but the effort can lead to more meaningful engagement with a wider world.

12:00 – 1:30 p.m.
Thursday, April 23
Lunch Presentation *by* Sarah Houston, Associate Director, CAESER

SESSION 1A

HYDROGEOLOGIC FRAMEWORKS OF THE MAP
(Moderator: Wade Kress, USGS)

STREAM RESTORATION
(Moderator: John Schwartz, UT)

SESSION 1B

STREAM QUANTIFICATION TOOL STUDIES
(Moderator: Angel Fowler, Blueway)

SESSION 2A

WATER MODELING
(Moderator: Alfred Kalyanapu, TTU)

URBAN STORMWATER MANAGEMENT
(Moderator: Paul Davis, P.E.)

FLOODPLAIN MANAGEMENT
(Moderator: Tom Palko, Metro Water Services)

REAL-TIME MONITORING
(Moderator: Shannon Williams, USGS)

SESSION 2B

WATER SUPPLY
(Moderator: Daniel Saint, TVA)

STORMWATER STUDIES
(Moderator: Michael Hunt, Metro Water Services)

SESSION 2C

MICROBIAL STUDIES
(Moderator: Wayman Ho, TDEC-DWR)

BIOLOGICAL ASSESSMENTS
(Moderator: Tom Byl, USGS)

WETLANDS RESTORATION
(Moderator: Andrea Ludwig, UT)

SANITARY SEWER ACCESS PROGRAM
(Moderator: Melissa Harris, USGS)

SESSION 3A

WASTEWATER
(Moderator: Tania Datta, TTU)

SESSION 3B

WEATHER AND CLIMATE
(Moderator: Md Nowfel Bhuyian, TDEC)

SESSION 3C

AGRICULTURAL STUDIES
(Moderator: Jenny Dodd, TDEC-DWR)

STUDENT POSTERS

PROFESSIONAL POSTER

SESSION 1A

HYDROGEOLOGIC FRAMEWORKS OF THE MAP (Moderator: Wade Kress, USGS)
1:30 p.m. – 3:00 p.m.

Improving Our Understanding of Groundwater-Surface Water Exchange Using Hydrogeophysical Methods
Ryan Adams

Hidden Complexity of the Mississippi Alluvial Aquifer Illuminated Like Never Before Using Regional-Scale Airborne Geophysics
Burke J. Minsely, Bethany L. Burton, Michael D.M. Pace, Stephanie R. James, Paul A. Bedrosian, Wade H. Kress, and J.R. Rigby

Integration of Hydrogeophysics into Hydrologic Models
J.R. Rigby, Randall J. Hunt, Andrew T. Leaf, Moussa Guira, Jonathan P. Traylor, Steven M. Peterson, and Burke Minsely

STREAM RESTORATION (Moderator: Scott Schoefernacker, CAESAR)
3:30 p.m. – 5:00 p.m.

The Use of High Definition Stream Survey to Document Channel Conditions for the City of Cleveland's MS4 Stormwater Permit
James Parham and Brett Connell

Case Study on Technologies for Urban Stream Restoration
Ken Barry and Patrick McMahon

Putting Flow-Ecology Relationships into Practice with a Decision-Support System Framework
Casey Caldwell and Steven Nebiker

IMPROVING OUR UNDERSTANDING OF GROUNDWATER-SURFACE WATER EXCHANGE USING HYDROGEOPHYSICAL METHODS

Ryan Adams

The U.S. Geological Survey (USGS) is currently conducting a multi-year analysis and recharacterization of the Mississippi Embayment Regional Aquifer System (MERAS) groundwater flow model focusing on the water resources within the Mississippi Alluvial Plain (MAP). Part of this recharacterization was the evaluation of the existing model based on uncertainty and data worth analysis. These data quality measurements indicated that the MERAS model was sensitive to groundwater-surface water exchange, but this component was poorly constrained and the confidence in the model forecast was low.

To increase the density of data within the models' most sensitive rivers and streams, the USGS completed 900 kilometers (km) of waterborne resistivity surveys within Mississippi to characterize streambed lithology. This technique characterizes streambed itself and the near surface (upper 15-30 meters) of the streambed that controls the recharge to the alluvial aquifer. These data can be used to map changes in the lithology of the streambed and identify areas of potential groundwater-surface water exchange.

To map these sediments, electrical resistivity data was collected using a resistivity meter connected to floating multi-electrode cables. Information about the spatial location of each data point, depth of the water column, and electrical properties of the water column were also collected.

Five rivers in the Mississippi Delta region were the focus of this study: the Bogue Phalia, Quiver, Sunflower, Tallahatchie, and Yazoo Rivers. These rivers flow over a variety of fluvial and deltaic deposits. While streambed sediments show a strong correlation with surficial geology, changes in the vertical extent of those geologic features had a strong impact on the aquifer recharge potential expected for a given water body.

The inverted waterborne resistivity data were transformed to hydraulic conductivity using relationships derived from geophysical logs collected within the study area. Estimated hydraulic conductivity values generated from downhole nuclear magnetic resonance (NMR) data were compared to electromagnetic induction logs to generate a relationship between electrical resistivity and hydraulic conductivity.

The resistivity-derived estimates of hydraulic conductivity show a significant increase in magnitude and spatial variability as compared to the estimates derived from groundwater model parameter estimation. Some amount of this change was expected due to the increased sampling density and smaller footprint of the resistivity surveys. The remainder of the difference between the two estimates is likely due to the incision of river channels into and beneath the shallow 5-10 m confining unit that overlays a large portion of the MAP within Mississippi.

HIDDEN COMPLEXITY OF THE MISSISSIPPI ALLUVIAL AQUIFER ILLUMINATED LIKE NEVER BEFORE USING REGIONAL-SCALE AIRBORNE GEOPHYSICS

Burke J. Minsley[1]*, Bethany L. Burton[1], Michael D.M. Pace[1], Stephanie R. James[1], Paul A. Bedrosian[1], Wade H. Kress[2], and J.R. Rigby[2]

INTRODUCTION

In 2018, the Mississippi Alluvial Plain (MAP) Regional Water Availability project began a multiple-year airborne geophysical mapping initiative using airborne electromagnetic (AEM), magnetic, and radiometric surveys. An initial high-resolution survey began in March 2018 that comprised ~2,500 line-km of airborne data over a 1000 sq. km area near Shellmound, MS, using the helicopter CGG Resolve AEM system. Later that year, we began the first phase of a regional AEM survey using the Resolve instrument to acquire ~17,000 line-km of data mainly along west-east flight lines separated by 6 - 12 km over the entire MAP region, nearly 100,000 sq. km. In late 2019, a second phase of regional mapping began using the fixed-wing Tempest AEM system, increasing data density across the MAP area, while also extending our depth of investigation from 60-100 m with the Resolve system to 250-350 m with the Tempest system. In addition to the west-east flight lines, over 3,000 line-km of data have been added to the west-east lines along the Mississippi River and several tributaries to characterize the connectivity between surface water and groundwater. AEM data are providing the first high-resolution system-scale view of the subsurface architecture of the MAP aquifer system. Geophysical interpretations are helping to refine estimates of confining layer thickness, surficial aquifer thickness and heterogeneity, and the geometry of subcropping Tertiary units beneath the surfical aquifer. By better quantifying and reducing uncertainty in the geologic framework, we hope to produce improved estimates of hydrogeologic structure and function to inform water management decisions.

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INTEGRATION OF HYDROGEOPHYSICS INTO HYDROLOGIC MODELS

J.R. Rigby[1]*, Randall J. Hunt[2], Andrew T. Leaf[2], Moussa Guira[3], Jonathan P. Traylor[3], Steven M. Peterson[3], and Burke Minsley[4]

INTRODUCTION

The Mississippi River alluvial plain is home to one of the highest concentrations of irrigated agriculture in the United States and serves as a major economic engine for the Lower Mississippi River Basin. Agriculture in the alluvial plain is overwhelmingly dependent on groundwater for irrigation which places tremendous strain on the Mississippi River Valley alluvial aquifer (MRVA). To address current and future groundwater availability for the region, the USGS is conducting an integrated water resources assessment, the Mississippi Alluvial Plain Water Availability Study, an innovative study using the development of a network of models and underlying data sets to support a central decision support system for water resources planning and management. In order to update the hydrogeologic framework of the MRVA, in 2019-2020 the MAP team conducted the largest airborne electromagnetic (AEM) survey for water resources in the continental United States to date. While traditional boreholes are employed to help interpret the AEM data, the airborne surveys return orders of magnitude more information on the structure of the aquifer than traditional borehole networks. A suite of hydrologic models incorporates the new AEM data using interpreted products such as facies maps and contacts with subcropping units. The AEM data allow for the incorporation of a more accurate subsurface hydrostratipgraphic framework in the groundwater-flow models over traditional methods of interpolation of borehole logs. The improved hydrostratigraphic framework will imporove the simulation of groundwater-flow processes in both the regional model and local inset models under development.

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THE USE OF HIGH DEFINITION STREAM SURVEY TO DOCUMENT CHANNEL CONDITIONS FOR THE CITY OF CLEVELAND'S MS4 STORMWATER PERMIT

James Parham[1] and Brett Connell[1,2]

Municipal responsibility under the Tennessee phase II MS4 general stormwater permit compliance is intended to minimize stormwater runoff and protect its citizens from various water pollution issues. The City of Cleveland, TN contracted Trutta Environmental Solutions to document the streambank and channel conditions within the city's boundaries using the High Definition Stream Survey (HDSS). HDSS method is adaptable to different sampling protocols including the Maryland Stream Corridor Assessment Survey Protocols which was used in the past by the city. Using the HDSS platform on both kayak and backpack, all necessary information was collected on 30 miles of stream in only 4 days with a crew of 2 technicians. In addition to completing MS4 Permit requirements associated with documenting the stream channel conditions, the city now has extensive geo-referenced, baseline condition video of its streams to track progress on the issues documented during this initial survey.

The HDSS approach was created to rapidly gather continuous geo-referenced data in a single pass for a broad range of stream and streambank conditions by integrating GPS, video, depth, water quality and other sensors. Once the data are collected, the videos are combined to create a virtual tour with four simultaneous views of the river survey (front, left bank, right bank and underwater). Other information such as side-scan sonar and a dynamic overhead map are also included when applicable. Because each second of video is linked to a specific GPS point, this allows for the identification, selection and prioritization of streambanks for restoration. The results can also be used to monitor restoration results, determine the extent and distribution of instream habitat, define the geomorphic condition for the stream, identify infrastructure impacts, and provide a powerful "virtual tour" experience.

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CASE STUDY ON TECHNOLOGIES FOR URBAN STREAM RESTORATION

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

Urban stream restoration is challenging since project sites are situated in highly modified watersheds that deliver elevated peak flows, diminished base flows, and pollutant laden waters; are hydro-modified and/or lined with hard armor; and are constrained by utility, transportation, and building infrastructure resulting in diminished or non-existent aquatic and riparian habitat and impaired water quality. This case study describes the key technologies utilized for the recently constructed (2019) enhancements to the Second Unnamed Tributary to 4th Creek in Knoxville, Tennessee at the Summit Medical-Deane Hill facility including design considerations, construction challenges, and early monitoring results. The project site receives run-off from the 1970s vintage West Town Mall. Constraints included highly modified flows; infrastructure interferences; primary site access through an active medical complex; and limited room for construction equipment operation and staging of equipment, supplies, or excavated soil. This project mixed "traditional" materials (large rock riprap, cross-vanes, constructed riffles, and riparian plantings) with newer technologies (two-dimensional hydraulic analysis, tied concrete block mat, bionic soil media/high-performance flexible growth media, and stormwater bio-retention) to meet the challenges at the site in a cost-effective manner.

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PUTTING FLOW-ECOLOGY RELATIONSHIPS INTO PRACTICE WITH A DECISION-SUPPORT SYSTEM FRAMEWORK

Casey Caldwell[1] and Steven Nebiker[2]

Understanding the relationship between the ecological health of a stream and its flow is critical for developing effective water management plans that address multiple and often conflicting uses throughout a river basin. Since objectives must be considered in a basin-wide context, it is important to conduct regional analyses between streamflow and riverine ecosystem. Further, for the flow-ecology recommendations to be scientifically credible, they must be derived from measured data.

Throughout the process, decision makers must be involved, to promote collaboration between stakeholders and easily demonstrate the trade-offs between different scenarios. Accordingly, it is helpful to distill the underlying analysis down to the most ecologically-relevant flow criteria so that models can quickly generate the results, and to summarize resulting environmental metrics in easily understood concepts. For decades, the integration described above has been elusive.

This presentation introduces a framework to operationalize flow-ecology relationships into decision-support systems of practical use to water-resource managers, who are commonly tasked with balancing multiple competing socioeconomic and environmental priorities. We illustrate this framework working with the USGS on a case study from the Tennessee River Basin -- one of the most ecologically diverse basins in the United States -- whereby fish community responses to various water-management scenarios were predicted in a partially-regulated river system at a local watershed scale. The modeling framework used - OASIS[a] (licensed by Tennessee for water planning) - is flexible, transparent, and allows for quick screening of scenarios, which positions it to be used in a collaborative setting with watershed stakeholders.

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SESSION 1B

STREAM QUANTIFICATION TOOL STUDIES (Moderator: Angel Fowler, Blueway)
1:30 p.m. – 3:00 p.m.

The TN Stream Quantification Tool (TN SQT): A Year in Practice
Adam Spiller and Josh Sitz

Assessing Potential Ecological Function Lift from Urban Stream Restoration
John S. Schwartz and Brian Alford

Tennessee Stream Quantification Tool (SQT) Case Studies, 2020
Matt Clabaugh

WATER QUALITY MONITORING (Moderator: Richard Cochran, TDEC-DWR)
3:30 p.m. – 5:00 p.m.

Periphyton Characteristics are a More Accurate Indicator of Trophic Status Relative to Water-Column Characteristics of a Shallow Lake in Dunbar Cave State Park in Middle Tennessee
Jefferson Lebkuecher[1], Cole Bell, Lauren Blenn, Danny Castellanos, Hailey Conn, Adrian Crucis Santaolalla, Chloe Dente, Morgan Jones, Kenan Lochmueller, Michelle McInnis, Gary Noel, Alec Sisson, and Matthew Trotter

Combining Waterbody Morphometry with Estimates of Nutrient Loading and Flushing Rate to Examine Reservoir Eutrophication
W. Reed Green

Evaluation of Nutrient and Escherichia coli *Loading Dynamics in a Middle Tennessee River*
Ryan Jackwood

THE TN STREAM QUANTIFICATION TOOL (TN SQT): A YEAR IN PRACTICE

Adam Spiller[1] and Josh Sitz[2]

The process of compensatory stream mitigation in Tennessee has gone through a sea change over the last couple of years. This process was finalized with the new TDEC Stream Mitigation Guidelines, which were adopted in spring 2019. As consultants and stream restoration practitioners we have been working through this process and various versions of the TN SQT for a number of years. It has only been this past year, while we have been using the TN SQT to develop stream mitigation banks, to assist in TDOT stream relocations, and work on permittee responsible mitigation projects that we have really gotten to know the intricacies, quirks, and nuances of the TN SQT. Overall we have found the TN SQT to be a powerful tool in compensatory stream mitigation projects. This presentation will discuss some of the lessons learned through working with the TN SQT and some of the things we "like" and "don't like" about the tool. After almost a year of working with the TN SQT this discussion is a valuable step for our industry to work towards finding the right means and methods to developing a compensatory stream mitigation practice that is reasonable for all of us involved in this work and protects the natural resources within Tennessee.

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ASSESSING POTENTIAL ECOLOGICAL FUNCTION LIFT FROM URBAN STREAM RESTORATION

John S. Schwartz and Brian Alford

Ecological improvement from stream restoration projects particularly in urban watersheds has been varied and incremental in stream condition. There is a critical need to better understand ecological responses to restoration in order to improve on design strategies, and assign restoration mitigation credits. Research goals were to: 1) compare field measured geomorphic, habitat, and biological data among urban streams (unrestored), urban restoration sites, and ecoregion reference stream sites, and by the comparisons assess the what metrics and indicators best quantify improvements to stream condition; 2) explore the use of species functional traits to discriminate among the three stream condition; and 3) assess the metrics applied in the state's stream quantification tool (TN SQT) to compute existing condition scores and the potential *functional lift* from urban stream restoration. Site data were collected from twelve streams in the Ridge and Valley Ecoregion consisting of four stream sites for each stream condition class. Results indicated that UR reaches showed improvement over UI reaches, but indices of biological integrity (IBI) did not score as high as the ERR streams. UR streams were observed with higher IBI scores on average than UI streams for both fish and insect IBI metrics, in addition to improved habitat quality index scores. Several pollution intolerant insect species were collected in restored areas. Also, UR streams tended to contain more sensitive fish species such as darters. TN SQT functional lift metrics associated with 1) a rapid geomorphic assessment based on the channel evolution model; 2) several from the state's habitat rapid bioassessment protocols; and 3) the state's macroinvertebrate index (TMI) proved to best discriminate among the three stream condition classes. The TN SQT classes ECS between 0 and1 as follows: not functioning (0.00-0.29), functioning at risk (0.30- 0.69), and functioning (0.70-1.00). ECS from our study found that UI sites averaged 0.53 (0.47-0.58), UR sites averaged 0.55 (0.52-0.59), and ERR averaged 0.71 (0.69-0.75, with two sites scoring 0.70). To note, ERR sites were barely classified as functioning through these sites are the state's biomonitoring program ecological reference sites. Results demonstrate in urban streams not all field-measured condition metrics discriminate functional lift, and the functional lift quantitative tool could be improved reflecting the metrics that do discriminate between the three conditional stream classes noted above. This presentation focuses on suggesting potential alternative metrics for the TN SQT.

TENNESSEE STREAM QUANTIFICATION TOOL (SQT) CASE STUDIES, 2020

Matt Clabaugh, Barge Design Solutions

INTRODUCTION

Based on the 2018 draft Tennessee Stream Mitigation Guidelines, the Tennessee Department of Environment and Conservation (TDEC) Division of Water Resources and the U.S. Army Corps of Engineers (USACE) have developed a new method to calculate the amount of stream compensatory mitigation required (debits) from a permitted proposed activity, and also the amount of mitigation credits generated from a proposed restoration activity on an impaired site. The new tool is the Tennessee Stream Quantification Tool (TN SQT). The tool calculates an existing condition score and a proposed condition score for the stream. The change in score is considered "uplift", and the amount of uplift is calculated in functional feet, as opposed to the old "ratio" method credits.

The TN Debit tool was developed to determine the amount of compensatory stream mitigation required for a proposed activity, and is based on the stream's existing condition and the proposed activity (culvert, bridge, stream fill, etc.).

APPROACH

Barge has assessed numerous streams on various projects for a wide range of clients using the new SQT tools and these case studies will be shared that highlight the use of the new tool to educate those less experienced with the SQT method. Also, out of almost a year of using the tool, there have been several recurring inconsistencies that have been identified. We will talk through these inconsistencies and also open up the floor to other practitioners and gather input on what is working and what needs revised.

RESULTS AND DISCUSSION

Project types that Barge has used the SQT on have varied from commercial development, transportation, PRM projects, and mitigation banking projects. Barge's experience has identified advantages of the tool, including recognizing a stream for what its function is and not just its length, and also detected some inconsistencies, including requiring an all-or-nothing sinuosity of 1.2 and several unattainable fully functioning vegetation categories. Barge believes the tool is an improvement from the ratio method used in the past; however, there are some areas that need updated or revised for the tool to realize its full potential.

PERIPHYTON CHARACTERISTICS ARE A MORE ACCURATE INDICATOR OF TROPHIC STATUS RELATIVE TO WATER-COLUMN CHARACTERISTICS OF A SHALLOW LAKE IN DUNBAR CAVE STATE PARK IN MIDDLE TENNESSEE

Jefferson Lebkuecher[1], Cole Bell, Lauren Blenn, Danny Castellanos, Hailey Conn, Adrian Crucis Santaolalla, Chloe Dente, Morgan Jones, Kenan Lochmueller, Michelle McInnis, Gary Noel, Alec Sisson, and Matthew Trotter

ABSTRACT

Swan Lake in Dunbar Cave State Park is impaired by nutrient enrichment as evidenced by nuisance biomass levels of macrophytes and mats of surface algae. Concentrations of total phosphorus and total nitrogen of water were below those expected in a eutrophic environment, most likely due to high demand. Other characteristics of the water column including chlorophyll *a* concentration, biochemical oxygen demand, and primary production were also below levels expected and presumably reflect the low concentration of phosphorus and nitrogen of the water. Periphyton characteristics accurately indicate the eutrophic status of the lake and include a high concentration of benthic chlorophyll *a*, high concentration of ash-free dry mass of benthic organics, and a high relative abundance of soft algal and diatom taxa listed as eutrophic indicators. The results indicate: (1) periphyton characteristics best characterize the trophic status of Swan Lake relative to water-column characteristics and (2) assessment and monitoring of shallow, eutrophic, lentic habitats should include measurements of periphyton characteristics.

INTRODUCTION

Phosphorus (P) enrichment frequently increases primary production and is a major cause for the degradation of aquatic communities worldwide (Chonova et al. 2019). Hallmarks of eutrophication include high rates of primary production, high concentrations of chlorophyll (chl) *a,* and changes of organism composition (Harris and Piccinin 1977). The primary objectives of this research were to characterize the water quality and biological integrity of Swan Lake in Dunbar Cave State Park such that changes can be monitored. We used multiple approaches to achieve the objectives including determinations of: (1) nutrient concentrations of water, (2) pigment concentrations of water and periphyton, (3) biochemical oxygen demand of water, (4) primary production on artificial substrates, and (5) composition of benthic soft-algal and diatom assemblages.

The above ground origin of Swan Creek is the entrance to Dunbar Cave in Dunbar Cave State Park in Clarksville, Tennessee. The creek is dammed approximately 0.3 km downstream of the cave entrance forming Swan Lake. The lake is approximately 35 ha and averages approximately 3 m deep. Swan Creek is part of the Lower Cumberland River Watershed which is in the Western Pennyroyal Karst (71e) and Western Highland Rim (71f) Level IV Ecoregions. The geologic base of the watershed is Mississippian-age limestone and includes some chert, shale, siltstone, sandstone, and dolomite. The soils are a thin loess mantle, highly erodible, and very

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fertile (Baskin et al. 1997). Forests are Western Mesophytic and consist largely of *Quercus* and *Carya* species. Over 50% of the Lower Cumberland River Watershed is used to produce agriculture products including tobacco, corn, soybean, and livestock (TDEC 2012). The cumulative effects of erosion, agricultural runoff, livestock access to streams, and poorly functioning sewage systems result in poor quality water in most of the tributaries in the watershed, including Swan Creek. The negative impact of eutrophic conditions of Swan Lake is obvious by the nuisance biomass levels of the aquatic macrophyte *Myriophyllum spicatum* L. and surface algal mats.

METHODS

Water-column characteristics of Swan Lake were determined on September 9, 2019 following the methods described by Lebkuecher et al. (2018a). Photosynthetic photon flux density (PPFD) was measured at the surface and at 0.25-m depths at 2 locations (2 replicates) with a spherical underwater quantum sensor coupled to a Li-Cor quantum meter (Li-Cor Cooperate, Lincoln, Nebraska). These data were used to calculate the vertical extinction coefficient of light (n"; Lind et al. 1992): n" = (ln $PPFD_{surface}$ - ln $PPFD_{depth}$)/depth. The value of n" is an expression of the PPFD-depth slope on a logarithmic axis and is largely a function of turbidity; the higher the n" value, the greater the vertical extinction rate of light as it penetrates the water column. Concentrations of total phosphorus (TP) and total nitrogen (TN) of water samples collected with a Van Dorn sampler at 0.25 m depth were determined using a Lachat QuickChem 8500 Flow Injection Analyzer. [TP] was determined using the persulfate-digestion and the ascorbic-acid method (Baird et al. 2017). [TN] was determined by the persulfate-digestion and cadmium-reduction method (Baird et al. 2017).

Concentration of chl *a* and turbidity of the water at a 0.25-m depths at six different locations (six replicates) were determined using a portable fluorometer and nephelometer (AlgaeChek Ultra, model RS232, Modern Water Incorporated, New Castle, Delaware). The fluorometer measures the intensity of fluorescence at 685 nm emitted from chl *a* upon excitation by low emission diodes (470 nm). The nephelometer measures the concentration of suspended particulates expressed as nephelometric turbidity units calculated from the intensity of scattered light reflected from a source beam due to particles in the water.

Primary production of the water was determined using a periphytometer holding glass microscope slides (25- by 75-mm) vertically 5 cm below the surface. The periphytometer was deployed on Aug. 30, 2019 and retrieved Sept. 9, 2019. No significant rainfall occurred during the deployment and most days were partly cloudy. Periphyton were removed from both sides of 12 slides using a razor blade (two slides per six replicates) into 100 mL of deionized water. The periphyton were suspended in water by swirling and concentrations of chl *a* determined using the AlgaeChek portable fluorometer probe described above.

The effect of organic matter in the water column on oxygen consumption by microorganisms was estimated by the biochemical oxygen demand 5-day assay (BOD_5 assay) as described by Baird et al. (2017). Water samples were retrieved from a depth of 0.25 m using a Van Dorn sampler. Samples were transferred to two borosilicate-glass bottles with ground-glass stoppers. Initial dissolved oxygen (DO) concentration was determined using a portable DO meter (model MW600, Milwaukee Instruments Incorporated, Rocky Mount, North Carolina). The bottles were incubated for 5 days in darkness at 25 ^{O}C and the concentration of DO consumed recorded as BOD_5 (mg DO · L^{-1} · 5 d^{-1}).

Periphyton chl *a* concentration, ash-free dry mass of benthic organics, and algal composition were determined from five cobbles removed from upper littoral zone (approximately 0.25 m depths) following the methods of Lebkuecher et al. (2015). Phytoplankton richness was estimated from multiple samples collected with phytoplankton nets (120-µm pore size) and Van Dorn samplers. Phytoplankton were preserved in 1 % glutaraldyde and concentrated by settling in darkness. Algae were identified to the lowest taxon possible using references listed in Grimmett and Lebkuecher (2017). Indices including the algae trophic index of soft algae assemblages (ATI, Grimmett and Lebkuecher 2017) and the pollution tolerance index for diatom assemblages (PTI, KDOW 2008) were used to infer the impact of trophic status on benthic algal assemblages. The ATI was calculated as: ATI = $[\Sigma_{j = 1 \text{ taxon}} n_j \, ti_j]/N$ where: n_j = number of taxon units j sampled at a site, ti_j = trophic-indicator value for taxon j, and N = total number of taxon units at the sampling site used to calculate the index (Grimmett and Lebkuecher 2017). The trophic-indicator values are the abundance-weighted averages of benthic [chl *a*] listed in Grimmett and Lebkuecher (2017). The pollution tolerance index for diatom assemblages (PTI; KDOW 2008) was calculated as: PTI = $[\Sigma_{j=1 \text{ sp.}} n_j \, t_j]/N$ where: n_j = number of individuals of taxon j, t_j = eutrophication-tolerance value for taxon j, and N = total number of individuals assigned a eutrophication-tolerance value and tallied to calculate the index. The eutrophication-tolerance values range from one (taxon very tolerant to eutrophic conditions) to four (taxon very intolerant to eutrophic conditions) and are based on decades of autecological studies (KDOW 2008). Although trophic indicator values assigned to taxa for both the ATI and PTI were determined from evaluations of streams and rivers, these indices were used because indices specific to lotic environments have yet to be developed.

RESULTS AND DISCUSSION

The physical characteristics of Swan Lake (Table 1) are typical of lentic environments in Tennessee. For example, the slightly basic pH is similar to other aquatic systems in the ecoregion given the limestone geologic base. The relatively low n" of Swan Lake on Sept. 9, 2019 most likely reflects the lack of significant precipitation, thus lack of sediment runoff during the previous 2 weeks. The majority of the light-extinction studies from a variety of natural freshwater lakes and reservoirs with different morphologies and chemistries report n" values near 1.3, a value which has been adopted as typical for purposes of comparison (Reynolds, 1990). Values of n" $\geq$ 1.8 indicate unusually high concentrations of suspended matter (Luettich et al., 1990). The relatively low concentration of suspended particles in Swan Lake is verified by the low value for the nephelometric turbidity units (NTU). For example, NTU values above 25 indicate the water column contains an unhealthy concentration of suspended particles (USEPA 1986).

Table 1. Physical characteristics of Swan Lake on Sept. 9, 2019.

pH at 0.25 m at 9:30 AM CST	7.1
Light extinction coefficient (n”)	1.0 ± 0.1
Nephelometric turbidity units	21 ± 5
Total phosphorus ($\mu g \cdot L^{-1}$)	20
Total nitrogen ($\mu g \cdot L^{-1}$)	841
Total phosphorus to total nitrogen ratio	42

The concentration of total phosphorus (TP) of water collected from Swan Lake is in the range suggested by Carlson and Simpson (1996) to designate lakes as mesotrophic (> 12 µg TP $\cdot$ L^{-1} to < 25 µg TP $\cdot$ L^{-1}). The high ratio of total nitrogen (TN) to TP suggests P limits photoautotroph growth in Swan Lake. For example, P may be considered limiting when the TN:TP ratio by mass is > 33 (Carlson and Simpson 1996). The ratio of TN to TP of Swan Lake was expected given P limits algae biomass in most freshwaters. The concentration of P is a primary criterion used to designate trophic status of aquatic habitats although several studies have demonstrated that eutrophic environments with high concentrations of algae may have low water [P] as a result of high P demand (Grimmett and Lebkuecher 2017).

The low concentration of chl *a* of the water column of Swan Lake (Table 2) indicates that the productivity of the water column was relatively low. For example, concentrations of water column chl *a* > 7.3 µg/L are indicative of eutrophic conditions (Carlson and Simpson 1996). The rates of photoautotrophic periphyton production (Table 2) are substantially lower than rates considered typical of eutrophic environments and support the conclusions from analyses of the concentration of chl *a* of the water column that the productivity of the water column is low. For example, primary production values $\leq$ 0.3 mg chl *a* $\cdot$ m^{-2} $\cdot$ day^{1} are typical of aquatic environments with good quality water in Middle Tennessee (Lebkuecher et al. 2009).

The mean value for the biochemical oxygen demand 5-day assay (BOD_5 assay) is typical for those determined from samples without excessive concentrations of organics. BOD_5 values from water without excessive concentrations of organics range from near 0 to 8 mg O_2 consumed $\cdot$ L^{-1} $\cdot$ 5 d^{-1}, while values of wastewater from wastewater treatment plants are often above 19 mg O_2 consumed $\cdot$ L^{-1} $\cdot$ 5 d^{-1} (Delzer and McKenzie 2003, Yun and An 2016).

Table 2. Biomass characteristics, OD_{664} to OD_{665} ratio, and biochemical oxygen demand (means $\pm$ S.E.) of Swan Lake.

Water column chlorophyll *a* ($\mu g \cdot L^{-1}$)	4.3 ± 0.2
Primary production on artificial substrates (mg chlorophyll *a* $\cdot$ m^{-2} $\cdot$ day^{-1})	0.1 ± 0.0
Biochemical oxygen demand (mg $0_2 \cdot L^{-1} \cdot$ 5 $days^{-1}$)	2.6 ± 0.3
Benthic (cobble) chlorophyll *a* (mg $\cdot$ m^{-2})	91.2 ± 29.1
OD_{664} to OD_{665} ratio	1.6 ± 0.02
Ash-free dry mass of benthic organics (mg $\cdot$ m^{-2})	12.1 ± 3.0

Concentrations of benthic chl *a* were > 70 mg·m^{-2}, a value suggested by Dodds et al. (1998) to designate aquatic systems as eutrophic. The OD_{664} to OD_{665} ratio of pigment extracts indicate the photoautotrophic periphyton collected from Swan Lake were in good physiological condition. Because pigment extracts from healthy algae may have no detectable pheophytin *a* determined by optical density (OD) measurements using a spectrophotometer, the chl *a* to pheophytin *a* ratio is indicated as the ratio of OD_{664} to OD_{665}. Pheophytin *a* is a chl *a* degradation product. An OD_{664} to OD_{665} ratio of 1.7 is interpreted as no detectable pheophytin *a* present and ratios < 1.5 indicate the algae contained high concentrations of pheophytin *a* (Baird et al. 2017).

The concentrations of ash-free dry mass of benthic organic matter was > 10 g · m^{-2}, a value indicative of eutrophic environments (O'Brian and Wehr 2010). This result supports the conclusions from the measurements of the concentrations of benthic chl *a* that demonstrate an unhealthy concentration of benthic photoautotrophic periphyton biomass. The high concentrations of benthic chl *a* and ash-free dry mass of benthic organic matter indicate that periphyton characteristics of Swan Lake are a more accurate indicator of the lake's eutrophic status relative to water-column characteristics measured such as nutrient concentration of water, chl *a* concentration of water, and primary production rate on artificial substrates suspended in the water column.

We identified 69 taxa of soft algae (Appendix 1). The most abundant benthic soft alga sampled was the filamentous cyanobacterium *Leptolyngbya angustissimum* (West and West) Anagn. and Komárek (28.1 %) followed by *Oedogonium* sp. (12.0 %) and *Cladophora glomerata* (L.) Kütz. (10.9 %). The taxa richness of the benthic soft-algal assemblage was lower relative to the phytoplankton assemblage (Table 3). The low Shannon diversity index for the benthic soft-algal assemblage in Swan Lake is typical for soft algal assemblages in Middle Tennessee (Lebkuecher et al. 2018b) and is due largely to the low evenness value. The high value for the algae trophic index (ATI) for the benthic soft algal assemblage indicates this assemblage is impacted by eutrophication. ATI values correspond with Dodds et al. (1998) suggested classification of [benthic chl *a*] ≥ 70 mg·m^{-2} as eutrophic. The high value for the ATI is due partially to the high abundance of *Cladophora glomerata* (L.) Kütz. (10.9 %) which has a high trophic-indicator value used to calculate the ATI given *C. glomerata* is common at eutrophic sites (Grimmett and Lebkuecher 2017).

Table 3. Metrics and indices for the benthic soft-algal assemblage and phytoplankton richness of Swan Lake.

Index	Index value
Taxa richness of benthic soft algae	41
Taxa richness of phytoplankton	49
Shannon diversity index for benthic soft algae	2.3
Evenness for benthic soft algae	0.6
Algae trophic index for benthic soft algae	77

We identified 38 taxa of benthic diatoms (Appendix 2). The most abundant diatom sampled was *Achnanthidium minutissimum* (Kütz.) Czarn. (28.1 %) followed by *Achnanthidium* sp. (9.6 %), and *Cocconeis placentula* Ehrenb. (7.9 %). The higher value for the Shannon diversity index for the diatom assemblage (Table 4) relative to the soft algal assemblage (Table 3) is due largely to the greater evenness value for the diatom assemblage. Greater values for evenness and the Shannon diversity index of diatom assemblages relative to soft algal assemblages are typical of benthic communities in Middle Tennessee (Lebkuecher et al. 2018b). The low value for pollution tolerance index (PTI) for the diatom assemblage indicates the assemblage is impaired by nutrient enrichment. A value for the PTI < 2.6 is a suggested value to indicate an assemblage is substantially impacted by eutrophic conditions (Lebkuecher et al. 2018b). The low PTI value for the diatom assemblage in Swan Lake results largely from the high percent compositions of *Navicula* and *Nitzschia* taxa, most of which are assigned low trophic-indicator values for the PTI given they are typically more abundant in eutrophic habitats (KDOW 2008).

Table 4. Metrics and indices of the benthic diatom assemblage sampled from cobbles in Swan Lake.

Index	Index value
Taxa richness	41
Shannon diversity index	2.8
Evenness	0.7
Pollution tolerance index	2.6

CONCLUSIONS

Concentrations of total P and total N of water sampled from Swan Lake were below those expected in a eutrophic environment, most likely due to high demand. Other water-column characteristics including chl *a* concentration, biochemical oxygen demand, and primary production on suspended substrates were also below levels expected and likely reflect the low concentration of water-column nutrients. Periphyton characteristics including a high concentration of chl *a*, high concentration of ash-free dry mass of benthic organics, and values for algal indices of the benthic assemblages accurately indicate the trophic status of Swan Lake. The results indicate that periphyton characteristics best characterize the trophic status of Swan Lake relative to water-column characteristics and that assessment and monitoring of shallow, eutrophic, lentic habitats should include measurements of periphyton characteristics.

ACKNOWLEDGEMENTS

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Appendix 1. Percent composition of benthic soft-algal taxa sampled from cobbles, benthic soft-algal taxa sampled from cobbles present (P) observed independently of determinations of percent composition, and phytoplankton taxa present (P) sampled from the water column in Swan Lake listed in alphabetical order by phylum.

Chlorophyta	**Percent composition of benthic soft-algal taxa**	**Phytoplankton taxa present (P)**
Aphanochaete polychaete (Hansg.) Fritsch.		P
Bulbochaete sp.	0.71	P
Chlamydomonas patellaria Whitford		P
Chlamydomona gloeogama Korshikov		P
Chlamydomonas sp.	0.02	
Chlorococcum humicola (Nägeli) Rabenh.	0.04	
Cladophora glomerata (L.) Kütz.	10.91	
Coelastrum microporum Nägeli	0.36	P
Coelastrum reticulatum (Dang.) Senn.		P
Cosmarium botrytis Menegh.	0.69	P
Cosmarium contractum Kirchn.		P
Cosmarium galeritium Nordst.	3.28	P
Cosmarium raciborskii (Racib.) Lagerh.	4.028	
Cosmarium sp.	0.02	P
Cosmarium subprotumidum Nordst.	0.09	P
Cosmarium turpinii Bréb.	0.07	P
Desmidium sp.		P

Gloeocystis gigas (Kütz.) Langerh.	3.74	P
Gloeocystis vesiculosa Nägeli	10.49	P
Mougeotia sp.	10.08	P
Oedogonium sp.	11.99	P
Oocystis sp.		P
Pandorina morum (Müller) Bory	0.47	P
Pediastrum araneosum (Racib.) G. M. Sm.	0.17	
Pediastrum integrum (Meyen 1829)		P
Pediastrum sp.	0.37	P
Pediastrum tetras (Ehrenb.)		P
Scenedesmus acuminatus (Lagerh.) Chodat	0.06	
Scenedesmus bijuga (Turp.) Lagerh.	0.51	P
Scenedesmus dimorphus (Turp.) Kütz.	0.04	
*Scenedesmus obliquus (*Turp.) Kütz.		P
Scenedesmus quadricauda (Turp.) Bréb.	0.07	
Scenedesmus sp.	0.06	
Selenastrum capricornutum Printz	0.06	P
Spirogyra sp.		P
Staurastrum obliculare (Erenb.) Ralfs	0.02	P
Staurastrum sp.		P
Sphaerocystis sp.		P
Sphaerocystis planktonia (Korsh.) Bourr.	0.34	
Volvox globulator L.		P
Zygnema sp.		P
Cyanobacteria		
Aphanocapsa elachista West and West		P
Chroococcus minor (Kütz.) Nägeli	0.04	
Chroococcus minutus Kütz.		P
Chroococcus sp.		P
Coelosphaerium sp.	0.21	
*Dactylococcopsis raphidiodes (*Hansg.) Chodat and Chodat		P
Komvophoron munitum (Skuja) Anagn. and Komárek		P
Leibleinia nordgaardii (Wille) Anagn. and Komárek	0.66	P
Leptolyngbya angustissimum (West and West) Anagn. and Komárek	28.11	P
Leptolyngbya sp.	4.68	P
Merispodedia tenuissima Lemmerm.	P	
Microcystis aeruginosa (Kütz.) Kütz.	0.02	
Microcystis incerta Lemmerm.	0.02	
Oscillatoria agardhii Gomont	0.09	
Oscillatoria limosa (Dylwin) C. Agardh		P
Oscillatoria sp.	0.24	P
Oscillatoria subtilissima Kütz. and De Toni	2.44	
Phormidium articulatum (Gardner) Anagn. and Komárek	0.37	

Phormidium diguetii (Gomont) Anagn. and Komárek	0.32	
Phormidium sp.	7.49	P
Synechocystis sp.	0.02	
Dinophyta		
Peridinium sp.		P
Euglenophyta		
Euglena sp.		P
Cryptophyta		
Chroomonas nordstedtii Hansg.		P
Chrooomonas sp.		P
Cryptomonas erosa Erenb.		P
Ochrophyta		
Dinobryon sp.		P
Lagynoin sp.	P	

Appendix 2. Percent composition of benthic diatom taxa sampled from cobbles and benthic diatom taxa sampled from cobbles present (P) observed independently of determinations of percent composition in Swan Lake listed in alphabetical order.

Taxon name	Percent composition
Achnanthidium gracillimum Lange-Bert.	2.31
Achnanthidium minutissimum (Kütz.) Czarn.	28.05
Achnanthidium rivulare Potapova and Ponander	5.28
Achnanthidium sp.	9.57
Cocconeis placentula Ehrenb.	7.92
Cocconeis placentula var. euglypta Ehrenb.	0.33
Cymatopleura solea (Bréb. and Godey) W. Sm.	0.33
Eunotia pectinalus (Kütz.) Rabenh.	P
Eunotia sp.	0.99
Frustulia vulgaris (Thwaites) De Toni	0.33
Gomphoneis olivacea (Horn.) Daws.	0.33
Gomphonema acutinatum Ehrenb.	0.66
Gomphonema angustatum (Kütz.) Rabenh	1.98
Gomphonema gracile Ehrenb.	0.33
Gomphonema minutum Ag.	0.66
Gomphonema parvulum (Kütz.) Kütz.	0.33
Gomphonema pseudoaugur Lange-Bert.	0.33
Gomphonema truncatum Ehrenb.	0.33
Melosira varians Ag.	6.60
Navicula capitatoradiata Germ.	4.62
Navicula cryptocephala Kutz.	1.65
Navicula crytotenella Lange-Bert.	P
Navicula lanceolata (Ag.) Ehrenb.	0.33
Navicula menisculus var. *upsaliensis* (Grun.) Grun.	0.66
Navicula sp.	1.98
Navicula veneta Kütz.	1.98
Nitzschia acicularis (Kütz.) W. Sm.	0.66
Nitzchia amphibia Grun.	1.65
Nitzschia angustata (W. Sm.) Grun.	0.33
Nitzschia capitellata Hust.	2.64
Nitzschia fonticola Grun.	0.66

Nitzschia frustulum (Kütz.) Grun.	1.65
Nitzschia inconspicua Grun.	1.32
Nitzschia sinuata var. tabellaria Grun.	0.66
Nitzschia flexa Schumann	P
Nitzschia sociabilis Hust.	1.98
Synedra delicatissima W. Sm.	2.31
Thalassiosira weissflogii (Grun.) G. Fryxell and Hasle	0.33
Ulnaria sp.	0.66
Ulnaria ulna (Nitzsch.) Compère	0.66
Ulnaria capitata (Erenb.) Compère	6.60

COMBINING WATERBODY MORPHOMETRY WITH ESTIMATES OF NUTRIENT LOADING AND FLUSHING RATE TO EXAMINE RESERVOIR EUTROPHICATION

W. Reed Green[1]

Estimates of nutrient loads and flushing rates were combined with measures of waterbody morphometry in lakes and reservoirs to aggregate waterbodies of similar Secchi depth and chlorophyll *a* concentration. Aggregation was completed for 320 lakes or reservoirs greater than or equal to 0.1 km^2 located in the eastern United States, Alabama, and parts of Mississippi and Tennessee, and were previously included in the U.S. Environmental Protection Agency National Lake Assessment Program in 2007 and 2012. Waterbodies were categorized by type (natural lakes (n = 95), headwater reservoirs (n = 165), and downstream reservoirs (n = 60)), and waterbody types were assessed independently. Recursive partitioning and model-based boosting were used to create four-node partition trees to aggregate waterbodies into five endpoints along a gradient of lowest to highest values relative to Secchi depth, chlorophyll *a* concentration, according to shared nutrient loading and morphometric characteristics. Trophic state designations were assigned relative to the median value within each of the five endpoints. These partition trees were then used to place all other waterbodies that were not included in the National Lake Assessment Program into one of the five Secchi depth or chlorophyll *a* aggregates. Results will aid water-resources management in prioritizing lake and reservoir protection and restoration efforts based on the susceptibility of these waterbodies to eutrophication relative to nutrient loading and morphometric characteristics. Examples are provided for Tennessee reservoirs.

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EVALUATION OF NUTRIENT AND *ESCHERICHIA COLI* LOADING DYNAMICS IN A MIDDLE TENNESSEE RIVER

Dr. Ryan Jackwood[1]

Excessive nutrient and microbial contamination of surface waters contribute to poor water quality that threatens environmental and human health. Nutrients drive increased occurrence and severity of harmful algal blooms whereas microbial contamination (indicated by the presence of *Escherichia coli*) can lead to swim advisories at local beaches or rivers frequented by swimmers. The Harpeth River was evaluated as a model system to better understand loading dynamics of bacteria and nutrients in middle Tennessee Rivers. Water quality data (total phosphorus, total nitrogen, *E. coli*, and discharge) were collected in the Harpeth River between 2012 and 2018. These data were used to identify temporal trends in loadings within the Harpeth River for total nitrogen, total phosphorus, and *E. coli*. Nutrient (total phosphorus and total nitrogen) loading trends are utilized to identify water management priorities within the Harpeth River watershed that will help reduce the occurrence of harmful algal blooms. Loading trends of *E. coli* are evaluated to predict when densities of *E. coli* are above the Tennessee Department of Environment and Conservation's Recreational Criteria (geometric mean of 126 colony forming units [CFUs]/100 mL or individual sample threshold of 941 CFUs/100 mL). Predicted *E. coli* densities can serve as an "early warning" system to advise members of the public when microbial contamination is unsafe for swimming in surface waters due to the threat on human health.

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SESSION 1C

SEDIMENT STUDIES (Moderator: Dennis Borders, TDEC-DWR)
1:30 p.m. – 3:00 p.m.

Extending the Period of Record of Extreme Floods
Evan A. Hart

Leveraging Community Scientists and GIScience to Model Roadside Stream Sedimentation in the U.S. National Forest
Jacob Hansen, Ingrid Luffman, and Andrew Brown

Extreme Floods, the New Normal? Sediments Reveal a 5,700-Year Record of Extreme Floods in the Tennessee River Valley and Yield New Insights into Extreme Flood Frequency
Lisa Davis, Ray Lombardi, Miles Yaw, and Curt Jawdy

OUTREACH AND EDUCATION (Moderator: Regan McGahen, TDEC-DWR)
3:30 p.m. – 5:00 p.m.

TN-GA 4-H Water Camp
L. Reynolds

Tennessee Water Education and Training Center
David Blackwood

New Ways to Address Old Problems: Public-Private Partnerships for Water and Education
Catherine Price and Will Caplenor

EXTENDING THE PERIOD OF RECORD OF EXTREME FLOODS BY STUDYING PRE-HISTORIC FLOOD SEDIMENTS

Evan A. Hart[1]

Direct measurement of flooding on the Cumberland River and its tributaries only extends back to about 1870 and extrapolation of flood return intervals is only valid out to about 1.5 times the period of record. The 2010 Cumberland River flood was estimated to be a 1000-year event. However, this estimate is based on extrapolation from known flood heights that extend back less than 200 years. The actual return interval of such extreme events is unknown due to the short period of record. One way to extend the period of record for floods, and thereby make more confident return interval estimates, is to use proxy records. Proxy records include sediment deposited by extreme floods and preserved on floodplains, in caves, and beneath cliff overhangs. Flood-deposited sediments have been used to extend the period of record on some major streams in the western US and a pilot study was recently done on the Tennessee River. However, no pre-historic flood studies have been conducted on the Cumberland River and its tributaries. Flood sediments have been observed in the Cumberland River watershed preserved in caves and rock shelters, and at paleo-Indian sites thought to be several centuries old. If the period of record can be extended by dating these pre-historic sediments it may benefit power generation and flood control managers along the Cumberland River who are tasked with planning for extreme events and ensuring the safety of dams and other infrastructure.

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LEVERAGING COMMUNITY SCIENTISTS & GISCIENCE TO MODEL ROADSIDE STREAM SEDIMENTATION IN THE US NATIONAL FOREST, NORTH CAROLINA

Jacob Hansen[1]*, Ingrid Luffman[1], Andrew Brown[2]

INTRODUCTION

The health of aquatic ecosystems is heavily affected by increased levels of sediment within freshwater streams. Suspended sediments cause a decline in fisheries and can lead to the degradation of aquatic ecosystems (Bilotta & Brazier, 2008). This issue affects everything in the aquatic ecosystem, from phytoplankton, through their inability to photosynthesize sufficient energy, to invertebrates, by clogging filter-feeding structures and damaging exposed organs via scouring, to local fisheries, such as trout and salmon, by reducing developmental habitat for salmonid eggs and larvae (Bilotta & Brazier, 2008).

Excessive sedimentation of streams and rivers is a problem anywhere human infrastructure exists. This is well-demonstrated in regard to unsealed (unpaved) forest roads. Forest roads impact hydrology by three different methods: intercepting water that would otherwise infiltrate the ground, concentrating water into a flowing channel in an adjacent ditch or on the road itself, and diverting water along the grade of the road, possibly discharging it directly into a stream (Orndorff, 2017). A first step in assessing the impact of sedimentation from roads on stream health is to quantify the problem. This may be accomplished in two ways: through boots-on-the-ground surveys and modeling. Assessing the needs of a network of forest roads can be daunting – modeling the condition and needs of the road inventory can save a lot of time and money. This research employs both field surveys and modeling to quantify stream sedimentation in a western North Carolina stream. To that end, a Trout Unlimited (TU) community science monitoring program was implemented and the data products were incorporated into a road sedimentation model. The purpose of this study is therefore to examine the effectiveness of using TU community science data to help calibrate a sedimentation model.

METHODS

Community volunteers were recruited and trained in sedimentation survey protocol as developed by TU in collaboration with the United States Forest Service (USFS) and the North Carolina Wildlife Resources Commission (NCWRC). Survey123 was used to collect and submit information about drainage features on National Forest roads and trails. Submitted data include measurements and assessments of each drain point, such as the contributing road length, condition and surfacing, sediment travel distance, whether sediments visibly make it to a stream, cobble embeddedness, GPS location information, and various other fields. Community scientists were encouraged to collect data in certain high-priority roads and trails within one of two focal

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areas: Sky Island, a high elevation area comprised of several watersheds, and Wilson Creek watershed (Figure 1).

The Geomorphic Road Analysis and Inventory Package (GRAIP) is a comprehensive sediment delivery model developed for use in Geographic Information Systems (GIS) (Cissel et al., 2014). This method requires an exhaustive GPS-collected road inventory, designed to determine, among other things, road condition, water entry to the road prism, and points where water and sediment leave the roads surface to travel down the hillslope (Black et al., 2012). GRAIP_Lite is an alternative that is based on results from several GRAIP studies, negating the need for field-collected data (Nelson, 2019). GRAIP_Lite was chosen as the model for this study.
An uncalibrated GRAIP_Lite model needs only a DEM and road line data; even if crucial parameters within the road data are missing, assumptions are made to produce model output (Nelson et al., 2019). It is possible to calibrate a GRAIP_Lite model with information collected in the field or otherwise, allowing users to add some local variation without performing the exhaustive inventory required for a full GRAIP model run (Nelson et al., 2019). USFS road FS-5000 (Wash Creek Rd) in the Mills River area of Sky Island was selected for the study area (Figure 1). An uncalibrated basic run of GRAIP_Lite was performed, followed by a run calibrated with *Known Drainage Points* collected as part of the community science project described earlier. Raster toolsets were used to calculate and classify the differences in accumulated sediment between the basic and calibrated model runs.

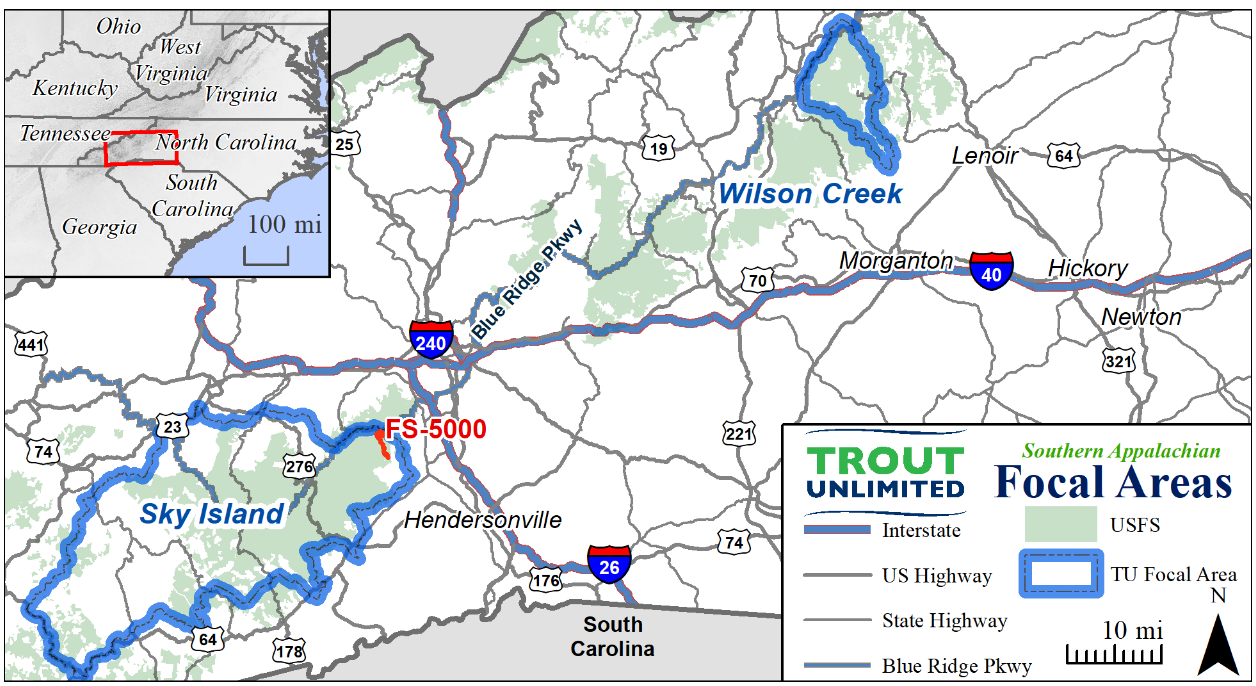

Figure 1. Focal areas for Trout Unlimited community science program: Sky Island (comprised of the upper portions of Tuckasegee, Pidgeon, French Broad, and Mills Rivers) and Wilson Creek watershed.

RESULTS AND DISCUSSION

According to both models, Wash Creek is affected by sediment from FS-5000. Sediment accumulation along the stream was calculated as a ratio of calibrated/basic, to compare differences between models (Figure 2). Excluding tributaries, most of the length of Wash Creek shows higher predicted sediment accumulation for the basic run (purple colors) with typical model ratios ranging from 0.90 to 0.99. Most of the stream segments showing little or no change are located on tributaries in the upper reaches of Wash Creek watershed. Most segments predicting a higher sediment accumulation in the calibrated model (orange colors) are found in short stretches of tributaries. The basic run predicts greater sediment accumulation over 27,042 stream feet (53% of the stream length impacted by FS-5000), while the calibrated run predicts greater sediment accumulation on only 1,075 stream feet (2%) (Table 1). Minimal change was detected between the two models for the remaining 22,936 stream feet (45%).

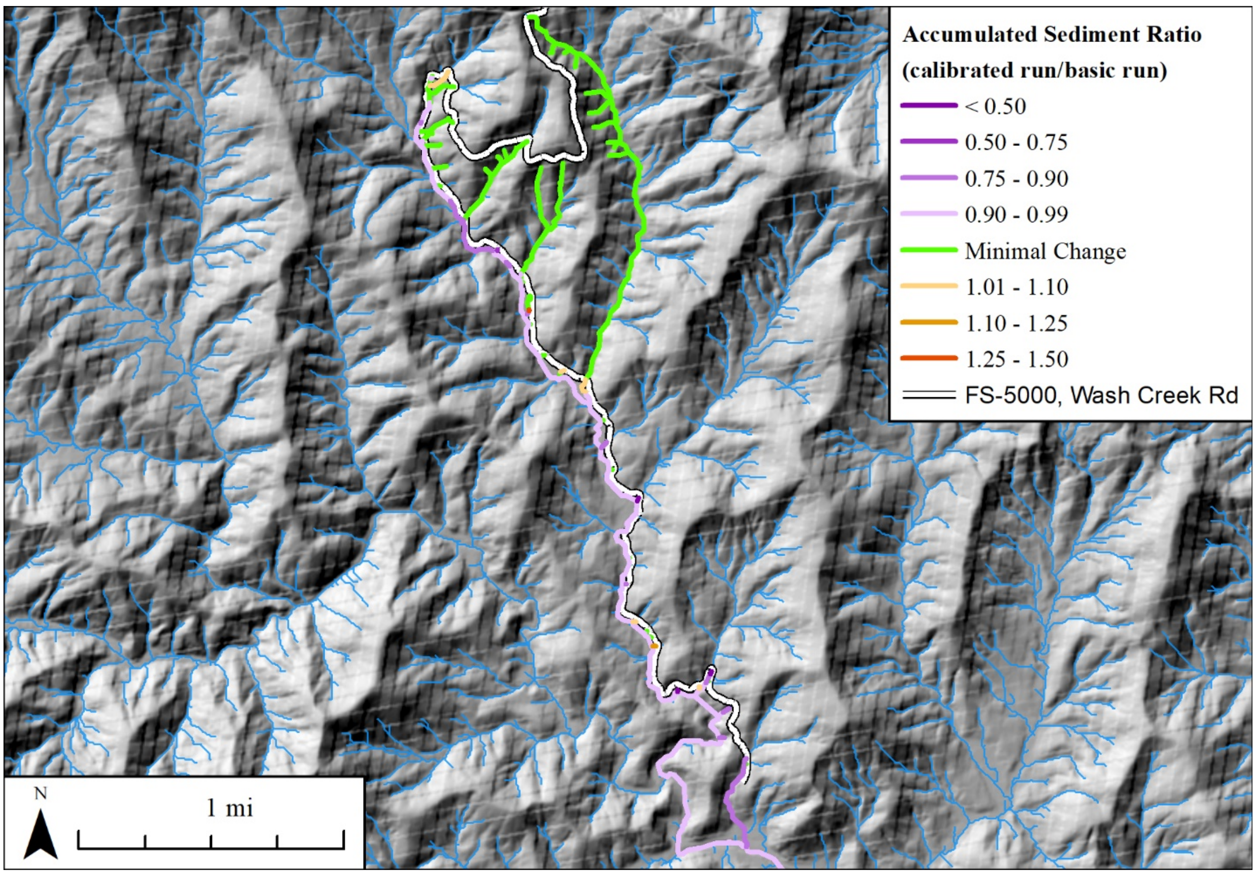

Figure 2. Ratio of predicted sediment accumulation between the GRAIP_Lite calibrated and GRAIP_Lite basic run. Shades of purple represent higher sediment predictions in the basic run, while shades of orange represent higher sediment prediction in the calibrated run; green represents minimal difference.

Table 1. Length of stream in feet falling under each ratio classification.

Ratio (calibrated/basic)		Length of Stream (ft)		Length of Stream (%)
Higher Sediment	< 0.50	156	**27,042**	**53%**
	0.50 - 0.75	15		

predicted in basic run	0.75 - 0.90	4,568		
	0.90 - 0.99	22,303		
Minimal Change			**22,936**	**45%**
Higher Sediment predicted in calibrated run	1.01 - 1.10	982	**1,075**	**2%**
	1.10 - 1.25	62		
	1.25 - 1.50	31		
	> 1.50	0		

The uppermost community science drainage feature is located where Wash Creek crosses FS-5000, above the northern-most orange section in Figure 2. The majority of minimal change (green) on Figure 2 occurred along tributaries in the upper reaches of Wash Creek watershed, supplied from areas that do not have community science datapoints. The calibrated model fairly consistently predicts less sedimentation than the basic run; this is likely due to the way in which known drain points are integrated into the model. In most instances, additional drain points added from community science datapoints are simply added to the collection of datapoints auto-generated by GRAIP_Lite (Figure 3). This increases the number of drainage points in the model, which likely equates to greater sediment dispersion – and therefore a shorter travel distance – of water and sediment. The end result is less sediment transported to the stream.

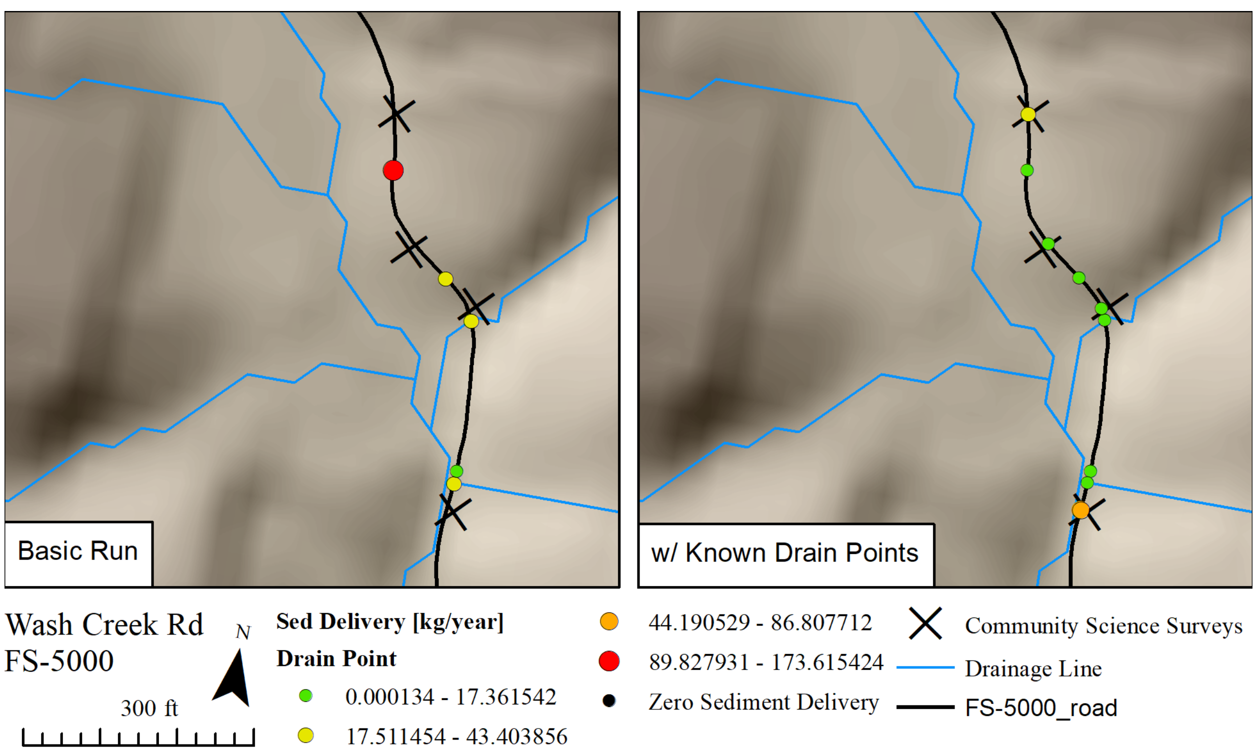

Figure 3. Community science drainage features (X) and GRAIP_Lite drainage points. **A.** Basic run drainage point placement; **B.** Calibrated run simply adds known drainage points without removing others.

Additional work is needed to create a drainage point input dataset that accurately represents the reality of the on the ground situation. Because Community Scientists are trained to collect every drainage feature on the road or trail they are surveying, road segments and drainage points are known for all surveyed segments and can be created manually and fed directly into the model. This will involve building an input file to replace the auto-generated road drainage point layer. This additional step will eliminate the ghost drainage points auto-generated during the basic model run.

Finally, a wealth of community science data were collected as part of the project, yet only road drainage points were used as model inputs. It may be possible to integrate several of the other measurements and parameters collected by community scientists, such as road condition and surfacing, sediment travel distance, and/or whether sediments visibly make it to a stream, to enhance the data available in the USFS roads layer or as *post-hoc* treatments. Methods to incorporate these parameters in the model inputs or as multipliers to model results should be investigated.

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EXTREME FLOODS, THE NEW NORMAL? SEDIMENTS REVEAL A 5,700-YEAR RECORD OF EXTREME FLOODS IN THE TENNESSEE RIVER VALLEY AND YIELD NEW INSIGHTS INTO EXTREME FLOOD FREQUENCY

Lisa Davis[1]*, Associate Professor
Ray Lombardi[1], Ph.D. Student
Miles Yaw[2], Hydraulic Engineer
Curt Jawdy[2], Hydrologic Lead

INTRODUCTION

With rainfall becoming more intense across the U.S. (Easterling et al. 2017) and multiple, major river basins experiencing 1-in-500-year events in recent years, many water professionals are asking whether extreme floods are the 'new normal' (Bolstad 2016)? As a case in point, the Iowa State University Institute for Transportation estimated that the 100-year flood of the 20th Century will be the 25-year flood of the 21st Century in the Cedar River Basin of Iowa (Anderson et al. 2015). Prediction of future changes in flood magnitude and frequency is hamstrung by relatively short streamflow records, which not only limit the data available to conduct flood frequency analyses but also makes validating model simulations of future precipitation and flooding scenarios challenging. Increasingly, hydrologists are working with geoscientists to combine flood information obtained from sedimentary deposits (paleoflood hydrology), which can provide thousands of years of flood information, with conventional hydrologic methods to improve predictions of extreme flood risk. The centennial- and millennial-scale records paleoflood reconstructions contain more extreme events, which lowers statistical uncertainty in flood frequency estimations (England et al. 2019). Additionally, paleoflood records can yield new insights into flow regime changes. They span longer cycles of climate variability and pre-date human modification of the landscape, which can help with discerning hydrologic change caused by climatological versus land-use changes. Recently revised USGS flood frequency guidelines provide a methodology for including paleoflood data in flood frequency analyses and were used to complete this research (England et al. 2019).

APPROACH

We have constructed a 5,700-year record of extreme flooding in the Tennessee River Basin using natural records of floods obtained from sediments deposited in caves and floodplains. A combination of radiocarbon dating (^{14}C), optically stimulated luminescence, and Bacon age modeling was used to determine flood ages. For the floodplain site (Big Oak), we measured particle size every 1 cm from a 3 m sediment core sample. Flood layers were identified based on peaks in medium to coarse sand identified using statistical analyses described in Toonen et al. (2015) and Leigh (2017). We estimated the size of extreme floods by determining the depth of flow required to transport the coarsest sand measured in a flood layer (the D90) and by reconstructing the pre-regulation hydraulic geometry of the river channel ascertained from soil and historical maps and bathymetry data supplied by Tennessee Valley Authority. The topographic position of the cave site (PBJ) was used to estimate minimum paleoflood peak stage.

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[2] Tennessee Valley Authority

Flood discharges were calculated using a 1-D, HEC-RAS model for both the floodplain and cave sites.

RESULTS AND DISCUSSION

Across the two sites (cave and floodplain), we found evidence of eight extreme floods. The three largest floods occurred between 3,200-3,700 BCE and generated an estimated upper discharge of 575,000 cubic feet per second (cfs). Four extreme floods occurred between 590 CE and 1690 CE that roughly equaled the estimated discharge, ~400,000 cfs, for the flood of record on the middle section of the Tennessee River, the Great Freshet of 1867 CE.

Though smaller than the three largest floods contained in the paleoflood record, the Great Freshet of 1867 was an exceptional flood and likely among the largest to have occurred within the last 2000 years.

Although floods of a variety of magnitudes occurred during the entire 5,700-year record, no evidence of extreme flood events were found between 3200 BCE and 590 CE. Interestingly, this time frame overlaps with the widespread settlement of floodplains and lower terraces in the Tennessee River Valley by indigenous peoples.

The timing of all the documented extreme floods coincide with major climate transition intervals experienced during the Holocene. The three largest extreme floods (occurred between 3200-3700 BCE), as the Holocene Thermal Maximum was drawing to a close. The Holocene Thermal Maximum was a globally warmer climate episode created by orbital changes that increased solar radiation. It was followed by a globally cooler and wetter climate episode called the Neoglacial Period during which alpine glaciers worldwide grew, and it culminated in the Little Ice Age, which extended into the early 20th Century. The climate of the Neoglacial period resulted from the combined effects of orbital changes and increased volcanic activity. Our data show that flood frequency increased and at least five extreme floods, including the Great Freshet of 1867, occurred between 590 CE and 1867 CE, as the Little Ice Age ended, and the Current Warming Period began.

The timing of past extreme floods during climatic transition intervals suggest that times of climatic transitions, such as the one happening currently, are prone to the most extreme floods. These findings validate concerns that contemporary floods are more extreme than in the recent past times (much of the 20th Century). They also demonstrate the utility of longer flood records, which span many climate episodes and transitions, in understanding trajectories of change as applied to estimating future flood risk.

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TN-GA 4-H WATER CAMP

L. Reynolds

The inaugural TN-GA 4-H Water Camp was held July 24-26, 2019 at Camp McCroy in the Cherokee National Forest in Polk County, TN. The idea for the camp was initiated by Lena Beth Reynolds, and was expanded to include McMinn & Polk Counties in TN, and Murray and Whitfield Counties in Georgia. The camp was organized and taught by Extension personnel from TN and GA. Camp participants included 45 youth, grades 4-12, and 10 adults. Lessons presented included Watersheds, Wetlands, Water Available on Earth, Creek Critters, Buoys and the Water Cycle. Activities included the Great Water Games, Poison Pump, tie-dye t-shirts, water cycle bracelets, and painting river rocks.

Tours were (of course) water related, utilizing the Ocoee (River) Whitewater Center, Copper Basin Museum, swimming in Copper Hill, and Ocoee Lake overlooks up on the mountain. The highlight of the camp for the TN 4-H'ers was the trip to the Hiwassee River, with a special session led by Jeronimo de Silva of the Southeastern Hellbender Institute. Ten youth and five adults enjoyed wading and snorkeling in the Hiwassee, complete with life vests. They learned about the habitat that hellbenders require, and were able to see and touch a live hellbender! The session ended with the release of the hellbender back to his native habitat, under a rock on the bottom of the river.

Surveys of the campers show that most would love to come back next year. Plans are underway for July 29-31, 2020!

TENNESSEE WATER EDUCATION AND TRAINING CENTER

David Blackwood[1]*

INTRODUCTION

The West Tennessee River Basin Authority, in partnership with the University of Tennessee Institute of Agriculture, is currently in the concept development phase of a unique facility that will use physical models and human-scale water management structures to educate users in the principles and practice of storm water infrastructure. This presentation will be an overview of how needs and solutions for hands-on water resource training were identified and developed.

APPROACH

Mission Statement: The WET Center will reduce flood risk, foster community resiliency and promote environmental conservation through education and training in hydraulics, hydrology, erosion and sediment control, and infrastructure installation.

Recent flooding has cause damage statewide and brought attention to the need for improvements. In an effort to reduce flood risk and increase flooding resiliency, the WTRBA examined damages and the response to disaster by different industries across Tennessee. Those patterns informed potential gaps in training, certification, and knowledge that could be creating recurring damages or unnecessary risk for storm water infrastructure. After the challenges were identified an analysis of the resources, tools, and facilities available for education helped create a picture of opportunities.

RESULTS AND DISCUSSION

The result of these activities was a concept for a new facility and program that will take fundamental concepts in hydraulics, hydrology, erosion and sediment control, and infrastructure installation and create a curriculum unique to each industry to fill the gaps in training and practice. Users will range across the spectum from K-12 STEM, Students, Teachers, Equipment Operators, Public Works, Environmental Consultants, and Engineers.

The education will be based on the STEM approach of learning through interacting (play). The facility will be have three main areas; classroom workspace, indoor physical model workspace, and a large outdoor reservoir with flumes and a heavy equipment training area that can be used to practice installation of engineering or environmental structures and then subject them to flow and watch them perform (or fail) in a controlled environment.

REFERENCES

[1] West TN River Basin Authority, 3628 East End Drive, Humboldt, TN 38343 David.Blackwood@tn.gov

NEW WAYS TO ADDRESS OLD PROBLEMS: PUBLIC-PRIVATE PARTNERSHIPS FOR WATER & EDUCATION

Catherine Price and Will Caplenor
Cumberland River Compact

INTRODUCTION

Implementation of water quality improvement projects (WQIPs) can be difficult as they often require multiple willing landowners, funding matches, skilled grant-writing and specialized field work. Due to the nature of non-point source pollution, these implementations often have to be multifaceted; focusing on in-stream work, public education and awareness and green infrastructure applications. The projects also usually involve multiple entities in different sectors. Having participation from private landowners, public utilities, government organizations, business owners and churches or parishes all within one specific project is very common so managing these relationships and building trust and participation is vital. This paper will address best management practices discovered through the Compact's multiple federal 319 Grants, in-stream restoration projects, WQIPs partnerships with City's and other one-off projects completed by the organization.

APPROACH

We will focus on two approaches to these public-private partnerships that implement both water quality practices and water education in schools and the community. First, we will share how we use 319 funding sources to implement large-scale, effective projects. Projects funded under the 319 grant program are intended to help bring waters into compliance with start and federal water quality standards. We will use our project in the Mansker's Creek watershed in Goodlettsville, TN as a case study. This project uses a large site, Moss-Wright Park, to implement several stream restoration projects including major and minor streambank stabilization, large-scale bioretention, tree plantings, and the installation of pet waste stations. Through this public-private partnership we have also held 3 water education festivals in the Park to educate the community on non-point source pollution. This project demonstrates how large restoration sites can improve project outputs and how to effectively engage in community education. This project's success can be traced back to key site identification and leveraging city and park needs. This stream was experiencing such severe erosion, that the park was losing upwards of 6-10 inches of land annually that was encroaching into park trails and becoming a hazard. This became the perfect site to develop projects around and we used this to justify developing a much needed Watershed Based Plan for the area, which eventually evolved into two separate funded 319 grants that have greatly improved local water quality.

Next, we will share how we continue to partner with MS4s to help them achieve their public education and engagement goals. We will present two similar models with the City of Franklin and Metro Nashville that respond to and reflect the needs of their communities. These partnerships include a focus on school-based education, community engagement, private landowner outreach, and more. We've found that this work serves two purposes, getting us out in the community and implementing worthwhile projects and dealing with some of the more nuanced calls and concerns municipalities receive from residents and either lack manpower or expertise to look into these concerns.

IMPACTS AND NEXT STEPS

The Cumberland River Compact has carried out five 319 Restoration Grants, enlisted several cities in a WQIP in which we serve as outreach and perform small-scale stormwater implementations and have removed dozens of low head dams from our waterways. The most difficult portion of these projects tends to be site identification and landowner participation/fund matching. Federal grants tend to require matching funds and developing a WBP, 319 Application or other grant without first identifying this can set you up for failure. Identifying a problem area within a willing landowners should be the first step and developing further projects around this would be ideal.

SESSION 2A

WATER MODELING (Moderator: Alfred Kalyanapu, TTU)
8:30 a.m. – 10:00 a.m.

Tennessee Valley Authority Flood Automation Tool
Trevor Cropp

Investigating Flood Mitigation Options in the Beech River System
Md N M Bhuyian, David Blackwood, Chris Story, and Justin Marlow

Mitigation of Delta-T Events in Wheeler Reservoir with Dam Releases
Rob Annear, Colleen Montgomery, Rich Wildman, and Lucas Nguyen

URBAN STORMWATER MANAGEMENT (Moderator: Paul Davis, P.E.)
10:30 a.m. – 12:00 p.m.

Comparison of DRAINMOD-Urban and the SWMM LID Module for Bioretention Modeling
Whitney A. Lisenbee

A Study on the Hydrologic and Water Quality Implications of Implementing Real-Time Control Schemes in Urban Bioretention Practices
Padmini P. Persaud, Jon M. Hathaway, Aaron A. Akin, and Branko Kerkez

Urban Waters Report Card – Tennessee Collaboration
John S. Schwartz

FLOODPLAIN MANAGEMENT (Moderator: Tom Palko, Metro Water Services)
1:30 p.m. – 3:00 p.m.

A River Runs Through It: I-24/I-75 Interchange Hydraulics
Ben Zoeller

The Seven Habits of Highly Effective Drainage Studies
Bradley Heilwagen

Come Hell or High Water: Developing Flood and Extreme Precipitation Risk Assessments for Hazard Mitigation Plans
Andrew Joyner, William C. Tollefson, Joseph B. Harris, and P. Andrew Worley

REAL-TIME MONITORING (Moderator: Shannon Williams, USGS)
3:30 p.m. – 5:00 p.m.

Dye Study to Monitor Flow from a Source River Through a Reservoir
John Michael Corn

Turbidity Informed Real-Time Control of a Dry Detention Basin
Aaron A. Akin and Jon Hathaway

Low-Cost, Real-Time Water Level Monitoring Network for Falling Water River Watershed
Alfred J. Kalyanapu, Dakota Aaron, Chris Kaczmarek, Vaibhav Ravinutala, and Phisuthisak Ngernkuakul

TENNESSEE VALLEY AUTHORITY FLOOD AUTOMATION TOOL

Trevor Cropp[1]

Barge Design Solutions in partnership with Riverside Technologies Inc. (RTI) has completed the development of an interactive tool and modeling framework for completing a series of meteorologic, hydrologic, and hydraulic modeling processes for the Tennessee Valley Authority (TVA). Through the use of a graphical user interface webpage, the tool automates the Probable Maximum Precipitation (PMP) generation, performs hydrologic computations through the use of Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), performs hydraulic routings through the use of Hydrologic Engineering Center's River Analysis System (HEC-RAS), postulates any required dam failures, and generates figures for hundreds of proposed Probable Maximum Flood (PMF) simulations.

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

[1] Barge Design Solutions

INVESTIGATING FLOOD MITIGATION OPTIONS IN THE BEECH RIVER SYSTEM

Md N M Bhuyian[1]. David Blackwood[21 above], Chris Story[21], Justin Marlow[21]

Rivers in West Tennessee were channelized in the last century to facilitate drainage of wetland areas and increase crop production. The channelization efforts primarily focused on the rapid release of floodwater without the evaluation of changes to river morphology and floodplain terrain. Therefore, in some areas, the channelization resulted in increased sand supply, degraded river conveyance, and worsening the flooding situation. Beech River located near the city of Lexington, TN is one such river. It accumulates flow from several subwatersheds and passes through a narrow valley opening before discharging into the Tennessee River. The Beech River was channelized once by the US Army Corps of Engineers (in the 1910s) and Tennessee Valley Authority (in the 1960s). Both of these efforts failed to sustainably mitigate flooding. Additionally, the operation of the reservoir in the Tennessee River has acted as a barrier for the undisturbed flow of the Beech River. Therefore, the West Tennessee River Basin Authority is studying the impacts of human interventions (e.g. channelization, reservoir operation) on the flooding behavior of the Beech River and the adjacent floodplain. The Agency also seeks to find a sustainable flood mitigation plan that would be beneficial to the property owners on the floodplain. This research presents the preliminary findings of the West Tennessee River Basin Authority through two-dimensional flow modeling for selecting the most reasonable flood mitigation measure in the Beech River system.

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MITIGATION OF DELTA-T EVENTS IN WHEELER RESERVOIR WITH DAM RELEASES

Rob Annear[1], Colleen Montgomery[2], Rich Wildman[1], and Lucas Nguyen[1]

Wheeler Reservoir is a reach of the Tennessee River near Huntsville, Ala. that stretches from Guntersville Dam to Wheeler Dam. It provides cooling water to Browns Ferry Nuclear Plant. The cooling water discharge of this power plant must not exceed a maximum difference in temperature (termed "delta-T") from an upstream monitoring location to a downstream one. The recent uprate of the capacity of Browns Ferry Nuclear Plant may make compliance with a delta-T limit of 10 F more challenging. The goal of this project was to explore dam release scenarios that might mitigate elevated delta-T in Wheeler Reservoir. The first step was to examine the monitoring record and identify times during the years 2015-2017 when variation in delta-T was notable. Then, the hydrodynamic and temperature model of Wheeler Reservoir, which uses the modeling software CE-QUAL-W2, was used to simulate the temperature of the reservoir and calculate delta-T during several different scenarios of flow patterns from Guntersville Dam and Wheeler Dam that can affect delta-T. Results suggest that a key variable for controlling compliance delta-T is the highest flow rate sustained for even a short period during a day. As this value was increased, delta-T was generally lower. Longer-duration high flows provided a longer decrease in delta-T, but the reduced flows needed to conserve water for these high flows raised delta-T at other times. This indicates that modified dam releases to manipulate delta-T could be used mainly as a targeted, short-term remedy for elevated delta-T events.

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COMPARISON OF DRAINMOD-URBAN AND THE SWMM LID MODULE FOR BIORETENTION MODELING

Whitney A. Lisenbee[1]*

INTRODUCTION

Over the last decade, bioretention systems have become a leading stormwater control measure that increases stormwater infiltration thereby reducing urban runoff volumes and peak flows. Although these systems have performed well in many site-scale field studies, modeling of bioretention systems has received less attention (Liu et al. 2014, Davis et al. 2009). Modeling of bioretention allows designers to optimize the function of bioretention cells better, provide guidance for design standards, and scale local impacts to the larger watershed. DRAINMOD has been applied to bioretention due to its advances in soil-water accounting through the soil-water characteristic curve and the ability to easily model underdrains and internal water storage (IWS) zones. This model was updated to create DRAINMOD-Urban which is capable of simulations at as small as 1-minute time steps to better match the temporal scale of urban systems. The US EPA Stormwater Management Model (SWMM) has become one of the most widely used models for bioretention, especially since the release of SWMM5 which includes dedicated LID modules (Rossman 2010). In this study, DRAINMOD-Urban and the SWMM LID module were compared through a detailed analysis of the internal processes of each model as well as through model calibration and output investigation. The objectives of this study are to evaluate 1) the performance of DRAINMOD-Urban and SWMM regarding bioretention systems 2) the applications that best suit each model 3) the minimum level of input detail required to meet each of the model applications.

APPROACH

The Ursuline Cell (UC) located near Cleveland, Ohio, USA, has been used for evaluation of DRAINMOD and DRAINMOD-Urban performance and sensitivity in previous studies and therefore is compared here to SWMM (Lisenbee et al., 2020, Winston et al., 2016, Winston, 2015). The UC cell was designed to treat stormwater runoff from a 77% impervious drainage area (3600 m^2) made up primarily of parking lot. Monitoring equipment collected precipitation on-site, combined drainage and overflow from the cell, and internal water level of the cell over seven months at 1-minute or 2-minute intervals. The inflow from the drainage area was determined using SWMM.

Prior to modeling, the governing equations used in SWMM and DRAINMOD-Urban were compared as they related to various components of the water balance of the bioretention cell. The inflow was almost identical, and both models used the Green-Ampt infiltration equation.

Differences emerged in the drainage and overflow equations. Although the two models used the same equation to process the infiltration into the bioretention cell, the inputs required for the Green-Ampt equation differed. DRAINMOD-Urban derives the required infiltration information from the measured soil-water characteristic curve (SWCC). SWMM requires soil moisture

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estimates and other soil properties that can either be entered by the user or estimated based on soil texture. These differences prompted an investigation of required model inputs, specifically estimated versus measured parameters.

Both SWMM and DRAINMOD-Urban were evaluated in both uncalibrated and calibrated scenarios because SWMM is often used as an uncalibrated model. Calibration of the two models followed a similar process to determine the best fit of the drainage and overflow hydrographs to measured values. The calibration parameters used in DRAINMOD-Urban were the saturated hydraulic conductivity of the bioretention layer, the saturated hydraulic conductivity of the sand layer, the drainage coefficient, the piezometric head and the thickness of the restricting layer.

The calibration parameters used in SWMM were the saturated hydraulic conductivity and suction of the bioretention media, the conductivity slope (HCO), and the void ratio of the storage layer. The goodness of fit tests used were Nash-Sutcliffe Efficiency (NSE) and percent bias (PBIAS).

After statistics were used to narrow the number of scenarios, hydrographs were visually inspected, and characteristics such as peak flow, time to peak and event duration were compared for each event that produced outflow. Next, cumulative and event volumes were summed and compared to observed values. These assessments aided in determining a final calibrated simulation for the UC cell.

RESULTS AND DISCUSSION

Early results show an uncalibrated SWMM model (NSE=0.56) can perform similarly to a calibrated DRAINMOD-Urban model (NSE=0.50) with respect to measured combined outflow hydrographs. Further calibration of the storage void ratio and conductivity slope led to improved SWMM performance (NSE=0.68). Although the drainage coefficient and saturated hydraulic conductivity were initially considered as calibration parameters in SWMM, the drainage coefficient showed no change in model outputs over a range of values and the saturated hydraulic conductivity was very sensitive to the model outputs but still produced the best hydrographs using the measured value.

As seen in Figure 1, both models overestimated peak outflow, but DRAINMOD-Urban was closer to the measured peaks. Following the peaks, the measured data levels out just above 0.5 cm/bioretention area (BRA) before decreasing. DRAINMOD-Urban begins steadily decreasing right away whereas SWMM levels out at about the same point as the measured data but holds the constant value to form a box shape. When considering the volume of outflow for this event, DRAINMOD-Urban underestimated the volume by 6 cm/BRA and SWMM overestimated by 10 cm/BRA.

Although SWMM performed well when calibrating the model to the hydrographs, the difference in measured and modeled drainage and overflow total volumes increased as the hydrographs improved. On the other hand, the simulation with the best modeled total volumes for both overflow and drainage only reached an NSE=0.31 based on the 2-minute hydrographs.

Therefore, a modeler using SWMM must determine if total volumes or hydrograph timing, peak and duration are more important for a given application. However, with DRAINMOD-Urban, improved hydrographs also showed the same or better model performance of total volumes.

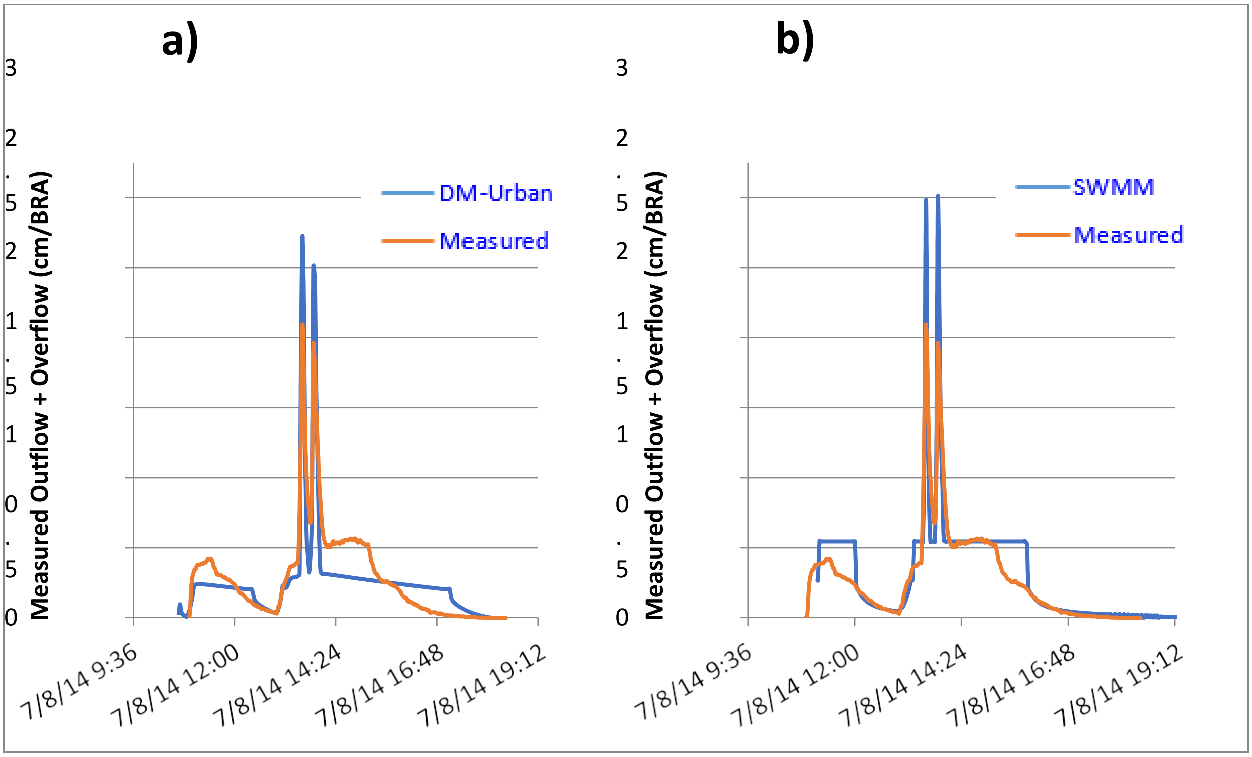

Figure 1. The event with the best NSE values from both calibrated models demonstrates the differences between (a) DRAINMOD-Urban (NSE=0.752) and (b) SWMM (NSE=0.781).

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A STUDY ON THE HYDROLOGIC AND WATER QUALITY IMPLICATIONS OF IMPLEMENTING REAL-TIME CONTROL SCHEMES IN URBAN BIORETENTION PRACTICES

Padmini P. Persaud[1], Jon M. Hathaway[2], Aaron A. Akin[3], and Branko Kerkez[4]

Key words: Bioretention, Real-Time control, Water Quality, Hydrology

INTRODUCTION

Urban expansion and the proliferation of extreme weather has caused an increase in runoff and water quality concerns. The aging infrastructure of established cities also compounds these issues as existing stormwater channels are not equipped to handle higher peak flows (Brabec et al., 2002). As stormwater is routed directly into stream and river systems, the downstream effects of the increase in nutrient input, and flow generation, has resulted in problems regarding erosion and eutrophication. Green infrastructure practices, like bioretention cells, have been developed to manage peak flows as well as improve water quality in urban watershed areas to mitigate larger downstream environmental issues. As point source practices, bioretention cells are implemented in places like parking lots and residential areas that experience a large amount of traffic (Hunt et al., 2009). To progress with growing populations and the increasing intensity of rain events, adding real-time control technologies to bioretention cells allows more direct control of the hydrologic and water quality capabilities of the cells. This technology uses sensors and control schemes to regulate the water levels within bioretention cells to allow for particular nutrient processing or to accommodate incoming expected rainfall. This research employs two real-time control schemes and compares their effects to traditional free draining and internal water storage bioretention cells. While improvements in nutrient management as well as differences in hydrologic processing have been observed as a result of the use of real-time control, further research on the impacts of microbial activity should also be studied to more accurately control nutrient processing conditions.

APPROACH

A nine-week column study yielding 18 storm events was conducted to test the use of two real-time control configurations against traditional bioretention design. A soil moisture control was used with the objective being to maintain field capacity of the soils while a volume control was used to maintain internal water storage levels. These configurations were compared to free draining and internal water storage bioretention designs (Figure 1). Over the course of this study weather predictions were sent to the real-time control columns to allow internal adjustments for

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incoming weather. Storm events were applied to each column and water quality samples were then collected 24 hours later. Samples were tested for nutrients and metals. Reductions were tracked over the course of the study to determine water quality differences between treatment types.

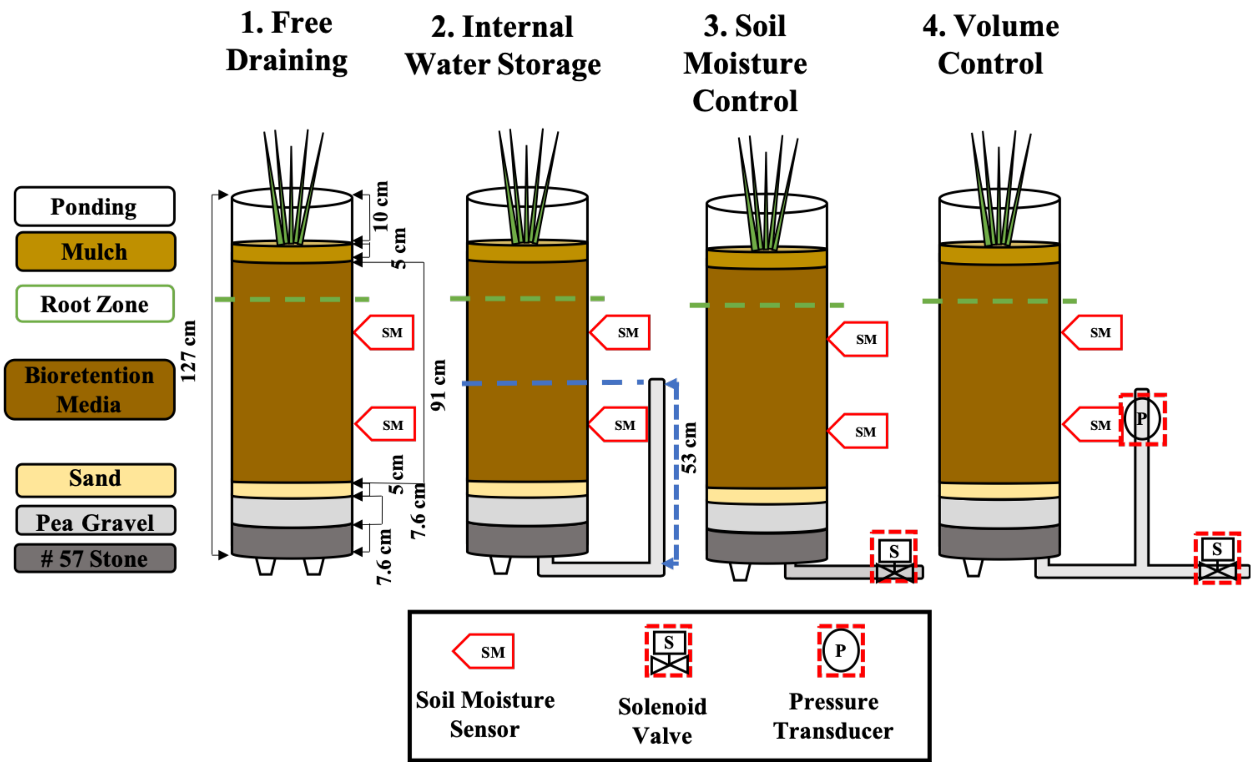

Figure 1. Bioretention Column Designs

CONCLUSIONS

Over the 9-week study real-time control and static bioretention designs were compared by observing water quality improvements of each treatment. Of particular importance were the differences in water quality for nutrients. Specifically, soil moisture control's performance (43% ammonia removal and 74% nitrate removal) compared to that of free draining systems (71% ammonia removal and 39% nitrate removal), and internal water storage systems (26.3% ammonia removal and 95.6% nitrate removal) suggest a high potential for promoting both nitrification and denitrification beyond the capabilities of free draining and internal water storage systems. Future work aims to study hydrologic implications of real-time control on bioretention as well as associate water quality data with observations of microbial activity and community structure to better manage and maintain microbial processes.

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URBAN WATERS REPORT CARD - TENNESSEE COLLABORATION

John S. Schwartz

EXTENDED ABSTRACT

An Urban Waters Report Card (UWRC) is under development in Tennessee through the cooperation by the cities of Nashville, Chattanooga, Memphis, and Knoxville, and counties of Hamilton, Shelby, and Knox. All jurisdictions are MS4 permittees. The goal for use of the UWRC is to provide MS4s a means to track improvements in streams from their stormwater management and stream rehabilitation efforts. Even though with considerable effort by the MS4s, in many cases streams will continue to fail to meet their designated uses remaining on the impaired waters (303d) list. A grading scale for the UWRC will span from A to F providing an assessment scheme that demonstrates the incremental enhancement of a stream's condition. Such a scheme is more informative to the local stakeholders including the MS4 professional and administrative staff, political leaders, and the public. The planned framework of the UWRC is simple and intuitive. A number of categories are to be considered for grades by the participating MS4s such as channel habitat, stream corridor, watershed connectivity and water quality. A composite grade is planned for each stream assessed. One benefit of the UWRC for the Phase II MS4s is that they must demonstrate program effectiveness. The use of the UWRC would provide them the tool to achieve their NPDES permit requirement. More details on this proposed categories and grading scheme follow, but first this article will describe the steps taken to date.

To give proper credit, the idea for the UWRC originated with Jennifer Dodd and Karina Bynum with the Tennessee Department of Environmental and Conservation (TDEC). The UWRC is not a regulatory program and its only purpose is to help MS4 programs. The Tennessee Water Resources Research Center (TNWRRC) offered to manage the development and maintenance of the UWRC. The kick-off meeting was held via teleconference on February 20, 2019. The idea was introduced to the MS4s, participants noted above, and all were supportive to move forward with it. During the spring period, John Schwartz and Tim Gangaware met with each of the MS4s to gather additional information on their stormwater program priorities and how they would like to see the UWRC development proceed. The first group meeting was held on July 29, 2019 in Murfreesboro Ag Extension Office to discuss the overall UWRC framework and what categories should be included. Those that attended the first meeting included: Roy Arthur - Knox County, Karina Bynum – TDEC, Chris Granju, Jennifer Dodd – TDEC, Tim Gangaware - TNWRRC, Don Green – Chattanooga, April Grippo – TDEC, Veronica Logue - Nashville Metro, Chris Masin - Shelby County, Wyn Miller - Knox County, Ann Morbitt – TDEC, Adam Reynolds - Hamilton County, and John Schwartz – TNWRRC. Joshua Rogers – Chattanooga provided input for the meeting, including an example report card used in Portland, Oregon.

Currently, all MS4s have implemented at least once a modified version of the Maryland Stream Corridor Assessment (MSCA) protocols. The MSCA scores related to physical channel metrics have been used for setting priorities for bank stability and stream restoration projects. Additional monitoring by the MS4s has included benthic macroinvertebrate (BMI) monitoring using the Tennessee Macroinvertebrate Index (TMI) protocols and fecal bacteria testing. Only the Phase I MS4s continue to conduct chemical water quality analysis from event-based stormwater and stream monitoring sites.

During the July 2019 meeting, discussion continued on monitoring issues in general and the potential for program changes. It was noted that the MSCA metrics used did not change over time such that the protocols with this assessment therefore the metrics do not reflect improvements in stream condition. UWRC metrics need to be able to measure changes over time. It was noted that stream size is important in order to detect improvements from implementation of stream restoration and stormwater control measures (SCM) retrofits. In addition to identifying the optimal spatial scale for an assessment, the frequency in which to conduct assessments are also important to detect physical, chemical, and biological conditions of the stream channel. The group will need to decide the assessment and reporting scale. One suggestion was to use the 303d listing scale per unavailable parameter (segments supporting, partially supporting, or not supporting biological criteria). The spatial selection and temporal frequency for monitoring maybe parameter dependent – this will be worked out during the development of the UWRC.

UWRC implementation requires a state-wide consistent definition of an urban stream. Defining an urban stream provides the framework to develop the UWRC categories and metrics that are science-based, and sets watershed condition parameters targeting restoration activities. It was noted that the report card needs to be flexible for application in different watershed and stream types. The issues/questions brought up were: the issue of scale, length of stream segment applied was revisited from the earlier discussions on that topic in the morning. Watershed size cannot be too large for the report card to be effective for the MS4 Programs – earlier discussions suggested the HUC-12 basin size would be appropriate. Are there two operating scales to define an urban stream, and the categories and metric that would go into the report card? Basically, are there response variables (metrics) at the watershed scale, e.g., water quality versus those at the reach scale, e.g., bank stability. It was noted that watershed scale factors likely influence the reach scale conditions. Several questions related to the urban stream definition were asked and discussed; they include:

> *Is there an existing grading system based on degree of urbanization?* It was noted that hydrologically 10% impervious starts to impact runoff, and about 25% impervious starts to impact BMI, though there is much variable about responses from degree of impervious. And there is the difference between total impervious area (TIA) and effective impervious area.
>
> *Are their three stream categories: urban, suburban or urbanizing, and non-urban (rural)?* Biologically, are there quantifiable differences between an urban stream and a non-urban stream? The question of what is not an urban stream was introduced to provide context on how to possibility define an urban stream. Would there be different metric criteria per common scoring stream quality categories for these three stream categories?
>
> *How do you address the issue of headwaters that may be disturbed by agricultural practices or other land use impacts, and the lower catchments of a watershed are urbanized?* This question is relevant for both defining what is an urban stream and how would an UWRC work under this situation of multiple impacts (stressors) in the watershed.
>
> *Is population density per catchment (HUC-12) or road density a useful means to categorize an urban stream?* There has been at least one published article that associates road density with channel geomorphic stability. The use of population density and/or road density appeared to be favored by the group. A GIS will be conducted by TDEC staff to provide

some population/ road density data in HUC-12 basins on what would be the threshold(s) to classify a stream as an urban stream. We will rely on this data to conclude on the definition of an urban stream for use in the UWRC.

After much discussion during our July 29th meeting, the four categories were selected with some suggested metrics. The four categories are: Watershed Hydrology, Water Quality, Stream Corridor, and Community Value. Below is a summary of the categories agreed upon by the group attendees:

Watershed Hydrology
- Treated Runoff Volumes from Stormwater Control Measures (SCMs)
- Effective Impervious Area (similar to SCMs/Retrofits)
- Flashiness Index
- Indices of Hydrological Alteration (IHAs)
- Land Use % Area (urban forest canopy, parks and open space): converted or preserved.

Water Quality
- Fine sediment (TSS), bacteria (pathogens), nutrients (P/N, periphyton), metals, toxics.
- Indices of Biotic Integrity (TMI sub-metrics/ IBI sub-metrics)
- Other Pollutants (with WQ standards)

Stream Corridor
- Physical Habitat – substrate, meso- and micro-habitat structure
- Riparian Buffer – setbacks, easements, vegetation composition and structure
- Hydrological Connectivity: floodplains and wetlands, biological refugia patches
- Biodiversity – plant/wildlife terrestrial/aquatic
- Channel Stability: Rapid geomorphic Assessment (RGA); bank erosion index
- Fish barriers (AOP), infrastructure crossings

Community Value
- Access, recreation
- Aesthetics, trash
- Socioeconomic factors

Development of the metrics per category and how to score each will be the next phase of this project. Depending on the metric development of a scoring system and desktop/field protocols for measurement may require expert's assistance.

A RIVER RUNS THROUGH IT: I-24/I-75 INTERCHANGE HYDRAULICS

Ben Zoeller[1]

The I-24/-75 interchange on the south side of Chattanooga is the primary connection point between Middle Tennessee, East Tennessee, and North Georgia and is currently being redesigned to increase capacity and improve safety and operation of the interchange. Drivers passing through this interchange may not notice another major confluence in the area. Just southeast of the interchange lies the confluence of South Chickamauga Creek, West Chickamauga Creek and Spring Creek totaling approximately 430 square miles of drainage area. The confluence of these three streams creates design and construction challenges for an already complex project with six bridges over the streams and roadway widening in the floodplain fringe. Attendees of this presentation will get an understanding of the complexity of hydraulics and floodplain management associated with the I-24/I-75 Interchange Design Project.

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THE SEVEN HABITS OF HIGHLY EFFECTIVE DRAINAGE STUDIES

Bradley Heilwagen[1]

My induction into the world of performing drainage studies was as a young agricultural engineering major at the University of Illinois. Back then, they truly were drainage studies, since we were most concerned with draining off excess water from pancake-flat and overly-saturated corn fields. From there I went to work for a hydroelectric utility in mountainous and arid Idaho, where the concern was less about draining off the water and more about capturing as much water as possible to maximize power production. From there I got into developing flood studies for making FEMA maps and performing risk assessments across Alabama, Florida, Kansas Kentucky, and Missouri. That evolved into local stormwater studies here in Tennessee that would result in the identification of flood reduction measures and rehabilitation alternatives for urban drainage ditches. Now nearly 20 years later, this point in my career finds me performing peer- and third-party-reviews of several drainage studies per year. While not unique by any right, this collective experience has allowed me to see drainage studies of all shapes and sizes created for a variety of purposes in a variety of geographic settings.

This experience has also allowed me to see numerous drainage studies that were not performed in the most effective way. I've reviewed and participated in the development of studies where the model software used was not appropriate for the terrain and geography. I've been 75% through the development of a flood study, only to receive new topographic data to use for input. I've seen municipalities caught off-guard when a developer submits plans to build a subdivision in an area where no previous drainage study was been done, and then I've seen that same community fund a new drainage study to completion, only to find that it wasn't done at a resolution that could be used to test the effects of the new subdivision on stormwater runoff. I've read drainage study reports written by the best technical minds that left me less knowledgeable about the basin and modeling methods than I was when I started. I've seen communities fund, and fund, and fund again studies of the same drainage system, but for varying purposes. These issues cost communities and engineers time, and as we all know, time is money.

In 1989, the businessman and author Stephen Covey published a self-help book titled The 7 Habits of Highly Effective People. The groundbreaking book presents a series of habits that, if followed by the reader, result in the alignment of one's values with universal principles that Covey calls "the character ethic." It has been recognized as one of the most influential business management books in history. While the character ethic may not apply to performing drainage studies, those seven habits that Covey presents in his book certainly do. Be proactive; begin with the end in mind; put first things first; think win/win; seek first to understand, then be understood; synergize; and sharpen the sword are tenants that we should subscribe to.

This presentation will draw parallels between Covey's seven habits of highly effective people and best practices that should be considered when performing drainage studies or all shapes and sizes. Examples will be given from the numerous projects I've been a part of in my 20 years as a

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water resources engineer that highlight the need to subscribe to these seven habits. Although not revolutionary by any means, it is my hope that the ideas presented help to increase the effectiveness of drainage studies across the State of Tennessee.

COME HELL OR HIGH WATER: DEVELOPING FLOOD AND EXTREME PRECIPITATION RISK ASSESSMENTS FOR HAZARD MITIGATION PLANS

T. Andrew Joyner, William C. Tollefson, Joseph B. Harris, and P. Andrew Worley

Tennessee has experienced many flood events over the past decade, from the 2010 Nashville floods to the record-setting February 2019 rainfall, some of which have even prompted Presidential Disaster Declarations. Flooding and other hazards highlight the need for comprehensive hazard mitigation planning that analyzes not only our historical understanding of a community's hazards, but also the risk of unprecedented events which may impact a community. Hazard mitigation planning consists of several components: hazard identification and profiling, risk and vulnerability assessments, critical infrastructure assessments, and mitigation strategies and actions. Climatological and geospatial analysis form the core methodological approach for identifying and profiling hazards in a community. Over the past four years, the Geoinformatics and Disaster Science Lab at East Tennessee State University has developed Hazard Mitigation Plans for Sevier County (Tennessee), Tufts University (Massachusetts), and ETSU based on in-depth analysis of hazards and critical infrastructure using novel approaches and GIS/climate datasets, allowing for better communication of risk and vulnerabilities to stakeholders and planning team members within each jurisdiction. This enabled the stakeholders to form better mitigation strategies for their communities and, more broadly, emphasized the need for better localized climate information and data. For flood and extreme rainfall events, various national climate datasets exist to fill this gap but can be difficult to access and use. Planning would be further improved through a state climate office that develops Tennessee-specific climate datasets, risk assessments, and other products.

Keywords: Hazard Mitigation, GIS, Risk Assessment, Natural Hazards, Climate Data

DYE STUDY TO MONITOR FLOW FROM A SOURCE RIVER THROUGH A RESERVOIR

John Michael Corn[1]

Tributaries to stratified lakes are expected to flow in the middle layer of a stratified lake under stable, i.e., non-flood, conditions. Lakes can have 3 to 4 independent stratified zones that are established during warmer months. In the south, including in Tennessee, the lake water column is expected to be completely mixed from top to bottom and the water temperature does not vary by more than about 3 to 5ºF from the surface of the lake to the bottom of the lake during the winter months. In April as air temperatures begin warming, distinct stratification zones can begin forming. Once established, the layers do not interact until they are disturbed through turbulence or when their physical properties become similar.

AquAeTer personnel performed a dye study to determine, if possible, where a river was actually flowing through the stratification zone in a reservoir. For this study, the reservoir was confirmed to be stratified prior to deployment of any other equipment. Once the stratification was confirmed, water quality sondes were deployed and a slug of Rhodamine WT dye was injected at a location on the upstream River that would allow for complete mix of the dye within the River's water column. The sondes were used to monitor the progress of the dye progression downstream. In addition to the deployed data sondes, water quality, sediment samples, and instantaneous measurements were collected. This dye study demonstrated that the river flows through the metalimnion within the reservoir. Water from the riverine portion of the river does not appear to interact with the upper layer (epilimnion) or the lower layer (hypolimnion) when the reservoir is stratified. This conclusion is based both on physical parameters measured in the river and reservoir, as well as the dye results monitored in the system.

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TURBIDITY INFORMED REAL-TIME CONTROL OF A DRY DETENTION BASIN

Aaron A. Akin[1] and Jon Hathaway

INTRODUCTION

As the threats of urbanization, climate change, and degraded infrastructure converge, there is a need to reimagine stormwater management. The majority of stormwater infrastructure is static, unable to adapt as watershed restoration needs are altered or rainfall patterns change. This includes stormwater control measures such as detention basins. However, recent studies have begun to investigate the usefulness of retrofitting such systems with a controllable valve on the outlet to increase or change detention times during rainfall events. Typically, these detention times are predetermined, and thus don't account for changing conditions between rainfall events such as shifts in water quality and are still a "static solution to a dynamic problem" (Kerkez et al. 2016). Therefore, new studies are required to investigate the impact and efficiency of adaptable systems which integrate real-time water quality data into the decision framework. The purpose of this research is to investigate the impact and use of real-time water quality data on a dry detention basin retrofitted with a controllable valve and a turbidity sensor.

APPROACH

A dry detention basin in the Conner Creek watershed of Eastern Tennessee was chosen for this study (Figure 1). The detention basin collects runoff from the impervious areas (such as roofs and parking lots) and practice fields of a local high school and elementary school. The contributing drainage area is 50 acres and the basin can detain approximately 500,000 cubic feet of water at a maximum stage of 10 feet before water overtops the outlet riser of the basin.

In order to convert this static stormwater infrastructure into an adaptable system, the outlet structure was retrofitted with a 6" butterfly valve (Valworx 564548) and matching electric actuator (Valworx 561877A), an ultrasonic depth sensor (Grove Ultrasonic Ranger), a dual sidescatter/backscatter turbidity sensor (Campbell Scientific OBS501), and a custom control circuit powered by a Particle Boron LTE development board. Additionally, a tipping bucket rain gauge was integrated into the system to record rainfall and assist in the control decisions made by the system.

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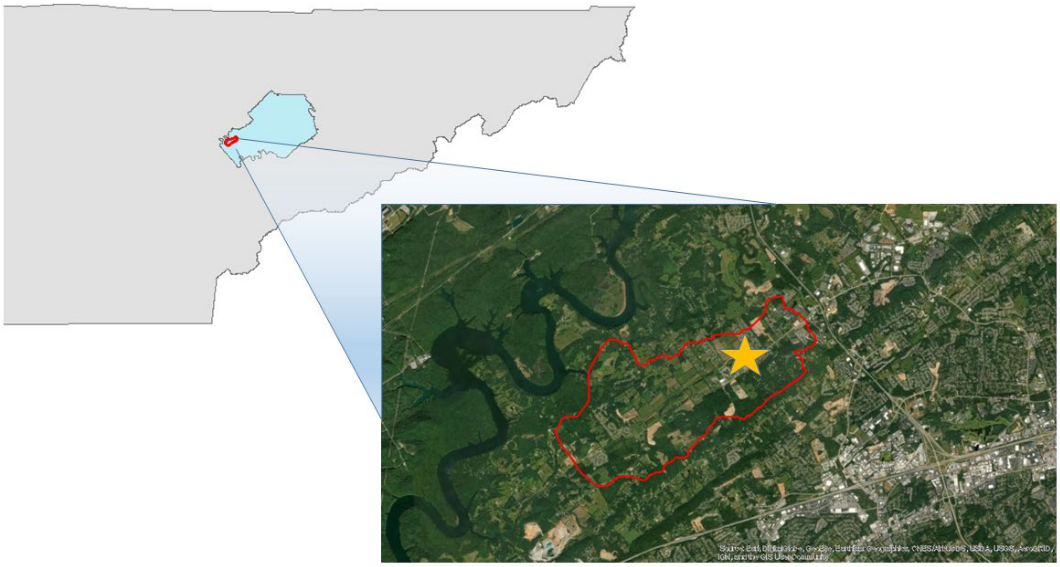

Figure 1. Study location in the Conner Creek watershed of Eastern Tennessee.

To investigate how the integration of real-time turbidity data affected system performance, a set of control rules for the system were established. When rainfall was detected, the basin's valve would close and detain all water (Figure 2) for a minimum of 24 hours following the end of a rainfall event. The valve would remain closed until either a maximum detention time of 72 hours was reached, or turbidity values fell below a predetermined threshold of 25 FNU. The minimum and maximum detention times were adopted from the Knox County, Tennessee, and Georgia Stormwater Management Manuals' chapters on dry detention basins (Knox County, Tennessee Stormwater Management Manual 2008; Georgia Stormwater Management Manual 2016). Additionally, since Tennessee does not have any explicit regulations regarding turbidity in surface waters, guidance for the turbidity threshold came from regulations for ponds, reservoirs, and streams from 8 states' water quality standards (Arizona, Hawaii, Iowa, Minnesota, North Carolina, Oklahoma, South Carolina, and Vermont).

Figure 2. Detention basin following rainfall event.

Fifteen events are proposed for the data collection period of this study. An event is defined as the time between when rainfall is initially detected at the site and when the system makes the control decision to release water from the detention basin. Released water exits the basin, travels down a rock channel, and enters Conner Creek.

RESULTS AND DISCUSSION

Twelve of the fifteen events of this study have passed through the system as of February 14th, 2020. The majority of rainfall events resulted in turbidity trends comparable to that of Figure 3, in which turbidity initially increases during the hours during and following rainfall before steadily decreasing over the next few days. Though similar trends in turbidity occurred, overall detention times were highly variable, highlighting the advantage of an adaptive system using real-time water quality data to meet water quality objectives over a system which detains water for a predetermined detention time. For example, 25% of storms reached the turbidity threshold approximately 24 hours after the end of a rainfall event (minimum detention time), while 42% of events reached the maximum detention time of 72 hours without reaching the required turbidity threshold. In the latter situation, though the turbidity threshold was not met, all events in this category still saw a median decrease of 11.91 FNU during the 24 to 72 hours following the end of the rainfall event with a median turbidity value of 32.94 FNU at release.

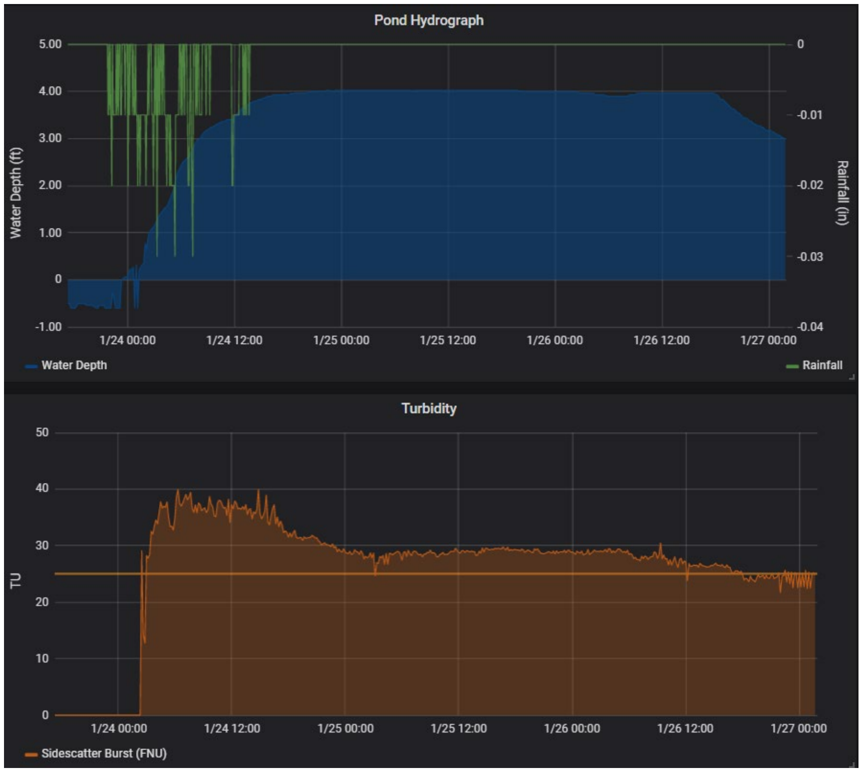

Figure 3. Real-time dashboard showing rainfall, water depth, and turbidity measurements for a single event.

Overall, 58% of events met the 25 FNU turbidity threshold for water release before the maximum detention time, and the median turbidity value all events in the study at release was 24.84 FNU. These combined results support the conclusion that the adaptive system integrated with real-time water quality data was effective in meeting water quality objectives that may not have been met with traditional systems, or those that rely on a predetermined detention time. This study should serve as a foundation for future studies investigating the use of water quality data to make real-time control decisions for stormwater infrastructure.

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LOW-COST, REAL-TIME WATER LEVEL MONITORING NETWORK FOR FALLING WATER RIVER WATERSHED

Alfred J. Kalyanapu [1], Dakota Aaron[2], Chris Kaczmarek[3], Vaibhav Ravinutala[4], and Phisuthisak "Note" Ngernkuakul[5]

Streamflow monitoring in the United States (US) is a cost-intensive venture, and usually performed by government agencies like the US Geological Survey (USGS). With reduced resources across the federal agencies towards environmental monitoring, agencies and stakeholders are challenged to respond with cross-cutting, collaborative and low-cost alternatives for streamflow monitoring. One such alternative is using low-cost environmental sensors and developing a real-time sensor network using IoT (Internet of Things) devices. With this technology, smaller watersheds (e.g., HUC-8 and HUC-10 level) can be equipped with low-cost sensors at many locations and a clear picture of hydrological response can be achieved. Therefore, the objective of our project was to develop a low-cost, real-time streamflow network for the Falling Water River (FWR) Watershed. To achieve the project objectives, the following three tasks were proposed: (i) Assemble a low-cost, real-time enabled water level sensor, (ii) Field-test of the sensor prototypes, and (iii) Install the sensors and expand the sensor network. The project area is the FWR Watershed in the middle Tennessee region, which covers Putnam, White and Dekalb counties, is home to the City of Cookeville, the urban center in the Upper Cumberland Plateau. The project team developed a collaborative partnership with its stakeholders including the Tennessee Division of Environment and Conservation, Tennessee Department of Transportation, Burgess Falls State Park, City of Cookeville, and Friends of Burgess Falls. During the course the project, the team successfully developed a low-cost sensor prototype, tested it at various environmental conditions and finalized on two design variants. The sensors are currently installed along the main channel and tributaries of the Falling Water River, which also include portions of the Window Cliffs State Natural Area. With continued support from the stakeholders, the number of sensors are projected to increase resulting in a dense sensor network across the watershed. This will over time enable the stakeholders to have a spatially variable hydrological response of the Falling Water River Watershed.

Key terms: Surface water, Streamflow monitoring, Hydrology, Emerging Technologies, Sensor Network, Low-cost technology

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SESSION 2B

WATER SUPPLY (Moderator: Daniel Saint, TVA)
8:30 a.m. – 10:00 a.m.

Identification of Factors Influencing the Drinking Water Microbiome in the Premise Plumbing
Clifford Swanson and Qiang He

Freshwater Delivery to the Gulf of Mexico: An Analysis of Streamflow Trends in the Southeast US from 1960-2015
Kirk D. Rodgers, Victor L. Roland, Anne B. Hoos, and Rodney R. Knight

Impact of First Flush on Rainwater Reuse
Kristen Wyckoff, Liu Cao, Andrew Steinman, and Qiang He

STORMWATER STUDIES (Moderator: Michael Hunt, Metro Water Services)
10:30 a.m. – 12:00 p.m.

Revisions to the New Jersey Department of Environmental Protection Laboratory Testing Protocol and Procedures for Hydrodynamic Separators: "The Times They are a Changin'"
Mark B. Miller

Storm Sampling to Assess Water Quality in a Karst Watershed
Porcha McCurdy and Ingrid Luffman

Reducing Campus Stormwater Impacts: Brush Creek Reconnaissance and Restoration Proposal
April D. Bledsoe, Porcha McCurdy, Jacob Hansen, Tosin James, Ingrid Luffman, and Christopher Tomsic

IDENTIFICATION OF FACTORS INFLUENCING THE DRINKING WATER MICROBIOME IN THE PREMISE PLUMBING

Clifford Swanson[1]* and Qiang He[1]

*Presenting author

Over the last century the widespread use of water treatment processes, including disinfection, has vastly improved public health. These technologies helped reduce waterborne illnesses that was prevalent at the start of the twentieth century. These waterborne illness outbreaks were typically associated with enteric pathogens known to be controlled through effective disinfection. However, more recently there has been concerns with potential waterborne diseases related to exposure to opportunistic pathogens in the water distribution system. These pathogens share several characteristics that allow them to persist and thrive within water distribution systems such as chlorine resistance, biofilm formation, and the ability to survive phagocytosis. These emerging pathogens have made it more important for understanding the drinking water microbiome and the water quality factors influencing it so improved control schemes can be developed to prevent further waterborne illness outbreaks.

The aim of this study was to determine what factors influence the drinking water microbiome at the point of use. Several different point of use locations were monitored over the course of the day to determine how dynamic the microbial community was over a relatively short period of time. Alongside this, several different water quality parameters were monitored as a way of determining factors that influenced the microbial community including pH, chlorine residuals, and trace metal composition. The microbial communities of "fresh" tap water, defined as water at the point of use that had not been allowed to stagnate, revealed very little dissimilarity among each sampling location, suggesting that the fresh tap water microbiome was related more closely to the water main system or the water treatment facility. On the other hand, the stagnant water microbiome showed significant differences not only from the fresh water, but also among the different sampling sites, suggesting that the changes to the microbiome occurring during stagnation were related to characteristics of the sampling site's premise plumbing. These characteristics include the water use frequency, the age of the premise plumbing system, and water quality changes within the premise plumbing. These results show that various factors can influence the drinking water microbial community, such as premise plumbing characteristics, which could lead to better methods for controlling drinking water safety at the point of use.

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FRESHWATER DELIVERY TO THE GULF OF MEXICO: AN ANALYSIS OF STREAMFLOW TRENDS IN THE SOUTHEAST US FROM 1960 – 2015

Kirk D. Rodgers[1], Victor L. Roland, Anne B. Hoos, and Rodney R. Knight

The U.S. Geological Survey and U.S. EPA are collaborating to assess the climatic, physiographic, and anthropogenic factors driving spatial variability and temporal trends in the freshwater delivery to the Gulf of Mexico. The timing and magnitude of fresh water delivery influences terrestrial and aquatic communities, changing community composition and altering habitats necessary to support indigenous life. Streamflow at 139 stream gaging stations in the southeastern United States were analyzed from 1950 to 2015 to determine if climatic oscillation, spatial correlation, and variability in the streamflow indicated significant increases or decrease for the period of record. This study examined spatial and temporal patterns in seasonal and monthly mean daily streamflow and for quantiles of streamflow. Three primary methods were used to analyze streamflow trends including: 1) the non-parametric Mann-Kendall trends test to identify monotonic change, 2) cluster analysis to determine if trends in streamflow were regional in nature, and 3) Quantile-Kendall analysis to identify trends over the period of record. Results from our analysis have identified significant trends in monthly and seasonal streamflow values as well as significant trends over the entire flow regime.

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[1] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center

IMPACT OF FIRST FLUSH ON RAINWATER REUSE

Kristen Wyckoff[1], Liu Cao[1], Andrew Steinman[1], Qiang He[1, 2]

Water reuse is becoming more important as water needs increase. One potential source for water reuse is rainwater runoff from rooftops. In order to further develop reuse technologies for capturing and treating rainwater from rooftops, it is important to further characterize the first flush, which is considered to be the portion of water that runs off of a surface first and contains the majority of the pollutants that will runoff during the course of a storm. In the literature, the definition of a first flush from rooftops varies significantly from 2 to 3000 Liters. This project attempted to better define the first flush through the characterization of temporal water quality in rooftop rainwater during storm events. Statistical analysis showed that all contaminants except for volatile suspended solids in this project did not wash off only in the beginning of a storm. Instead, contaminants washed off over the course of an entire storm event. Sequencing analysis from the first samples, which was originally assumed to be the most contaminated, showed that bacterial populations varied by site and storm, but had the same predominant microbial populations, including *Protobacteria*, *Cyanobacteria*, *Bacteroidetes*, and *Actinobacteria*. These results suggest that first flush diversion might not be necessary for rooftop rainwater collection.

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REVISIONS TO THE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION LABORATORY TESTING PROTOCOL AND PROCEDURES FOR HYDRODYNAMIC SEPARATORS: "THE TIMES THEY ARE A-CHANGIN'"

Mark B. Miller[1]

Many stormwater regulatory programs rely on New Jersey Department of Environmental Protection (NJDEP) certifications and/or New Jersey Corporation for Advanced Technology (NJCAT) verifications for the approval of stormwater manufactured treatment devices (MTDs). The NJDEP certification program is based on laboratory test protocols and procedures for hydrodynamic separation and filtration technologies. During the first two years of the program following implementation in 2013, clarifications and interpretations were addressed to ensure that the program remained consistent with NJDEP's original intent. Following a series of MTD stakeholder meetings in 2019, it was determined that changes to the hydrodynamic separator (HDS) protocol would not only strengthen the protocol but also enhance the NJCAT verification and NJDEP certification processes. This presentation identifies essential elements of these changes and explores varied potential outcomes that are anticipated from these changes.

The HDS protocol continues to address both sediment removal efficiency (performance) testing and scour (re-suspension) testing associated with pretreatment of stormwater runoff according to NJDEP rules. Total suspended sediment (TSS) removal efficiency still requires at least 50% annual sediment removal based on the NJDEP weighting factors. Seven performance test runs now range from 10% to 150% of the maximum treatment flow rate (MTFR) while the current five NJDEP annual weighted removal efficiency factors still apply. A performance curve is now used to calculate the NJDEP annual weighted removal efficiency. Additionally, regulatory agencies other than NJDEP can select weighting factors appropriate for local rainfall conditions and desired annualized TSS removal efficiency based on the performance curve. The test sediment particle size distribution (PSD) specifications for both sediment removal and scour testing remain unchanged.

A significant change in the HDS protocol is that a modified mass balance (mass collected) test method must be used for TSS removal efficiency testing. Effluent sampling test methods will no longer be accepted which previously allowed either grab sampling (end of pipe), an autosampler, or an isokinetic array.

Scour testing is conducted in order to establish that an HDS can be installed in an online configuration. The primary change to scour testing is the inclusion of effluent sampling of pre-loaded test sediment during a shortened flow rate ramp-up period. An online configuration is allowed when the average effluent TSS concentration does not exceed 20 mg/L.

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Other new or clarified aspects of the HDS protocol address inlet/outlet test pipe diameters and piping slope, mass and location of test sediment injection, analytical laboratory certifications, as well as qualifications and tasks for independent test observers when utilized for in-house testing programs.

Changes to the HDS protocol and process will require that the NJDEP/NJCAT program be reset, currently anticipated in January 2020. This reset will necessitate NJDEP recertifications for existing certifications according to an 18-month or five-year schedule that accounts for those HDSs that obtained certification via the 2013 protocol prior to and after July 2016, respectively. The public comment (peer review) period for an NJCAT verification will continue to be in effect but time limits have been shortened to better facilitate this process.

STORM SAMPLING TO ASSESS WATER QUALITY IN A KARST WATERSHED

Porcha McCurdy[1]* and Ingrid Luffman[1]

INTRODUCTION

Sinking Creek (HUC06010103046) (Figure 1) in the Watauga watershed (TN06010103) of northeast Tennessee, is impaired for *Escherichia coli (E. coli).* (Tennessee Department of Environmental Conservation 2017). Geologically, Sinking Creek flows through karst topography consisting of limestone and dolomite (Swingle et al. 1966), and the dissolution of limestone has resulted in the presence of multiple springs in the area (Moore 2006). The location has a Cfa climate (Kottek et al. 2006), and this humid subtropical climate region receives an average of 104 cm (41 in.) of rainfall annually (National Weather Service 2020).

Approximately 5.31 km from the East Tennessee State University (ETSU) campus, Sinking Creek flows through Jacob's Nature Park (36.32°N, 82.32°W), a Johnson City park. Two sites within the park, were sampled during seven inclement weather events to better understand the variability within and among water quality parameters (*E. coli,* turbidity, Dissolved Oxygen (DO), Electrical Conductivity (EC), and optical brighteners (OB)) under these conditions. Storm sampling was able to aid in determining the first flush, which is when the highest concentrations of a constituent are incorporated into the runoff during the beginning of a storm event. The aim of the study was to measure the timing of changes in various water quality parameters to aid in watershed remediation.

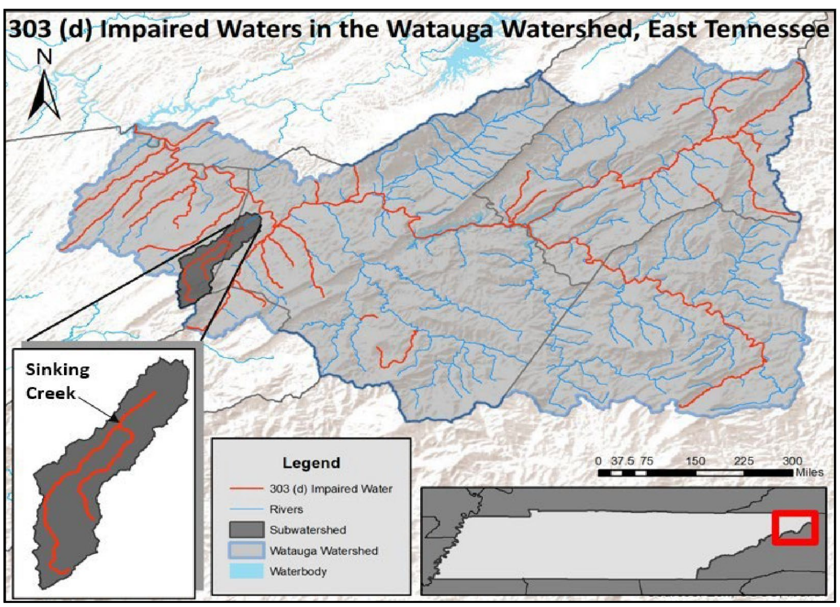

Figure 1. Sinking Creek of the Watauga watershed. Waterbodies in red are impaired.

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METHODOLOGY

Seven storm events were captured at Sinking Creek; at least five hours of forecasted continuous precipitation was desired to trigger storm sampling, knowing that turbidity in Sinking Creek peaked between 3 – 4 hours after onset of precipitation (Luffman 2016). The ETSU Geosciences weather station (https://www.wunderground.com/weather/us/tn/johnson-city/KTNJOHNS46) was utilized for meteorological data such as forecast, precipitation rate, and precipitation accumulations. Storm sampling was conducted at both the creek and a spring to assess surface and groundwater quality in this karst watershed (Figure 2).

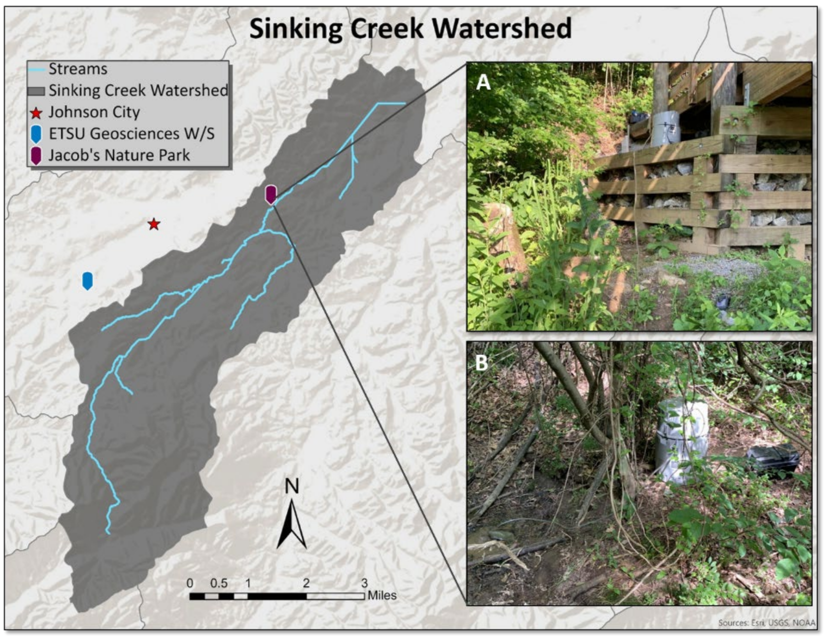

Figure 2. Sinking Creek ISCO automated sampler deployment. A) Creek location underneath bridge. B) Spring location, concealed by vegetation.

Following the methods of King and Harmel (2003), ISCO samplers were programmed to collect at 30 minute intervals. Turbidity and fresh water conductivity data loggers were deployed in the creek, logging at 15-minute increments. Dissolved oxygen was measured in-situ at both sites. Water samples were retrieved and transported to the ETSU Department of Geosciences Hydrology Laboratory in separate ice filled coolers to prevent cross contamination (Tavares et al. 2008). Periodically throughout each sampling event, samples were collected, returned to the lab, and processed immediately to meet the 6 hours processing window for *E. coli* per the Colilert Quanti-Tray method (IDEXX 2020). Samples were incubated at 35°C for 24 hours and examined under an ultra-violet light to identify the presence and concentration of *E. coli* in colony forming units/100 mL.

Cotton fabric squares were deployed in duplicate at both sites during 2 separate storm events to assess the presence of OB. Following instructions provided by Ozark Underground Laboratory (OUL), the fabric squares were deployed for 4 to 7 days and during retrieval, were rinsed in creek or spring water according to location. They were then frozen and mailed to OUL for processing and spectrofluorophotometric analysis.

Quality Assurance and Quality Control (QA/QC) methods included lab and trip blanks, which were processed using the same protocol as the water samples. ISCO sampling bottles were sterilized after each sampling event by triple washing with a 10% bleach solution, triple rinsing with tap water, and triple rinsing with DI water. The ISCO base was similarly washed between sampling events.

The relationship between water quality parameters *E. coli,* turbidity, and EC was assessed using Spearman's correlation coefficient in IBM SPSS Statistics 25 (IBM 2017). The relationship between *E. coli* and antecedent precipitation at both the creek and spring was assessed using cross-correlation at hourly time lags of precipitation that occurred prior to the sampling events. A Mann Whitney U-test was conducted to assess differences in DO between the creek and spring.

RESULTS

Of the original seven storm events, two are described here, and summary statistics for all storms follow. Precipitation during storms 2 and 4 (Figure 3) varied with storm 2 receiving ~ .20 inches of rainfall during the first 4 hours while storm 4 received .23 inches during the first hour. For both storms, *E. coli* at the spring increased within 30 minutes of onset of precipitation, but decreased quickly to background levels for the duration of the storm. *E. coli* at the creek also increased following rainfall from 30 minutes to one hour after onset. Turbidity increased within 30 minutes of onset during storm 4's more intense precipitation but was unaffected by the low intensity precipitation experienced during storm 2. Electrical conductivity decreased from baseline levels of ~325 µS/cm within 1.5 hours after onset. OB results showed a moderately positive sample at the spring during one of the storms.

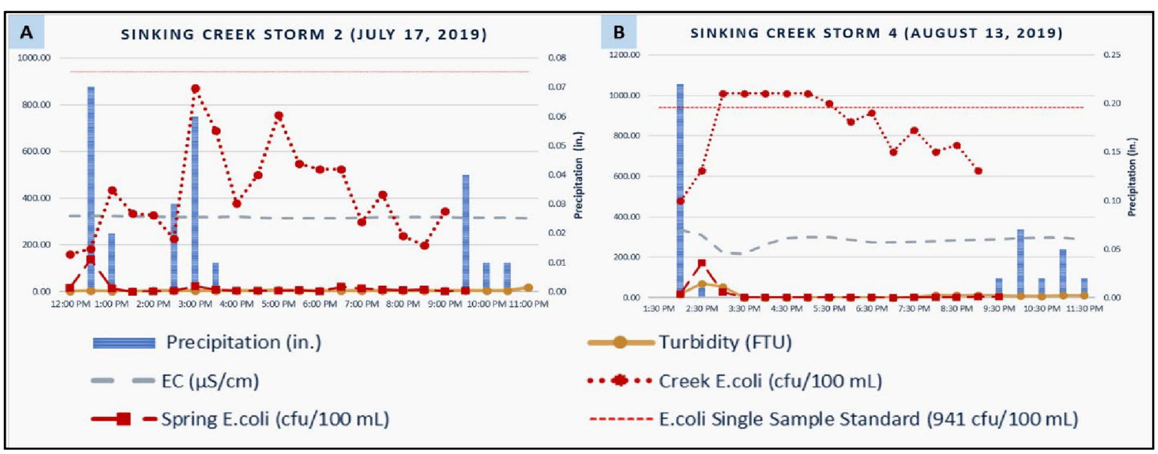

Figure 3. A) Sinking Creek Storm 2. B) Sinking Storm 4

At the creek, *E. coli* was negatively correlated with EC (r = -0.332); at the spring, *E. coli* was positively correlated with turbidity (r = 0.507). *E. coli* at the creek was positively cross-correlated to antecedent precipitation at lags of 1 to 6 hours (Precip-1 through Precip-6) and at lags of 8 and 9 hours (Precip-8 and Precip-9) (Figure 4). The highest cross-correlation for lagged precipitation and *E. coli* at the creek occurred at Precip-4 (r=0.377). At the spring, *E. coli* was cross-correlated to precipitation in the current period and in the prior two hours (Precip-1 and Precip-2), with the peak at a lag of one hour (r=0.312). Mann-Whitney U-test results revealed that DO measurements between the creek ($\bar{x}$ = 8.05 mg/L) and spring ($\bar{x}$ = 6.77 mg/L) were statistically different.

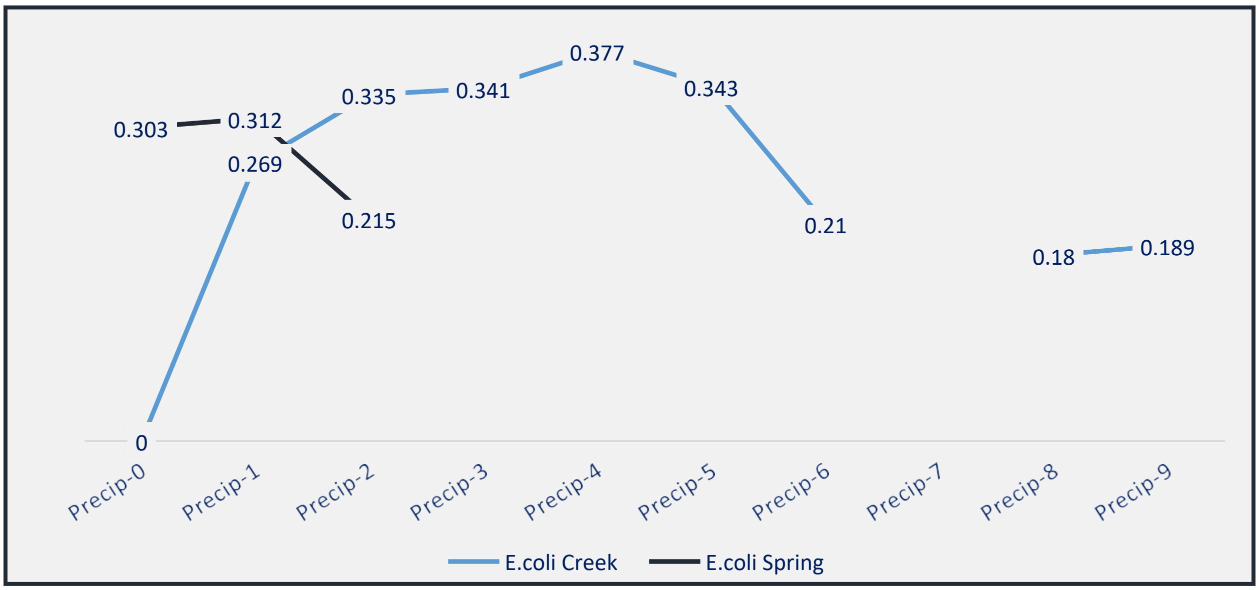

Figure 4. Cross-correlation of E. coli concentration with antecedent precipitation.

DISCUSSION AND CONCLUSION

Storm sampling at Sinking Creek and a tributary spring conducted to understand the relationship between precipitation and water quality shows that *E. coli* concentration at both sites is positively correlated to precipitation. The spring responded more quickly than the creek; a short peak at onset or within 30 minutes of precipitation for the spring versus an elongated period of high *E. coli* concentrations beginning within one hour of onset and continuing throughout the storm for the creek. The karst topography of the area, coupled with possible failing septic systems in the surrounding community indicate a connection between the *E. coli* source and the spring outlet. The positive OB sample at the spring and the initial high concentration of *E. coli* at the spring further implicate residential wastewaters as a source of *E. coli* at the spring. The prolonged high concentrations of *E. coli* at the creek and the later peak relative to onset of precipitation indicate that upstream agricultural areas may be responsible for the high concentrations in the creek.

The effects of precipitation on runoff can be linked to storm intensity, duration, and location in the watershed. During the 7 storm sampling events turbidity did not respond to low rainfall accumulation (< 0.25 in.), however, when storm intensity was higher with accumulations >0.25 in. turbidity increased within 30 minutes. This increase in turbidity during higher rainfall intensities is likely a result of increased sediment erosion rates. EC decreased within 1.5 hours of precipitation, and like turbidity, it also had only slight responses to low rainfall amounts. The decrease in EC is attributed to lower amounts of dissolved ions in the water due to dilution from the increased runoff. The peak concentrations for *E. coli* (creek and spring) and turbidity usually occurred within the first 2.5 hours of the storms. DO at the creek was higher indicating that turbulence of the stream created more dissolved oxygen as opposed to the low turbulence at the spring. The effects of runoff and precipitation show that the first flush occurs within the first 2.5 hours of a storm.

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REDUCING CAMPUS STORMWATER IMPACTS: BRUSH CREEK RECONNAISSANCE AND RESTORATION PROPOSAL

April D. Bledsoe[1]*, Porcha McCurdy[1], Jacob Hansen[1], Tosin James[1], Ingrid Luffman[1], Christopher Tomsic[2]

Brush Creek (HUC 06010103009) in the Watauga River watershed is 303(d) listed for nitrates and nitrites, siltation, habitat alterations, and *E. coli* due to discharge from MS4 Area (TDEC 2006; TDEC 2015; TDEC 2017). East Tennessee State University (ETSU) in Johnson City makes up part of the MS4 Area and its stormwater drains into Brush Creek through multiple outlets. ETSU owns property along a greenway adjacent to the creek that is the focus of this study (Figure 1).

The creek-side greenway, the Millennium Trail, connects ETSU to Johnson City and to the Tweetsie Trail, a rails-to-trails recreational multi-use pathway. The study reach is located upstream of several previous restoration efforts including litter clean-ups, a tire removal project, and construction of two new community flood mitigation parks: Founders Park and King Commons (Figure 1). This reach was selected because of persistent and increasing problems with bank erosion and channel degradation.

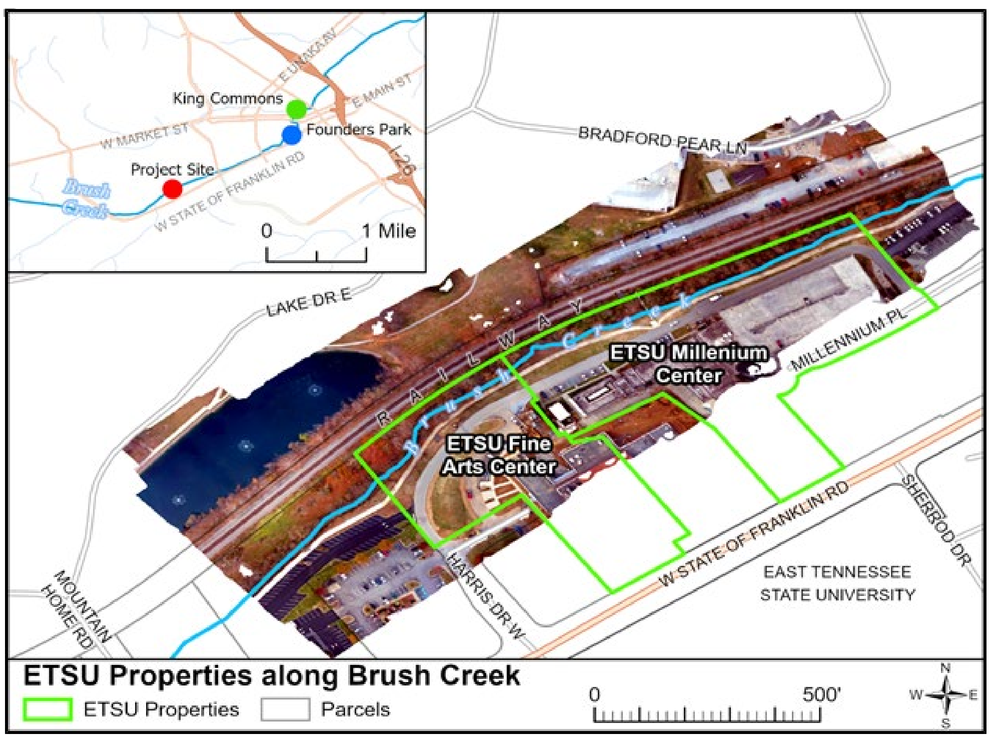

Figure 1. ETSU property map illustrating the segment of Brush Creek that runs through ETSU properties

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SITE EVALUATION

Site reconnaissance in fall 2019 revealed several large slabs of concrete in the channel that were redirecting flow and causing undercutting and scouring of the banks at several locations. Bush Honeysuckle (*Lonicera maackii*) was found in serveral areas of the riparian zone, choking out native vegetation, resulting in loss of valuable stream side terrestrial habitat. Other areas of the bank suffered significant erosion, with a four-foot vertical bank in one location and undercutting of the Millennium Trail. These problems may be attributed in part to high volumes of stormwater from the ETSU campus, which reach Brush Creek through storm sewers from main campus and the two campus parcels adjacent to the creek.

Water quality (turbidity, dissolved oxygen, nitrates, nitrites, and *E. coli*) was assessed at four campus culverts that drain to Brush Creek during fall 2019. Precipitation data were collected from a weather station on campus. Results indicated a significant ($p<0.05$) positive correlation between total rain and turbidity, and rain rate and turbidity. Data confirmed a significant negative correlation between turbidity and dissolved oxygen. This is concerning as highly turbid water negatively affects aquatic life by decreasing the amount of sunlight available to aquatic plants for photosynthesis (Hollis et al. 1964). Additionally, increased turbidity can decrease the dissolved oxygen available for aquatic organisms in streams (USEPA 2012). These findings drove the following recommendations for implementation of Best Management Practices (BMPs) at four sites along the study reach to address bank erosion, reduce storm flows, and improve riparian habitat.

PROPOSED BMPS

Two culverts at site one (Figure 2) discharge runoff from the ETSU Fine Arts Center to Brush Creek, and two large concrete blocks in the channel redirect flow toward the stream bank, causing scouring. The two concrete blocks will be utilized to contruct a crossvane upstream of the culvert to redirect flow toward the center of the channel. Live stakes will be harvested from native dogwood and willow bushes on site and planted in the riparian zone to improve habitat, water quality, and bank integrity. Low growth forbes and grasses that do not require mowing will replace the grass between the Millennium Trail and the riparian zone to provide a transition from the manicured trail to a more wild riparian zone.

Site two contains a sharp cut-bank with heavy erosion. We propose bank grading (2:1 slope) and installation of a log vane to redirect stream flow toward the center of the channel to deter bank erosion (Figure 3). Coir fiber matting and live stakes will be installed on the newly graded banks to inhibit bank erosion until the riparian zone is established. Newly established vegetation on the stream banks will increase water percolation and water quality as well as protect the stream from future bank erosion.

The major challenge at site three is significant bank failure (Figure 4); we propose to reshape using a cut and fill strategy and backfill where necessary. Coir fiber matting and planting of bare root trees and lives stakes will improve bank stability.

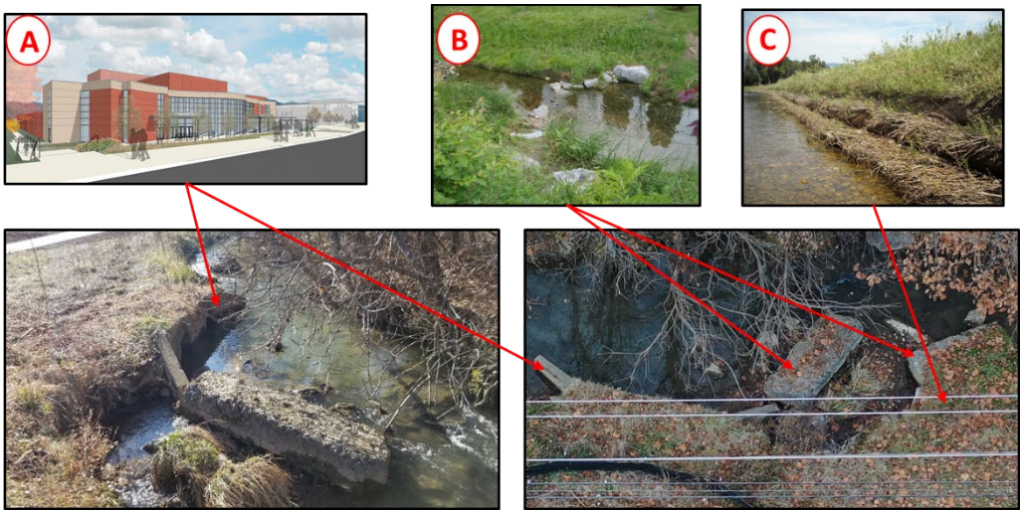

Figure 2. Site 1: culverts and concrete blocks. A: ETSU Fine Arts Center culvert. B: Concrete structures causing bank erosion will be reused in a cross-vane. C: 2:1 slope bank shaping to be implemented on the south bank.

Figure 3: Site 2: vertical banks and undercutting. A: log-vane to redirect stream flow toward the center. B: bank shaping. C: bank shaping, matting and live-stake planting.

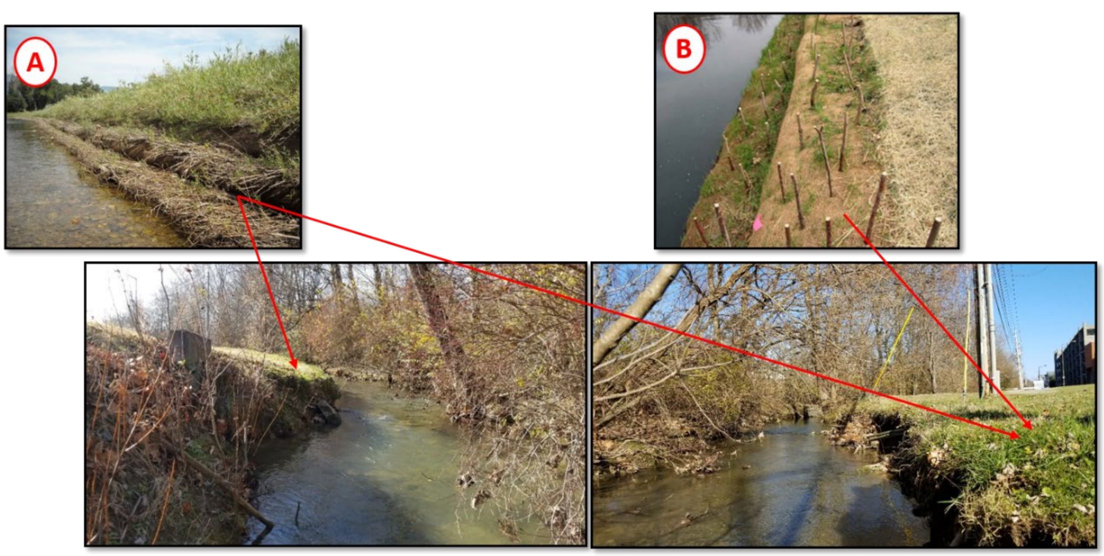

Figure 4: Site 3: bank erosion. A: bank shaping. B: bank shaping, matting and live-stake planting.

Site four is the farthest downsstream and the most complex. Considerable bank erosion undercuts the adjacent Millennium Trail (Figure 5). The undercut portion of the trail will be backfilled, planted with live stakes, and a cross-vane will be installed upstream of the failure location. In this reach bedrock is exposed, which will provide a solid foundation for the cross vane. Between an adjacent parking lot and the Millennium Trail, a 300 ft^2 rain garden will be construted to reduce connectivity between the parking lot, the trail, and the creek. A curb will be constructed between the parking lot and the trail to direct surface flow into the rain garden.

Figure 5: Site 4: undercutting. A: backfilling and bank shaping where the Millennium Trail is undercut. B: cross-vane installation. C: rain garden.

Stream restoration along a greenway is an excellent opportunity to engage the public with their local waterways. To that end, educational signage will be installed to provide information about the restoration sites and techniques utilized in the design process. Such signage may empower the community to become personally involved in continued Brush Creek restoration and beautification efforts.

EXECUTION & CONCLUSIONS

The evaluation and restoration work proposed above was developed as part of ETSU’s submission to the 2019 EPA Campus Rainworks Challenge competition. In addition, an ETSU Facilities Improvement Fund proposal was submitted in fall 2019 with the support of Facilities Director, Dan O’Brien, and the Director of Sustainability, Kathleen Moore. That proposal was developed to provide a funding source for the project outlined in the Rainworks Challenge entry and summarized here. If successful, the demonstration project outlined in this proposal would be funded through this proposal with volunteer support from several ETSU student organizations (e.g., Service Saturdays, Geoscience Club, and EcoNuts) for in-kind labor to plant live stakes, design signage, and participate in stream clean-ups.

Each of the proposed BMPs play a specific role in improving water quality, habitat, or bank integrity:

- Cross-vanes and log vanes redirect flow toward the center of strean channels to mitigate scouring, bank erosion, and undercutting of the Millennium Trail. This reduces stream sedimentation and improves bank integrity.
- Bank grading at a 2:1 slope establishes a stable stream bank and permits plantings to take hold as well as reduces energy along the bank-water interface, reducing sedimentation and improving bank integrity.
- Riparian plantings (including rain gardens) decrease runoff and transport of pollutants to the creek. They increase bank integrity, improving Brush Creek's capacity to handle intense precipitation events. By decreasing pollutants like turbidity, dissolved oxygen may improve (Hollis et al., 1964; USEPA, 2012).

In addition to physical improvements, educational signage along the Millennium Trail (adjacent to Brush Creek) that tells the story of the restoration project from water quality, engineering, biological, and aesthetic perspectives will provide educational opportunities for the ETSU and Johnson City communities. Brush Creek as an aquatic ecosystem, though anthropogenically altered, makes an excellent natural laboratory for budding biologists, hydrologists, environmental engineers, and environmental scientists.

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SESSION 2C

MICROBIAL STUDIES (Moderator: Wayman Ho, TDEC-DWR)
8:30 a.m. – 10:00 a.m.

Application of Next Generation Sequencing (NGS) Based Microbial Source Tracking (MST) in Nashville, TN
Yanchong Huangfu, Mary Bruce, Shawn A. Hawkins, and Veronica Logue

Patterns of Microbial Assemblage in Wetland Ecosystems Across Habitat Type and Core Incubations
N. Reed Alexander, Danna Baxley, Taryn Bradley, Robert Brown, Shrijana Duwadi, Michael Flinn, Jeffrey Fore, Alfred Kalyanapu, Morgan Michael, Shelly Morris, Justin Murdock, Kristen Veum, Donald Walker, Lisa Webb, Spencer Womble, and Howard Whiteman

Microbiology and Redox Potential of the Shallow and Memphis Aquifers in the Allen Well Field, Shelby County, Tennessee
Tom D. Byl and Michael Bradley

BIOLOGICAL ASSESSMENTS (Moderator: Tom Byl, USGS)
10:30 a.m. – 12:00 p.m.

Software Wars Episode IV: A New Hope
Gerald A. Burnette

Investigating the Effects of Impoundments on Flood Availability and Condition of Freshwater Mussels in the Pigeon and Nolichucky Rivers of Northeast Tennessee
John W. Roden III and Joseph R. Bidwell

Assessing Short-Term Effects of Translocation on the Spatial Ecology of Eastern Hellbenders
Bradley Nissan, Emilly Nolan, Michael Freake, Rebecca Hardman, and William Sutton

WETLANDS RESTORATION (Moderator: Andrea Ludwig, UT)
1:30 p.m. – 3:00 p.m.

The Return of Nutrient Retention in Restored Agricultural Wetlands
Justin Murdock, Robert Brown, Spencer Womble, Shrijana Duwadi, Morgan Michael and Alfred Kalyanapu

Influence of Topography and Physical Properties on Hydric Soils in Devil's Kitchen Branch Bog, Greeneville, TN
William Jarvis, Joshua Welty, Dr. Ingrid Luffman, and Dr. Arpita Nandi

Regulation of Wetland Restoration and Compensatory Mitigation in Tennessee
R. Wayne **(Abstract not available)**

SANITARY SEWER ACCESS PROGRAM (Moderator: Melissa Harris, USGS)
3:30 p.m. – 5:00 p.m.

Introduction to the Sanitary Sewer Access System in the City of Memphis
L. Yu Lin

Identification of Water Features for Sanitary Sewer Access
Thomas B. Lawrence

Development of Inspection and Maintenance of Sanitary Sewer Access System Program of the City of Memphis
L. Yu Lin and J.T. Malasri

APPLICATION OF NEXT GENERATION SEQUENCING (NGS) BASED MICROBIAL SOURCE TRACKING (MST) IN NASHVILLE, TN

Yanchong Huangfu[1]*, Mary Bruce[2], Shawn A. Hawkins[1] and Veronica Logue[2]

Streams associated with elevated bacteria levels are often attributed to multiple sources. Microbial source tracking (MST) is the science to profile and compare the microbial communities between fecal sources (e.g., from human beings, industries and animals) and environmental samples (e.g., water, soil, and sediment). Recent years, MST utilizes the Next Generation Sequencing (NGS) technique to determine a library of Operational Taxonomic Units (OTUs) from sources of known fecal contamination. In this project, we collected both fecal samples from suspected contributors (e.g., fox, raccoon, squirrel, deer, and opossum) and in-stream samples from streams with history of elevated *E. coli* and investigated their microbial communities by using NGS based MST. We also evaluated the intragroup variability to discover whether microbial communities differ among different sources of fecal materials. In the results, statistical (e.g., PCA and PCoA) analyses can reveal significant separation between different fecal source sample types (e.g., fox, raccoon, squirrel, deer, and opossum) and clustering within sample type. We also applied this tool for predicting the most substantial sources present in the watershed. The information from this project can provide us the guidance on the "next step" in reducing the pathogen levels in impaired watershed and improving surface water quality.

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PATTERNS OF MICROBIAL ASSEMBLAGE IN WETLAND ECOSYSTEMS ACROSS HABITAT TYPE AND CORE INCUBATIONS

N. Reed Alexander[1], Danna Baxley[2], Taryn Bradley[3], Robert Brown[4], Shrijana Duwadi[4], Michael Flinn[5], Jeffrey Fore[2], Alfred Kalyanapu[6], Morgan Michael[4], Shelly Morris[2], Justin Murdock[4], Kristen Veum[7], Donald Walker[1], Lisa Webb[8], Spencer Womble[4], and Howard Whiteman[3]

Recent work has suggested that microbial assemblages within wetland ecosystems may serve as bioindicators for the restoration of wetland functions, as microbes make direct contributions to nutrient loading and cycling, and establishment of redox potential within soils (Urakawa and Bernhard 2017). Studies of spatial ecology are both defined and constrained by two parameters, grain and extent. Patterns of ecological significance inferred from spatial studies have been shown to be scale-dependent, requiring analysis across multiple scales to generate confidence in results (Wiens 1989). Our lab has developed a novel methodology for collecting soil cores for microbial community analysis, allowing for a fine-scale spatial analysis within the organic layer of wetland soil. The purpose of this study is to elucidate patterns of microbial biogeography within and among wetlands by developing diversity profiles from high-throughput sequencing data, phospholipid fatty acid profiles, and soil geochemistry, to investigate the forces driving spatial variation of community structure across habitat types among wetlands. Comparisons will be made between microbial assemblages contained in the top and bottom of the organic layer, as well as between remnant forest, tree planting, and shallow water habitats across two wetlands. The response of community assemblage to core incubation will also be assessed.

Literature Cited:

Urakawa, Hidetoshi, and Anne E. Bernhard. "Wetland management using microbial indicators." *Ecological engineering* 108 (2017): 456-476.

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MICROBIOLOGY AND REDOX POTENTIAL OF THE SHALLOW AND MEMPHIS AQUIFERS IN THE ALLEN WELL FIELD, SHELBY COUNTY, TENNESSEE

Tom D. Byl[1,*] and Michael Bradley[1]

INTRODUCTION

The shallow and Memphis aquifers in Shelby County, Tennessee, are valuable natural resources that are used for domestic, public-supply, and agricultural water use. The Memphis aquifer is the primary source for public supply in West Tennessee and provides 170 to 175 million gallons of water per day for more than 900,000 people (Robinson, 2018). The shallow aquifer includes the unconfined water table, provides domestic water supplies in Shelby County, and is susceptible to contamination from urban and industrial activities, underground storage tanks, old dumps, and other sources. Both aquifers are likely to be stressed in the future by factors such as population increase, contaminant migration from historical contamination sites, industrial and agricultural activities, climate change, and other competing demands on the water resources.

Several studies in the Memphis area have confirmed and identified areas of leakage ("windows") through the confining unit that generally separates the shallow and Memphis aquifers (Parks and Carmichael, 1990; Bradley, 1991; Kingsbury and Parks, 1993; Parks and others, 1995; Bradshaw, 2011; Kingsbury and others, 2017). Additional studies documented contamination in the shallow aquifer, further raising the concern of the vulnerability of the Memphis aquifer (Parks and others, 1995; Barlow and others, 2012). Locally, very low levels of benzene and organochlorine compounds were detected in some of the monitoring and production wells in the Allen well field (University of Memphis, 2019). Although concentrations were below drinking water criteria, their presence in the Memphis aquifer highlights the need to better characterize the bacteria and redox conditions present in the Allen well field. Water-quality data have been collected through the years to evaluate and provide insight into the flow patterns and types of chemicals entering the two aquifers, but data and research on microbial communities and geochemical conditions relative to potential contaminant bioremediation are lacking.

During 2017 – 18, the U.S. Geological Survey (USGS), in cooperation with Memphis Light, Gas and Water Division (MLGW), and the University of Memphis conducted a geochemical and microbial investigation of the shallow and Memphis aquifers in southwest Shelby County. The objective of this study was to investigate the microbial and geochemical conditions related to oxidation-reduction (redox) potential in the aquifers in Shelby County, focusing on the Allen well field, and the potential for natural or enhanced bioremediation. The scope of this study included evaluating historical (1997–2019) geochemical data from the USGS National Water Information System (NWIS) and collecting new data to characterize redox conditions and microbiology in wells located in the Allen well field, southwest Shelby County.
This report summarizes the findings of the investigation designed to characterize the redox geochemistry as related to microbial biodegradation processes and bacteria types. Geochemical and microbial information can be used in conjunction with contaminant information to determine if natural bio-attenuation processes are active or if supplements would facilitate development of

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appropriate conditions for enhanced bioremediation. Twelve Memphis aquifer wells and 15 shallow aquifer wells were sampled once in 2017 for bacterial activity, geochemical indicators, and field parameters.

HYDROLOGY AND STUDY AREA

The Memphis aquifer is primarily a thick sand deposit ranging from about 500 to 900 feet (ft) thick and includes some minor lenses of clay and silt (Parks, 1990). The aquifer is overlain and confined by the Jackson-upper Claiborne confining unit, which separates it from the overlying shallow aquifer. The movement of water and potential contaminants down to the Memphis aquifer was thought to be prevented by clay layers of the Jackson-upper Claiborne confining unit. Graham and Parks (1986), however, reported several general areas in Shelby County where shallow water could migrate down to the Memphis aquifer. The “windows” in the Jackson-upper Claiborne confining layer occur where the confining unit is thin or absent and provide a pathway for contaminants to move from the shallow aquifer down to the Memphis aquifer (Parks, 1990).

Water-quality sampling for this project focused on the shallow aquifer and the Memphis aquifer near the Allen well field in the southwest corner of Shelby County (fig. 1). Twenty-seven wells were sampled in the Allen well field: 12 of the wells are screened in the Memphis aquifer, and 15 wells are screened in the shallow aquifer (fig. 2). The Allen well field has been in use since the 1950s and currently (2020) has about 20 wells completed in the Memphis aquifer. In 2010, the wells located in the well field produced about 19 million gallons per day from the Memphis aquifer (Robinson, 2018). In this area, the Jackson-upper Claiborne confining unit is present over the Memphis aquifer with a reported thickness ranging from 82 to about 200 ft, with 68 to 149 ft of aggregated clay thickness (Parks, 1990). The confining unit is thin, however, with potential windows about 3 miles to the southeast (Parks, 1990) and about 2 miles to the east (Bradshaw, 2011) of the well field.

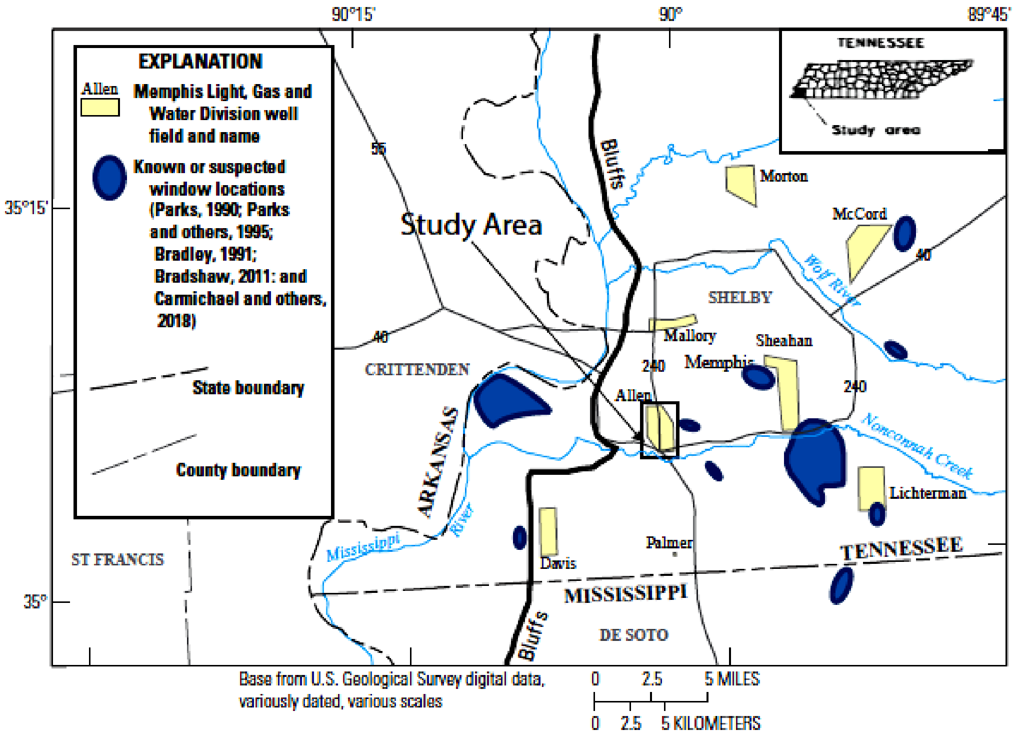
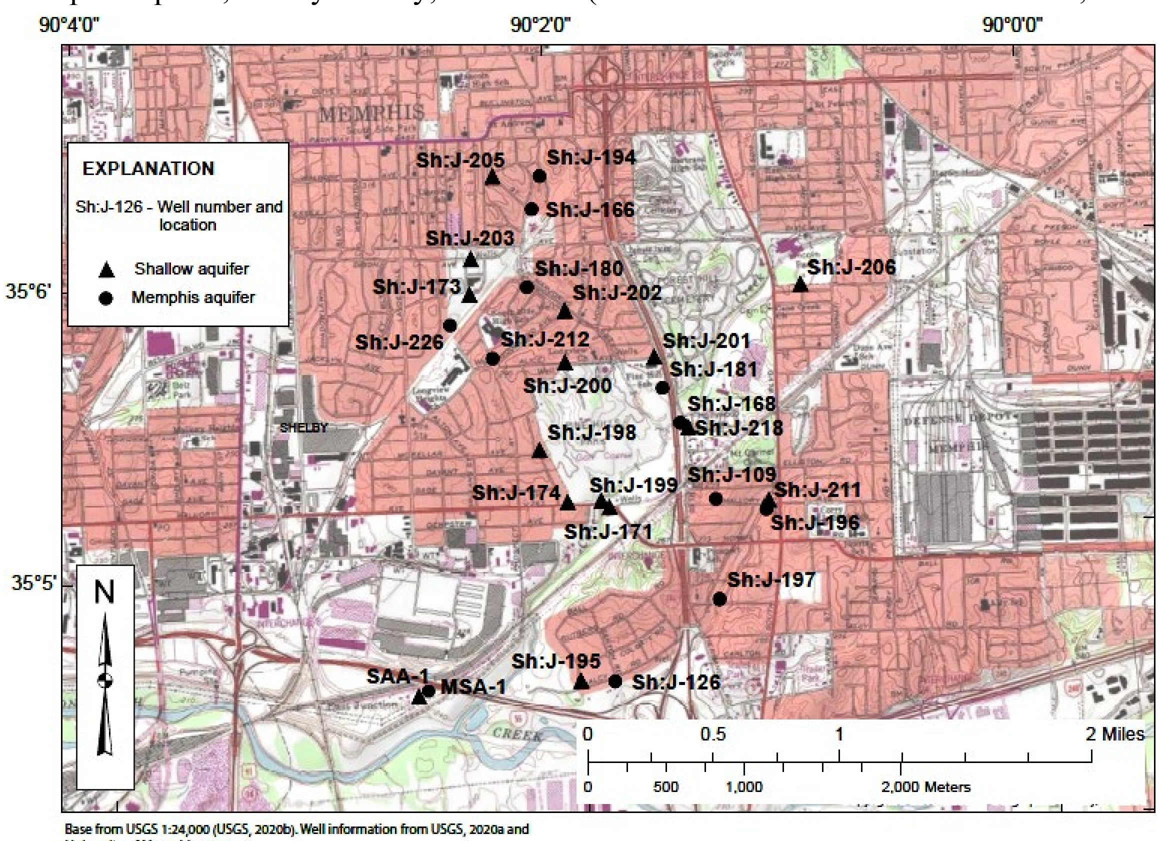


Figure 1. Location of study area, major well fields, and areas of potential leakage to the Memphis aquifer, Shelby County, Tennessee (modified from Carmichael and others, 2018).



Base from USGS 1:24,000 (USGS, 2020b). Well information from USGS, 2020a and University of Memphis, 2019.

Figure 2. Location of wells completed in the shallow and Memphis aquifers sampled for microbiological and geochemical indicators, Shelby County, Tennessee, August 2017.

REDOX GEOCHEMISTRY AND MICROBIOLOGY IN AQUIFERS

Geo-bacteria use a wide variety of metabolic processes to generate energy and maintain cellular growth in groundwater aquifers. These processes involve the transfer of electrons from an electron donor (food source) to an electron acceptor in a series of controlled biochemical redox reactions (Chapelle, 1993). The metabolic processes can breakdown contaminants in groundwater. Chlorinated organic compounds, such as perchloroethylene or carbon tetrachloride, are electron-poor molecules, and they serve as electron acceptors in a reaction called reductive dechlorination.

The transfer of electrons and the breakdown of contaminants are influenced by the redox potential of the aquifer; thus, it is important to know the redox conditions and microbiology of the aquifer to assess the potential for natural attenuation. One of the best ways to measure aquifer redox conditions is to analyze redox-sensitive geochemical indicators referred to as terminal electron acceptor process (TEAP) geochemistry (Chapelle, 1993; Chapelle and others, 1995). The biochemical energy associated with each TEAP is a thermodynamic function of the redox potential of the inorganic TEAP (table 1): the more positive the redox potential, the more energetically favorable the redox reaction.

Table 1. Common terminal electron acceptors involved in microbial metabolism in groundwater systems, reaction byproducts, types of microbial processes, and ranges in redox potential. [aq, aqueous]

Electron acceptor[1]	Byproduct	Microbial process	Range in redox potential (Eh in millivolts [mV])[2]
Oxygen (O_2)	Carbon dioxide (CO_2)	Aerobic respiration	150 to 850 mV
Nitrate (NO_3^-)	Ammonia (NH_3)	Nitrate reduction	−100 to 400 mV
Ferric iron (Fe^{3+})	Ferrous iron (Fe^{2+}_{aq})	Iron reduction [3]	−550 to 50 mV
Sulfate (SO_4^{2-})	Sulfide (S^{2-})	Sulfur reduction [3]	−600 to −100 mV
Carbon dioxide (CO_2)	Methane (CH_4)	Methanogenesis [3]	−650 to −150 mV

[1]The electron acceptors are arranged from most energetic oxidation reaction at the top to least energetic at the bottom. [2]Eh is a measure of the redox potential of a chemical compound and is reported in millivolts (mV).[3] Iron-reducing, sulfur-reducing, or methanogenic conditions are conducive for reductive dechlorination (adapted from Byl and Williams, 2000).

Chlorinated solvents become thermodynamically favorable as electron acceptors once the aquifer environment becomes more reducing and when the active TEAPs are iron, sulfur, and carbon dioxide. Information on the bacterial and geochemical conditions in the shallow aquifer and the Memphis aquifer would have implications on the potential degradation of contaminants such as the low levels of benzene and organochlorine compounds that were detected in some of the monitoring and production wells in the Allen well field (University of Memphis, 2019). Additional biodegradation pathways for organic compounds are described in Byl and Williams (2000), and the use of supplemental microbial food injections to enhance bioremediation is described in Byl and others (2017).

METHODS

The USGS collected water samples for bacterial and geochemical analyses concurrent with sample collection for volatile organic compounds (VOCs) by the University of Memphis and EnSafe Inc. during the summer of 2017. VOC analysis was conducted by Waypoint Analytical Labs, Inc., Memphis, Tennessee, a lab certified by the U.S. Environmental Protection Agency (EPA), using EPA Method 8260 (EPA, 2019). The VOC data were provided by the University of Memphis (University of Memphis, 2019). Historical water-quality data (1997–2019) used to evaluate regional groundwater conditions for the Memphis aquifer and the shallow aquifer in Shelby County were retrieved from the USGS NWIS database (USGS, 2020a). The TEAP, microbial and VOC data, and historical data pulled from NWIS were used to evaluate the spatial geochemical patterns in the Allen well field.

Ten of the Memphis aquifer wells sampled were active MLGW production wells and did not require additional purging before sampling because they were pumping. The 15 wells in the shallow aquifer and 2 monitoring wells in the Memphis aquifer were purged by using low-flow methods according to EPA protocols as described in University of Memphis (2019). Aquifer water was pumped through a flow-through chamber with a calibrated multiprobe field meter to monitor field parameters (water temperature, specific conductance, dissolved oxygen, and pH). After the appropriate amount of water was purged from each well and the measured field parameters were stable for at least 30 minutes, water samples were collected in a manner to minimize contact with the atmosphere as described in the USGS National Field Manual (USGS, variously dated).

GEOCHEMISTRY

Alkalinity, ferrous and total iron, and sulfide were measured within minutes of collecting the samples to avoid the effects of oxidation or degassing. Additional water samples were collected for sulfate, nitrate, ammonia, and bacteria analysis. Clean, sterile bottles were filled to overflowing and then capped without headspace and stored at 4–8 degrees Celsius (°C). Sulfate, nitrate, and ammonia analyses were conducted within 24 hours to avoid redox chemical changes due to holding time. Methods and meters used for the analysis of water quality and TEAP parameters are described in table 2.

A preliminary county-wide evaluation of dissolved oxygen levels in the Memphis aquifer was done to determine the extent of anoxic conditions. The USGS NWIS (USGS, 2020a) was queried to retrieve all dissolved oxygen data for wells in Shelby County that were identified as completed in the Memphis Sand. The well location, depth, aquifer, and water-quality data were retrieved and plotted. For wells with multiple samples, the latest value was used in the analysis. No temporal trends were observed with increasing or decreasing dissolved oxygen for wells with multiple sampling dates.

Table 2. Analytical methods for water-quality parameters and terminal electron acceptor process (TEAP) parameters.

Analyte	Method description and meter
Dissolved oxygen, milligrams per liter	Optical sensor in a flow-through chamber, USGS Techniques and Methods 09-A6.2 (USGS, variously dated). YSI EX03 multi-parameter sonde and meter (YSI, 2020a).
Specific conductance, microsiemens per centimeter	Calibrated electrode and field meter, USGS Techniques and Methods 9-A6.3 (USGS, variously dated). YSI EX03 multi-parameter sonde and meter (YSI, 2020a).
pH, standard units	Calibrated electrode and field meter, USGS Techniques of Water-Resources Investigations 09-A6.4 (USGS, variously dated). YSI EX03 multi-parameter sonde and meter (YSI, 2020a).
Total alkalinity, $CaCO_3$, milligrams per liter	Alkalinity titration determined on a whole-water sample, USGS Techniques of Water-Resources Investigations 09-A6.6 (USGS, variously dated). The pH was monitored with YSI ProDSS (YSI, 2020b).
Ferrous (Fe^{2+}) iron, milligrams per liter	Unfiltered water using ferrous phenanthroline adapted from Standard Methods for the Examination of Water and Wastewater, 27th edition, Method 3500-Fe B (Baird and Bridgewater, 2017). CHEMetrics Model V-2000 Photometer (CHEMetrics, Inc., 2018).
Total iron (Fe^{2+} + Fe^{3+}), milligrams per liter	Unfiltered water using Hach FerroVer method adapted from EPA Method 8008 (EPA, 2019). Hach Spectrophotometer DR3900 (Hach, 2020).
Sulfide (S^{2-}), milligrams per liter	Unfiltered water using methylene blue method adapted from EPA Method 8131 (EPA, 2019). CHEMetrics Model V-2000 Photometer (CHEMetrics, Inc., 2018).
Ammonia (NH_3 as N), milligrams per liter	Unfiltered water using Hach salicylate method adapted from EPA method 350.1 (EPA, 2019). Hach Spectrophotometer DR3900 (Hach, 2020).
Nitrate (NO_3^- as N), milligrams per liter	Unfiltered water using Hach azo-dye method adapted from EPA Method 353.2 (EPA, 2019). Hach Spectrophotometer DR3900 (Hach, 2020).
Sulfate (SO_4^{2-}), milligrams per liter	Unfiltered water using Hach turbidimetric method adapted from EPA Method SW-846 (EPA, 2019). Hach Spectrophotometer DR3900 (Hach, 2020).

BACTERIA

Biological activity reaction tests (BART) were used to characterize three bacteria types: heterotrophic aerobic bacteria, iron-related bacteria, and sulfur-related bacteria. Enumerating and identifying environmental bacteria by using agar plate culturing techniques have some shortcomings due to low cultivability of environmental bacteria (Barton and others, 2004). The BART assays provide an aqueous growing environment which provides parallels to the aqueous environment of the aquifer. A previous study comparing several enumeration methods for groundwater bacteria found good agreement between BART assays and microscope visualization counts (Byl and others, 2014). Furthermore, the BART growth assays provided important information concerning the viability and vigor of the aquifer bacteria types. The three bacteria types quantified in this study represent different metabolic pathways and are influenced by the aquifer redox conditions and TEAPs. The BART tubes were inoculated with 20 milliliters of raw water according to the manufacturer’s instructions, incubated at 22 °C in the dark, and observed for bacteria growth every 24 hours for 7 consecutive days (Cullimore, 2008). The growth patterns provide a quantitative estimate of actively growing bacteria and are reported as bacteria per milliliter.

RESULTS AND DISCUSSION

Water-quality samples from the Memphis aquifer and the shallow aquifer near the Allen well field were analyzed and evaluated in terms of groundwater bacteria types that serve as microbial TEAPs and indicators of redox-sensitive geochemistry. Additional geochemical data were used to look at simple measures of redox conditions in the Memphis aquifer in Shelby County. The results provide information that can be used to evaluate possible bioremediation as an option at contamination sites in the county.

Geochemistry in Wells Located at Allen Well Field

The geochemical data collected for the project show similarities and differences between the two aquifers. Analytical results for the water-quality parameters for each well from the Memphis aquifer and the shallow aquifer are listed in table 3. The pH values for water samples from both aquifers were near neutral, with values ranging from about 6 to 7 units in both aquifers. Results for alkalinity and specific conductance indicate there are differences in inorganic water quality between the two aquifers. Samples from the shallow aquifer were more mineralized and more variable, with specific conductance ranging from 191 to 884 microsiemens per centimeter (µS/cm) and alkalinity ranging from 47 to 353 milligrams per liter (mg/L). Samples from the Memphis aquifer had specific conductance ranging from 129 to 263 µS/cm and alkalinity ranging from 56 to 140 mg/L. In terms of the geochemistry, the biggest difference between the two aquifers was dissolved oxygen concentrations. The dissolved oxygen values for the shallow aquifer were variable and ranged from 0.28 to 4.73 mg/L. The dissolved oxygen values for samples from the Memphis aquifer were all less than 0.3 mg/L.

Nitrate concentrations ranged from 0.01 to 0.687 mg/L in water from the Memphis aquifer and from 0.04 to 4.5 mg/L in water from the shallow aquifer. Sulfate concentrations were generally lower in the Memphis aquifer, ranging from 10.8 to 21.3 mg/L; sulfate concentrations ranged from 13.1 to 75.3 mg/L in the shallow aquifer. Sulfide was present in water from all 12 Memphis aquifer wells, ranging from 0.04 to 0.55 mg/L. The sulfide concentrations in samples from the shallow aquifer ranged from below detection in two wells to a high of 0.342 mg/L. The median ferrous iron (Fe^{2+}) concentration was greater in the Memphis aquifer wells (0.717 mg/L) as compared to the shallow aquifer wells (0.444 mg/L). The median ammonia concentration was 0.033 mg/L in the shallow aquifer wells which was more than the median in the Memphis aquifer wells (0.008 mg/L). Based on the range of values of water chemistry, the shallow aquifer had oxic and anoxic conditions while the Memphis aquifer was anoxic; however, the redox processes are unknown (Jurgens and others, 2009). Supplementing the geochemical data with microbial data can help identify the redox processes that are occurring in the aquifers.

Table 3. Results of terminal electron acceptor process (TEAP) geochemical analysis of groundwater samples from the Memphis and shallow aquifers in the Allen well field area, Shelby County, Tennessee, 2017-18. [USGS, U.S. Geological Survey; mg/L, milligrams per liter; NO_3 –N, nitrate as N; SO_4 –S, sulfate as S; $CaCO_3$, carbonate; S^{2-}, sulfide; Fe^{2+}, ferrous iron; NH_4 –N, ammonia as N; NTU, nephelometric turbidity units; °C, degrees Celsius; µS/cm, microsiemens per centimeter; DO, dissolved oxygen; >, greater than; na, not available; ND non-detect]

USGS well number	NO_3-N, mg/L	SO_4-S, mg/L	Total alkalinity, $CaCO_3$ mg/L	S^{2-}, mg/L	Fe^{2+}, mg/L	Total dissolved Iron, mg/L	NH_4-N, mg/L	Turbidity, NTU	Temperature, ºC	Specific Conductance, µS/cm	pH units	DO, mg/L
Memphis Aquifer												
Sh:J-109	0.013	18.1	65	0.101	0.83	0.845	0.009	0.20	17.50	193	6.10	0.26
Sh:J-126	0.064	14.3	140	0.092	11.75	13.260	0.049	38.50	18.13	263	6.40	0.20
Sh:J-166	0.039	13.5	78	0.550	0.84	0.872	0.002	0.18	17.50	179	6.20	0.18
Sh:J-168	0.079	21.3	65	0.036	1.27	2.309	0.007	0.25	17.40	207	6.09	0.28
Sh:J-180	0.687	11.0	64	0.110	0.47	0.465	0.045	0.12	18.60	139	6.26	0.25
Sh:J-181	0.043	11.4	63	0.147	0.41	0.464	0.004	0.18	18.20	135	6.17	0.25
Sh:J-194	0.054	10.8	63	0.098	0.78	0.819	0.001	0.46	17.30	157	6.19	0.29
Sh:J-197	0.061	10.8	56	0.079	0.27	0.322	0.007	0.34	17.60	124	6.07	0.26
Sh:J-211	0.088	17.8	66	0.072	0.62	0.636	0.010	0.35	17.60	189	6.25	0.27
Sh:J-212	0.015	15.5	74	0.084	0.65	0.655	0.009	0.26	17.90	189	6.25	0.27
Sh:J-	0.121	12.4	74	0.163	0.59	0.597	0.007	0.11	17.40	163	6.20	0.25

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MSA-1*	0.134	17.8	86	0.288	10.49	11.930	0.094	31.60	18.67	177	6.41	0.21
Median	***0.063***	***13.9***	***66***	***0.100***	***0.717***	***0.737***	***0.008***	***0.255***	***17.60***	***178***	***6.20***	***0.255***
Shallow Aquifer												
Sh:J-171	0.044	13.1	131	0.126	5.29	5.579	0.171	8.46	18.78	284	6.46	0.11
Sh:J-173	4.410	72.8	143	0.071	0.06	0.072	ND	4.78	19.90	512	6.33	na
Sh:J-174	1.770	15.8	147	0.096	ND	0.133	0.002	10.40	21.63	313	6.96	2.70
Sh:J-195	1.100	75.3	353	0.098	ND	0.008	ND	1.02	19.24	884	6.62	0.54
Sh:J-196	0.411	27.8	47	0.039	ND	0.047	ND	1.08	20.21	191	5.80	2.38
Sh:J-198	2.000	30.2	129	0.135	0.25	0.296	0.010	20.60	23.00	331	6.83	na
Sh:J-199	0.068	13.3	153	0.342	4.09	>6.000	0.727	13.80	19.97	341	7.05	0.31
Sh:J-200	3.820	61.7	97	ND	ND	ND	ND	1.05	21.21	433	6.18	4.49
Sh:J-201	4.540	55.2	121	ND	ND	ND	ND	10.10	19.45	495	6.32	4.73
Sh:J-202	1.100	17.2	142	0.120	0.64	0.423	0.150	10.20	20.97	306	6.50	0.32
Sh:J-203	3.730	56.1	71	0.078	0.06	0.058	0.004	3.19	19.53	364	6.06	na
Sh:J-205	4.060	67.0	89	0.086	ND	0.046	ND	1.37	20.43	437	6.36	0.57
Sh:J-206	0.044	37.3	239	0.231	0.92	1.111	0.033	1.42	19.12	556	6.74	0.28
Sh:J-218	0.107	59.9	215	0.086	0.21	0.221	0.418	3.33	19.27	481	6.58	na

SAA-1 *	1.170	33.7	176	0.076	ND	0.038	0.004	0.69	21.62	495	6.53	0.76
Median	***1.170***	***37.2***	***142***	***0.096***	***0.444***	***0.103***	***0.033***	***3.33***	***19.97***	***433***	***6.50***	***0.57***

* Well number assigned by University of Memphis (University of Memphis, 2019).

The results of the TEAP analysis provide evidence that certain aerobic and anaerobic microbial process are active in the shallow and Memphis aquifers. Geochemical patterns in the data collected from the two aquifers during this study can be associated with specific geomicrobial processes. For example, the plot of dissolved oxygen and nitrate concentrations in the shallow aquifer (Figure 3), supports the premise that as oxygen is consumed by bacteria during metabolism, the bacteria switch to nitrate as their next preferred TEAP. This concept is reinforced in Figure 4, which shows that as nitrate levels in the shallow aquifer decrease, the byproduct of nitrate reduction, ammonia, increases. Dissolved oxygen, nitrate, and ammonia concentrations were very low in samples from the Memphis aquifer. Because dissolved oxygen and nitrate concentrations were low in the Memphis aquifer, the bacteria shifted to iron as the next most favorable TEAP. Iron-reducing bacteria reduced ferric iron (Fe^{3+}) into the soluble ferrous iron (Fe^{2+}_{aq}) when oxygen levels dropped below 0.5 mg/L, regardless of the aquifer (Figure 5). A similar pattern was observed when oxygen levels were compared with sulfide concentrations (Figure 6). Conversely, the concentration of oxidized sulfur, sulfate (SO_4^{2-}), generally increased with increasing oxygen levels in the shallow aquifer (Figure 7).

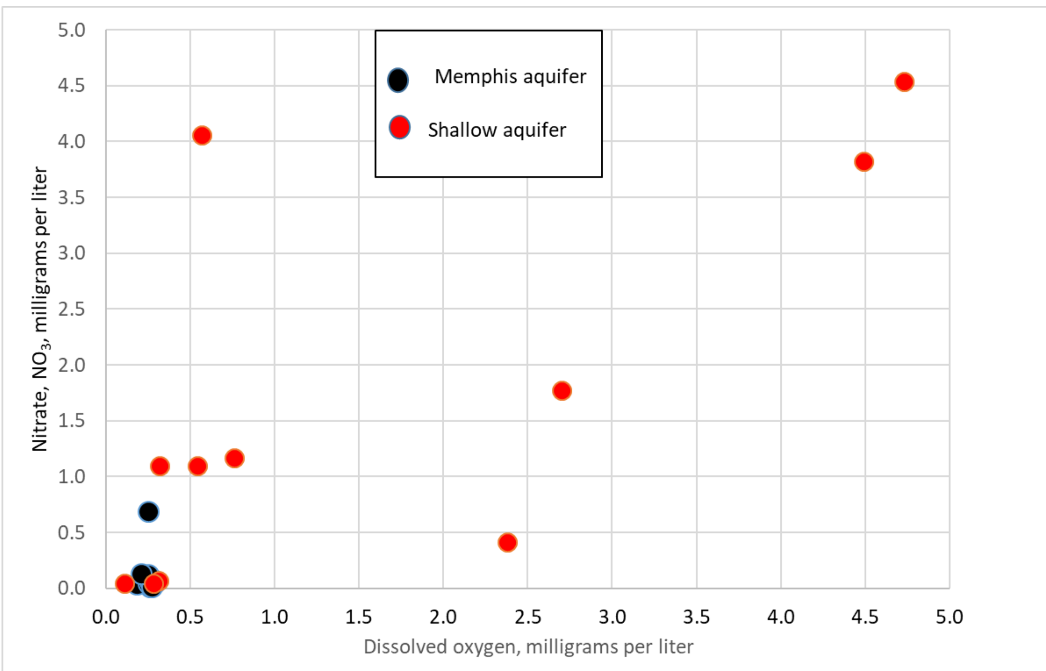

Figure 3. Concentrations of nitrate as nitrogen (NO_3) and dissolved oxygen (O_2) in the shallow and Memphis aquifers, Shelby County, Tennessee.

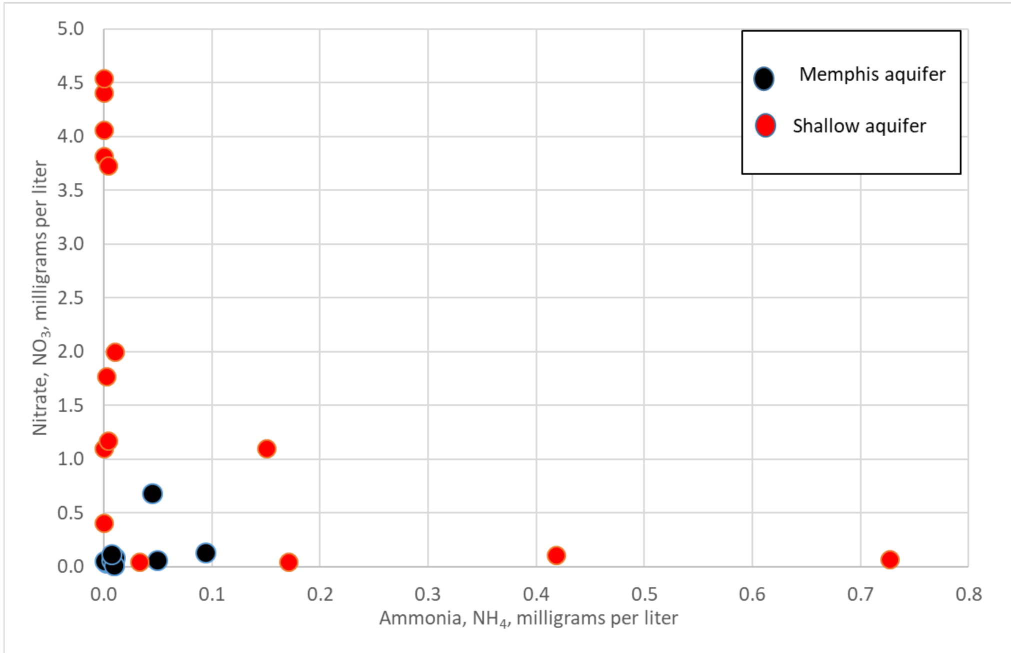

Figure 4. Concentrations of nitrate as nitrogen (NO_3) and ammonia as nitrogen (NH_4) in the shallow and Memphis aquifers, Shelby County, Tennessee.

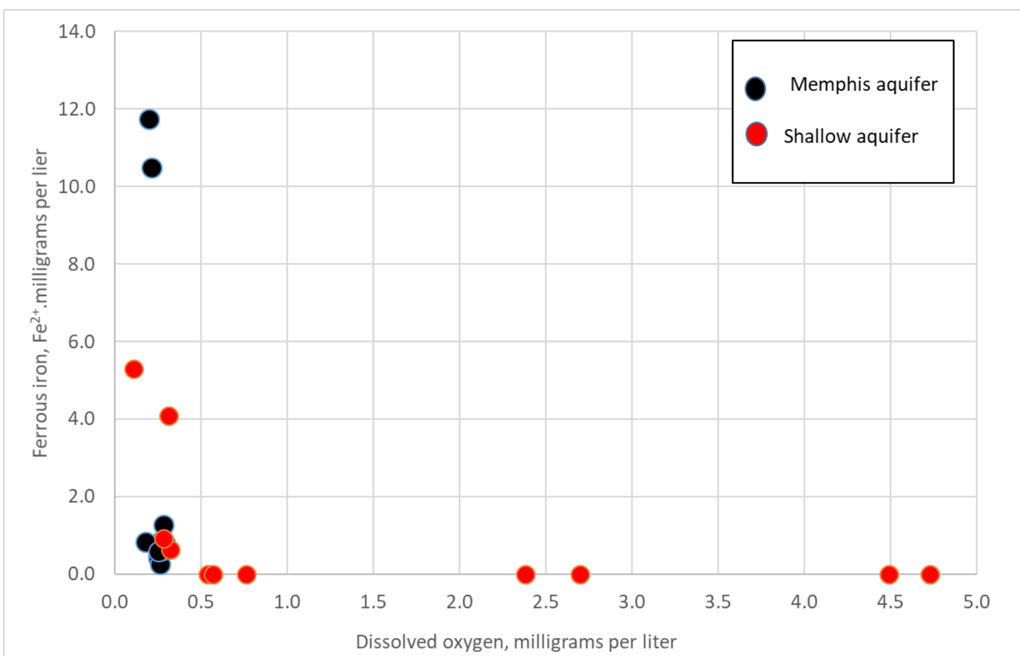

Figure 5. Concentrations of ferrous (Fe^{2+}) iron and dissolved oxygen in the shallow and Memphis aquifers, Shelby County, Tennessee.

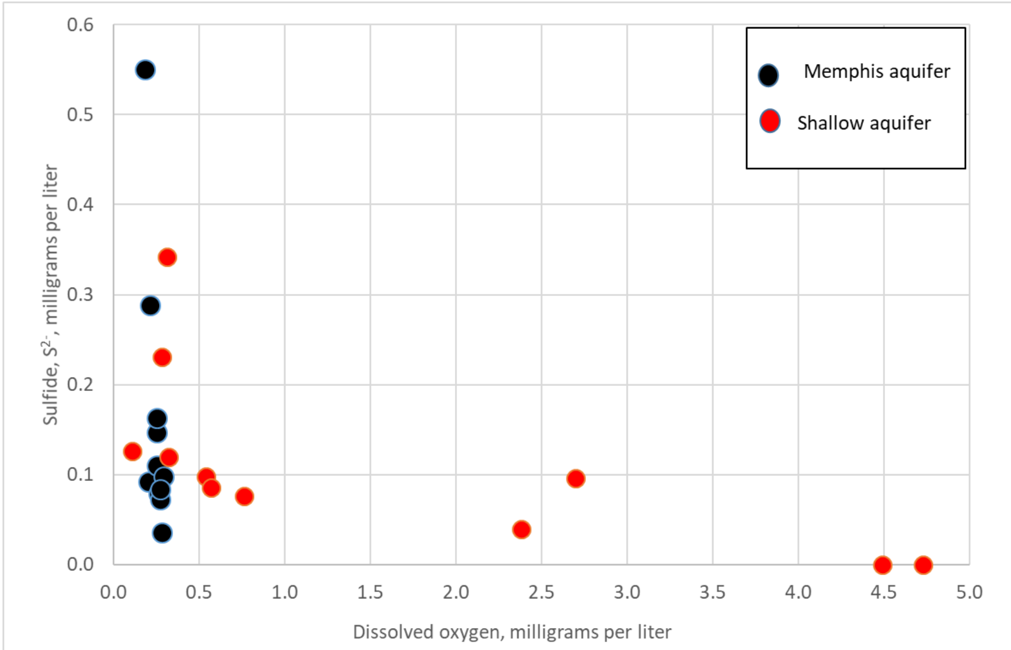

Figure 6. Concentrations of sulfide (S^{2-}) and dissolved oxygen (O_2) in the shallow and Memphis aquifers, Shelby County, Tennessee.

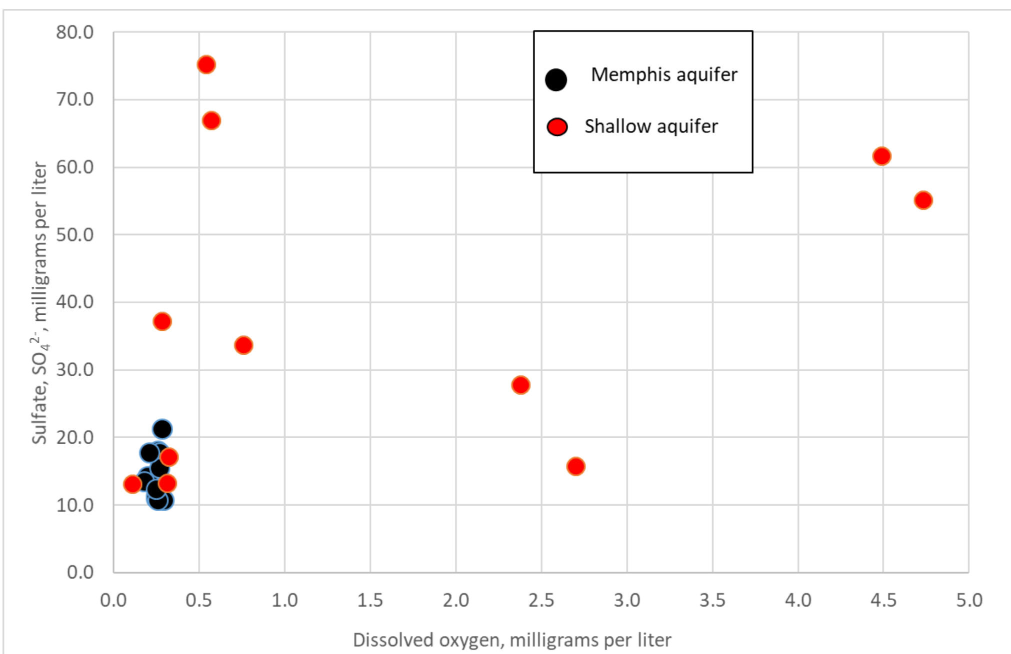

Figure 7. Concentrations of dissolved oxygen (O_2) and sulfate (SO_4^{2-}) in the shallow and Memphis aquifers, Shelby County, Tennessee.

Microbiology Test Results

The BART assays provided quantitative estimates of three bacteria types in the Memphis aquifer and the shallow aquifer (table 4). The bacteria types were heterotrophic aerobic bacteria (HAB), which are needed for fuel biodegradation; iron-related bacteria (IRB), which provide moderate fuel and limited chlorinated solvent biodegradation capabilities; and sulfur-related bacteria (SRB), which are needed for chlorinated solvent biodegradation. HAB were the most numerous bacteria type in the shallow aquifer (5,500–3,750,000 bacteria per milliliter), followed by IRB (1,450–140,000 bacteria per milliliter), and SRB (3,100–37,100 bacteria per milliliter). The most numerous bacteria types in the Memphis aquifer were HAB (100–500,000 bacteria per milliliter), followed by SRB (600–700,000 bacteria per milliliter), and IRB (263–80,000 bacteria per milliliter). Water from the two monitoring wells in the Memphis aquifer, Sh:J-126 and MSA-1, had very high counts for all three bacteria types. It was observed during purging that leaf particles were pumped from well Sh:J-126. Well MSA-1 had recently been drilled, and artifacts from the drilling process could possibly influence the microbial community. The microbial data for the two wells are included in table 4, but are not necessarily representative of the aquifer.

The greater number of bacteria harvested from the shallow aquifer wells than from the Memphis aquifer wells may have been influenced by pumping disturbance of biofilm on soil particles in the aquifer (Harvey and others, 2010; Painter and others, 2011). A bacteria-geochemical pattern worth noting was the greater number of anaerobic SRB in the Memphis aquifer wells as compared to the shallow aquifer wells. The higher concentration of SRB and sulfide supports the premise that sulfate is a major TEAP in the Memphis aquifer at the Allen well field (Tables 3 and 4). This microbial process is important in the reductive dechlorination of chlorinated solvents. The presence of *cis*-dichloroethylene, a biodegradation byproduct of trichloroethylene (TCE) in well Sh:J-168 (University of Memphis, 2019), suggests that reductive dechlorination is occurring in the Memphis aquifer. Three of the 15 shallow aquifer wells had low levels of chlorinated solvents; Sh:J-205 had 3 micrograms per liter (μg/L) of perchloroethylene (PCE), Sh:J-203 had 2 μg/L of PCE, and SAA-1 had 4 μg/L of TCE (University of Memphis, 2019). Those same wells had nitrate levels above 1 mg/L, which would prevent the microbial use of the chlorinated compound as an electron acceptor, rendering the reductive dechlorination pathway noncompetitive until the nitrate has been depleted.

Table 4. Results of biological activity reaction tests (BARTs) for sulfur-related bacteria (SRB), heterotrophic aerobic bacteria (HAB), and iron-related bacteria (IRB) for wells in the Memphis and shallow aquifers in the Allen well field area, Shelby County, Tennessee. [BART results provide an estimated most probable number and not a direct count of the bacteria.
mL, milliliter]

Memphis aquifer wells	HAB per mL	IRB per mL	SRB per mL	Total per mL
Sh:J-109	**750**	**4,750**	**11,500**	**17,000**
Sh:J-126*	**500,000***	**33,500***	**700,000***	**1,233,500***
Sh:J-166	**7,000**	**500**	**11,500**	**19,000**
Sh:J-168	**500,000**	**13,750**	**7,500**	**521,250**
Sh:J-180	**750**	**262.5**	**11,500**	**12,513**
Sh:J-181	**500,000**	**11,300**	**3,100**	**514,400**
Sh:J-194	**275,000**	**2,300**	**34,000**	**311,300**
Sh:J-197	**500,000**	**1,650**	**28,100**	**529,750**
Sh:J-211	**500,000**	**13,750**	**11,500**	**525,250**
Sh:J-212	**4,000**	**1,000**	**11,500**	**16,500**
Sh:J-226	**100**	**500**	**600**	**1,200**
MSA-1*	**500,000***	**80,000***	**700,000***	**1,280,000***
Average	***273,967***	***13,605***	***127,567***	***415,139***
Shallow aquifer wells				
Sh:J-171	**50,000**	**11,300**	**20,500**	**81,800**
Sh:J-173	**500,000**	**14,650**	**5,600**	**520,250**
Sh:J-174	**3,750,000**	**94,500**	**36,750**	**3,881,250**
Sh:J-195	**500,000**	**13,500**	**18,600**	**532,100**
Sh:J-196	**750,000**	**25,650**	**3,100**	**778,750**
Sh:J-198	**500,000**	**140,000**	**21,100**	**661,100**
Sh:J-199	**275,000**	**5,650**	**5,000**	**285,650**
Sh:J-200	**5,500**	**7,050**	**7,500**	**20,050**
Sh:J-201	**500,000**	**49,000**	**18,000**	**567,000**
Sh:J-202	**500,000**	**49,000**	**23,000**	**572,000**
Sh:J-203	**30,000**	**1,450**	**18,000**	**49,450**
Sh:J-205	**500,000**	**44,500**	**12,100**	**556,600**
Sh:J-206	**3,750,000**	**49,000**	**36,500**	**3,835,500**
Sh:J-218	**400,000**	**10,150**	**5,600**	**415,750**
SAA-1	**500,000**	**64,500**	**37,100**	**601,600**
Average	***834,033***	***38,660***	***17,897***	***890,590***

* Well Sh:J-126 had leaf detritus in the pumped water which may have influenced the bacteria count. Well MSA-1 had recently been drilled and artifacts from the drilling process could influence the microbial community numbers.

Regional Geochemistry

The dissolved oxygen data provide the most basic redox information concerning oxic and anoxic conditions in the Memphis aquifer. Previous studies and data from this study demonstrate that when dissolved oxygen concentrations are below 0.5 mg/L, nitrate, iron, and sulfur reducing begin (Byl and Williams, 2000). Dissolved oxygen data were available for 62 Memphis aquifer wells (USGS, 2020a) in Shelby County. The dissolved oxygen concentrations across the county range from greater than 2 mg/L in eastern Shelby County (closer to the outcrop of the aquifer which is unconfined and where much of the recharge occurs) to generally less than 0.5 mg/L in central and western Shelby County (Figure 8). The dissolved oxygen concentrations for the Memphis aquifer in Shelby County also show a general decrease with increasing depth of the well (figure 9). With the exception of two wells in eastern Shelby County (A and B on Figures 8 and 9), wells deeper than 400 ft in the Memphis aquifer had dissolved oxygen values less than 1 mg/L. The low dissolved oxygen values in the Memphis aquifer indicate anoxic conditions that could support the reductive dechlorination of chlorinated organic compounds. Additional geochemical data are needed to determine if competing terminal electron acceptors, such as nitrate or ferric iron, are present.

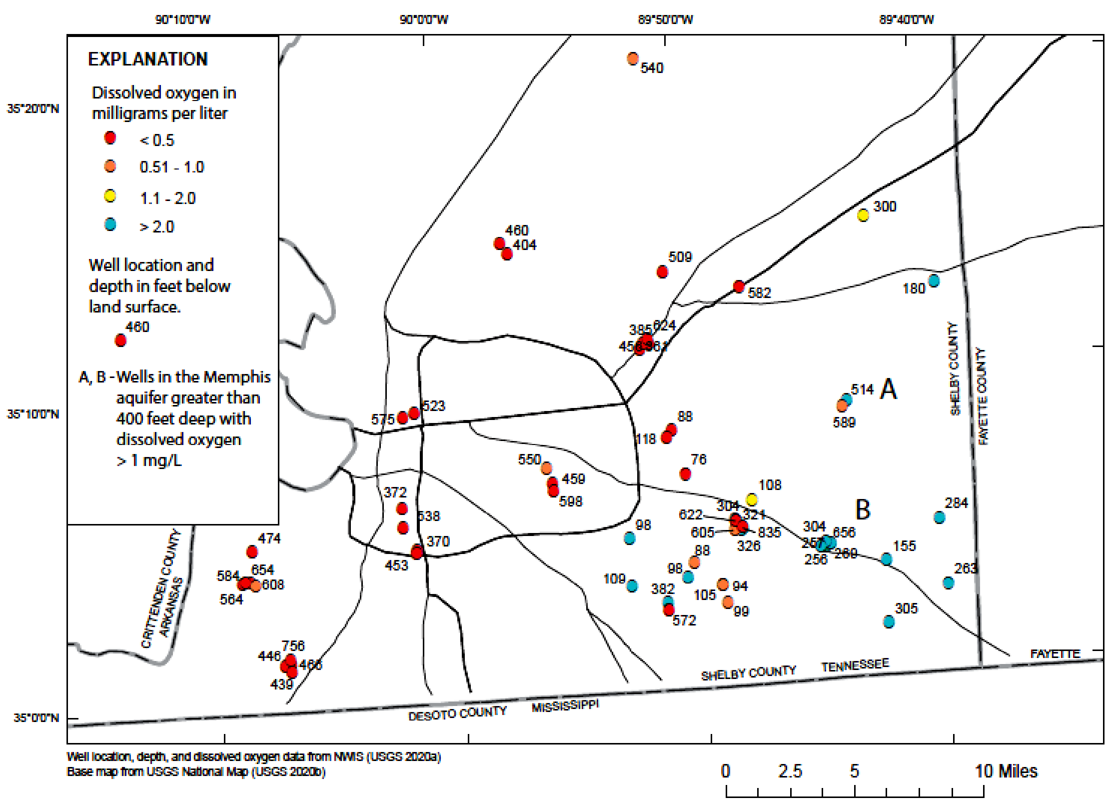

Figure 8. Dissolved oxygen concentrations (1997–2019) and well depths for wells completed in the Memphis aquifer in Shelby County, Tennessee.

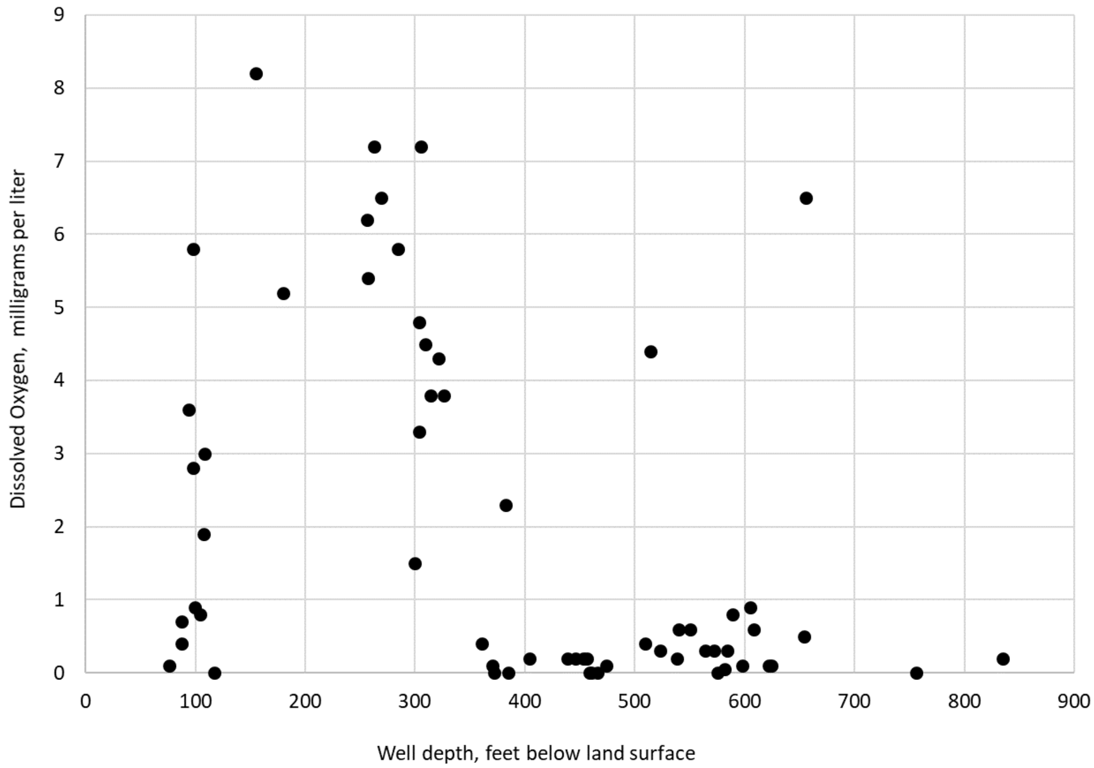

Figure 9. Dissolved oxygen concentrations and depths of well screened in the Memphis aquifer in Shelby County, Tennessee. (Data from USGS, 2020a).

SUMMARY

Water-quality data have been collected through the years to evaluate the shallow and Memphis aquifers in the Memphis area, but data and research on microbial communities and geochemical conditions relative to potential contaminant bioremediation are lacking. Very low levels of benzene and organochlorine compounds were detected in some of the monitoring and production wells in the Allen well field (University of Memphis, 2019). Although concentrations were below drinking water criteria, their presence in the Memphis aquifer highlights the need to better characterize the bacteria and redox conditions in the aquifer. The USGS, in cooperation with Memphis Light, Gas and Water Division and the University of Memphis, conducted a study during 2017–18 to evaluate geochemical and microbial conditions of the shallow and Memphis aquifers in the well field.

The results of this study provide evidence that there is a diverse and active microbial community capable of biodegrading chlorinated solvents in the shallow and Memphis aquifers in the Allen well field. However, the mere presence of these different bacteria types is not always enough to drive bioremediation processes to completion. The microbial community needs appropriate redox conditions favorable to the metabolic process that transforms the contaminant of concern into benign byproducts (Pachon, 2010; Byl and others, 2017). For example, aerobic or nitrate-reducing conditions are the most favorable processes for petroleum hydrocarbon biodegradation; however, anerobic sulfur-reducing processes are the most favorable for reductive biodegradation of chlorinated solvents.

The shallow and Memphis aquifers were dominated by heterotrophic aerobic bacteria, which is common in groundwater systems (Byl and others, 2017). Most heterotrophic aerobic bacteria can easily switch between oxygen and nitrate as an electron acceptor depending on which becomes limiting. After the oxygen and nitrate concentrations are depleted, many heterotrophic bacteria turn to the less efficient fermentation metabolic pathway (Chapelle, 1993), or the inorganic TEAPs, ferric iron and sulfate. The patterns of microbial activity and geochemical indicators in the two aquifers provide evidence that conditions exist that could support the natural or enhanced biodegradation of organic contaminants. An evaluation of dissolved oxygen in the Memphis aquifer across Shelby County indicates anoxic conditions that could support the reductive dechlorination of chlorinated organic compounds. The geochemical indicators used to identify microbial electron acceptor process are strengthened by the BART data. The two lines of evidence come together to verify redox processes that are active in the aquifers and could indicate contaminant degradation at different locations.

In summary, the microbial community in the Allen well field appears capable of biodegrading most contaminants that were measured in samples from the aquifers. Assessment of the optimal TEAP conditions and presence of adequate electron donors on a well-to-well basis, along with the contaminant of concern, would provide additional details to determine if conditions are suitable for efficient biodegradation. On a wider scale, anoxic conditions in the Memphis aquifer indicate that biodegradation of chlorinated solvents could be a potential remediation strategy. Additional research and site-specific studies to further evaluate the microbial community as well as the redox and geochemical conditions at groundwater contamination sites in Shelby County could provide valuable data to inform future remediation approaches.

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SOFTWARE WARS EPISODE IV: A NEW HOPE

Gerald A. Burnette[1]

IN THE BEGINNING...

Organizations that concern themselves with environmental issues and public health have for years established limits that they consider safe levels of exposure to various chemicals. The earliest examples were specific values for various exposure pathways or media (e.g., total Mercury in water must be <5 ug/l). These types of limits would sometimes vary when the evaluation addressed a more targeted objective – for instance, an environment that supports a healthy fish population – but in general, they still limited evaluation to a single constituent. Over time, as more investigations identified the complexities of interactions between individual constituents as well as interactions between constituents and organisms, a new paradigm evolved in which limits were sometimes defined as a combination of value boundaries for more than one condition. These combinations most often referenced a chemical constituent and some other property. An example might be a limit that identifies an exceedance as occurring when total Cadmium in water >5 ug/l while at the same time the total hardness < 100 mg/l.

IDENTIFYING EXCEEDANCES: THE EARLY YEARS

If your job involves monitoring water quality, identifying regulatory exceedances is an important activity. For relatively simple investigations involving a small amount of data, it can be acceptable to use some form of spreadsheet for managing monitoring results. In that situation, identification of the simple case exceedances is a relatively easy endeavor that can be accomplished with a formula in another spreadsheet cell. The most challenging part that effort is making sure the correct limit is entered into the formula. Addition of a second comparison complicates things a little, but not that much. Now your formula must reference values in two cells, so in addition to getting two limits entered correctly, you must also make sure to check values in the correct cells. Still, not that much of a challenge.

As data volume and/or complexity grows, a more robust data management system is usually required. This typically means moving to a database, most commonly one that adheres to the relational model (Microsoft Access, Microsoft SQL Server, Oracle, etc.). You may choose to develop your own database, or you might purchase a commercial off-the-shelf (COTS) solution tailored to your specific type of monitoring. Database solutions offer the best choice because of their ability to enforce data integrity rules which reduce the chances of introducing invalid or duplicate data. That advantage comes with a price, however, in that data descriptors become scattered over multiple tables. Any attempt to view or analyze data in a more traditional configuration requires assembling related data from multiple tables using a query or report.

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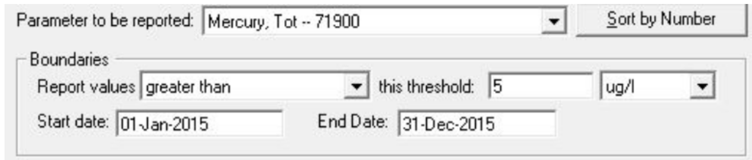
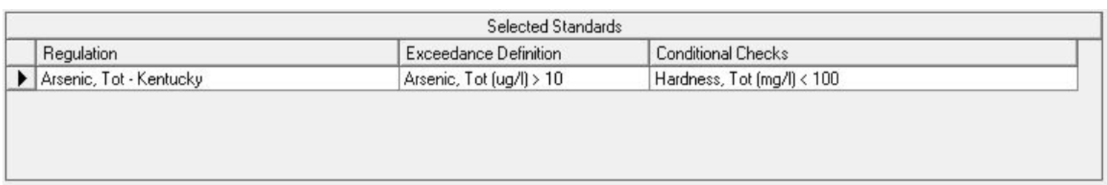


Figure 2. Defining a simple exceedance

COTS solutions or comprehensive systems developed locally almost always include some sort of interface that facilitates data retrieval and analysis tasks without forcing you to learn the actual query language. Any interface will include the ability to identify the simplest types of exceedances by retrieving results for a parameter, allowing you to simply scan and pick out the problematic results. Better products might include the ability to retrieve *only* the results that exceed the limits. These types of reports might include additional filtering options that allow you to focus on only one set of locations or a specified time frame (see Figure 1).

This feature of a typical database user interface makes it easy to identify the simplest types of regulatory exceedances – those that are based solely on the value of a single parameter. This type of query, though, will not address even the second type of limit noted in the opening paragraph. For that evaluation, a more complex definition must be identified. Fortunately for those who develop databases and interfaces, this is a relatively simple enhancement. With the proper database design, the system can be modified to accommodate examination of multiple parameters when identifying exceedances (see Figure 2).


Selected Standards

Regulation	Exceedance Definition	Conditional Checks
Arsenic, Tot - Kentucky	Arsenic, Tot (ug/l) > 10	Hardness, Tot (mg/l) < 100

Figure 3. Defining a limit involving two parameters

Properly designed and implemented, the database can enable the definition of regulatory limits that involve an unlimited number of parameters. (Fortunately, cases involving more than two comparisons are extremely rare.)

A NEW APPROACH ARISES

As scientists continued to explore what makes a particular constituent dangerous, the definition of regulatory limits began to get more complex and involve more factors. Additionally, these new definitions frequently involved calculations much more complex than simply comparing observed values to one or more numeric standards. Consider, for instance, this definition of the regulatory limit for total Chromium as defined in Ohio Administrative Code Chapter 3745-1 "Water Quality Standards":

limit for Chromium in $e^{((0.819 \times \ln(H))+4.4187)}$ ug/l= where H is total Hardness in mg/l.

This type of definition introduces much more complexity into the prospect of adapting a database management system to the process of evaluating regulatory exceedances. Database management software is adept at storing and retrieving parameter values, but most of them have very limited capabilities for performing even moderately complex mathematical calculations. The options for addressing this situation are therefore limited: either code the calculations into the user interface or force users to extract data to another format for analysis. Both solutions are problematic. Hard coding the interface means capturing potentially hundreds of specific cases. It also means that any change in the regulations means altering the interface code, potentially delaying the ability for timely analysis. Forcing users to resort to use of another tool such as a spreadsheet introduces the very types of errors the database was intended to eliminate.

MEANWHILE, IN BIOLOGY LAND...

The evaluations we've discussed so far are related to physical conditions and chemical constituents. Biologists have their own means of assessing environmental quality, and many of those are also increasingly complex. A common tool devised by biologists is the Index of Biotic Integrity (IBI). Typically, an IBI involves evaluating multiple metrics based on various assessments of water quality, assigning scores to each metric result, and then combining the scores for an overall IBI result. Individual metrics are typically based on the relative population of various classes of organisms or other measures. Considerations of other properties such as drainage area are often also part of the metric calculations.

The complexities of IBI evaluation introduce the same concerns for database systems as those for the newer approaches to regulatory limits for chemicals. Additionally, states and other regulatory agencies tend to define multiple IBI variations that must be applied to different types of conditions or locations. These issues have caused most database systems to avoid even attempting to capture this process.

A NEW HOPE

Fortunately, environmental scientists aren't the only ones developing new approaches. Advances in computer science and technology have provided new tools that allow software developers alternative methods for dealing with these new requirements. In particular, open source mathematical function libraries have evolved to allow customization and adaptation to specific tasks. This allows developers to create application-specific macro languages to address specific situations. Following are examples of how these new tools have been used to enable calculation of complex regulatory limits and IBI metrics.

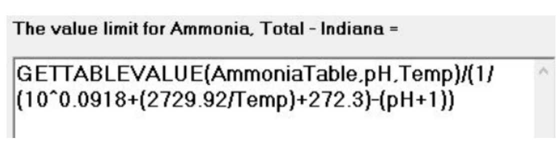


Figure 4. Equation-based limit

Figure 3 shows the implementation within one particular database management system that allows users to enter complex calculations for identifying the regulatory limit for Ammonia. Factors in the equation are defined by associating text entries with specific parameters (e.g., "Temp" = water temperature in deg C). The equation involves using standard math operators as well as functions defined in the new macro language developed for the system. In this example, only one such function is used (GETTABLEVALUE). The only code required for the user interface to evaluate this equation is a parser that recognizes the functions and arguments, and then takes appropriate action. For instance, the GETTABLEVALUE function requires three arguments: a lookup table (defined by the user), and the variables used to specify the row and column in the table. The function returns the specified value and inserts it into the equation.

The form for entering the equation includes reference materials for the various application-specific functions in order to better facilitate proper equation definition. Also, the equation is parsed at the time of definition to ensure it is correctly formed and completely recognized. The equation is implemented when the user chooses to query the database to identify regulatory exceedances for Ammonia. The code that parses and evaluates the equation retrieves the specified parameters, evaluates the equation, and then uses the result for the regulatory limit.

Figure 4 shows the implementation in the same system for defining IBI metrics. This image illustrates the additional complexity of the IBI process. Entry of the equation follows the same principles as described above. For evaluating metrics, the specific factors in the function definitions are groups of organisms instead of individual parameters. The wizard for defining the IBI requires users to create names and identify members of organism groups before using them in the equation. In this example, the NUMTAXA function is used to count the number of individual darter and sculpin species found in the sample results. The metric value is then the sum of these two values.

The macro parser for IBIs includes all the functions that might be found in a typical IBI metric calculation. Another example can be seen in Figure 4 in the instructions displayed for user assistance. A common metric evaluation factor involves determining the number of specimens of each organism within a group, multiplying that by some factor that varies by organism, and then summing over all the organisms within the group. The example cited in the instructions in Figure 4 is for this function (SUMOF).

Another characteristic common to IBIs is that metrics may have different variations depending on some other property or value. The grid in Figure 4 includes a column labeled “Include in IBI when.” This allows the user to identify multiple variations for a particular metric and specify a condition under which each is used. In this case, the inclusions are based on the drainage area contributing to the site.

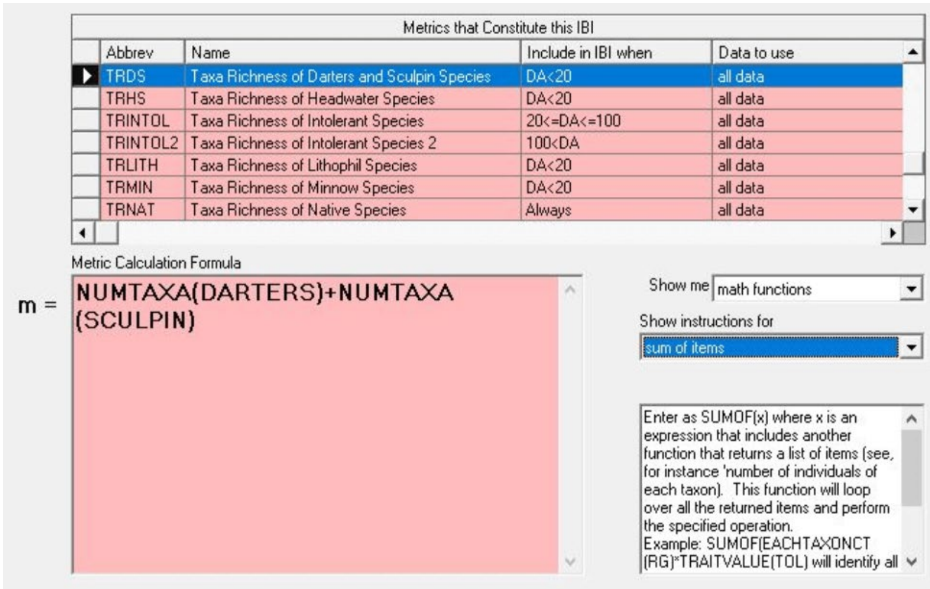


Figure 5. Defining a metric evaluation equation in an IBI

Figure 4 shows one part of the wizard that guides users through the definition of an IBI. Other parts of the wizard involve defining variables to be used (e.g., drainage area) and organism groups (e.g., darters); these steps come before the definitions of the metrics and their evaluation equations. After the metrics are defined, the next step involves entering scoring criteria for each metric (again, with an equation).

At evaluation time, the user simply selects a sampling event and the IBI to be evaluated.

CONCLUSION

Processes for assessing water quality have evolved into more complex methods. This has forced software developed for managing water quality data to employ novel and specialized approaches in order to meet user needs.

INVESTIGATING THE EFFECTS OF IMPOUNDMENTS ON FOOD AVAILABILITY AND CONDITION OF FRESHWATER MUSSELS IN THE PIGEON AND NOLICHUCKY RIVERS OF NORTHEAST TENNESSEE

John W. Roden III and Joseph R. Bidwell

INTRODUCTION

The southeastern United States is unparalleled in terms of freshwater mussel biodiversity. However, significant declines have been noted over the past century due to anthropogenic factors such as pollution, land use, and hydrologic alterations. In order to address these declines in mussel biodiversity, many state resource agencies have developed conservation strategies focusing on habitat remediation and augmentation or reestablishment of native assemblages using laboratory-reared mussels. The Pigeon River tailwater of Northeast Tennessee has been a focus of such management strategies by the Tennessee Wildlife Resources Agency (TWRA). While the Pigeon River was historically subjected to severe pollution resulting in loss in biodiversity, considerable strides have been made in restoring habitat and fish fauna within the river over the past 30 years. However, attempts to reintroduce native mussel fauna in the Pigeon River have had limited success. In coordination with the TWRA, the objective of this study was to compare survival, growth and whole-body glycogen content of juvenile pocketbook mussels, *Lampsilis ovata,* transplanted in the regulated Pigeon River tailwater and the free-flowing Nolichucky River and to characterize the quantity and quality of seston between the two rivers as a way to gain insight into any observed differences in performance of the transplanted mussels. It was hypothesized that the altered flow regime of the Pigeon River would lead to differences in primary production and organic content of the suspended seston that is a primary food resource for filter-feeding mussels. As such, it was predicted that *L. ovata* transplanted in the Pigeon River would exhibit reduced survival, growth, and whole-body glycogen content as compared to mussels transplanted in the Nolichucky River. Additionally, it was predicted that seston collected from the Pigeon River would have lower organic content and chlorophyll$_a$ levels as compared to seston from the Nolichucky River.

METHODS

Juvenile *L. ovata* were transplanted in silos to a single site on the Pigeon and Nolichucky Rivers in July, 2019. Mussel survival and growth were assessed monthly, and whole-body glycogen content was determined after 1, 2, and 4 months of deployment following methods described by Naimo et al. (1998). Water temperature was continuously monitored throughout the study at these two sites using temperature data loggers placed inside the silos. Water samples were collected and filtered at four sites on each river on a monthly basis and used to determine chlorophyll$_a$ and organic material concentrations following methods established by Steinman et al. (2007). Additionally, at the sites where mussels were transplanted, water samples were collected immediately prior to, during, and after peak flow events. At each sampling event, water temperature, percent dissolved oxygen, specific conductance, salinity, pH, and flow rate were also measured. Mussel survival, growth, and glycogen content were compared between the Pigeon and Nolichucky rivers as well as average chlorophyll$_a$ and organic material concentrations of all samples collected at the sites where mussels were deployed to determine if differences in mussel condition were related to differences in seston quantity and quality between the two rivers. Chlorophyll$_a$ and organic material concentrations were also tested for correlation with water quality variables measured at each sampling event and with the flow rate at the time of sampling to determine if seston concentrations were influenced by elevated flow. Within each river, $chlorophyll_a$ and organic material concentrations at sites along the length of the rivers were compared to provide insight on differences in primary production and organic matter along the length of each river system in relation to different land use practices and activity occurring in the immediate proximity of each site.

RESULTS AND DISCUSSION

Over the course of the study, no significant difference in survival was observed, with only one mortality occurring on each river. However, mussels placed in the Nolichucky River exhibited significantly greater growth (increasing from an average initial length of 1.370cm to an average length of 2.779 at month 4) than those in the Pigeon River (increasing from 1.338cm to 1.483cm in the same time). Mussels deployed in the Nolichucky River were also found to have significantly greater glycogen concentrations than those in the Pigeon River. At the sites where mussels were deployed, average $chlorophyll_a$ and organic material concentrations in the Nolichucky River (0.001380mg/L and 1.3mg/L, respectively) were significantly greater than in the Pigeon River (0.000623mg/L and 1.1mg/L, respectively). These findings suggest that the mussel deployment site on the Nolichucky River had higher levels of algae and other organic material to be utilized as food sources for mussels than the site on the Pigeon River. Furthermore, $chlorophyll_a$ and organic material concentrations at the mussel deployment site on the Pigeon River were found to be significantly correlated with flow rate, suggesting that frequent alterations to the flow regime within the Pigeon River are likely flushing the system of organic material and restricting the retention time of pools suitable for primary production. However, the mussel deployment site on the Nolichucky River was located below the inactive Davy Crockett impoundment, and $chlorophyll_a$ concentrations at sites above the reservoir were found to be significantly lower than those downstream from the reservoir, suggesting that Davy Crockett Reservoir could be significantly influencing downstream seston quality by serving as a large pool with substantial retention time, creating ideal conditions for primary production. In consideration of these findings, it could be that the differences in mussel growth and glycogen content and in $chlorophyll_a$ and organic content of seston observed between the Nolichucky and Pigeon rivers is a product of both detrimental conditions on the Pigeon River and artificially favorable conditions on the Nolichucky River. These results and findings not only illustrate deleterious ecological effects of frequent flow alterations from active impoundments, but also suggest that even inactive impoundments have significant ecological impacts by artificially influencing watershed dynamics.

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ASSESSING SHORT-TERM EFFECTS OF TRANSLOCATION ON THE SPATIAL ECOLOGY OF EASTERN HELLBENDERS

Bradley D. Nissen[1]*, Emilly Nolan[1], Michael Freake[2], Rebecca Hardman[3], William Sutton[1]

INTRODUCTION

Eastern Hellbenders (*Cryptobranchus alleganiensis alleganiensis*) are fully-aquatic salamanders that are found throughout the Appalachian region of the Eastern United States. They are highly sensitive to environmental disturbances, largely due to their porous skin and a specialized method of cutaneous respiration which limits their occurrence to swift flowing, cool, clear streams where dissolved oxygen levels are high (8.4 – 13.6 ppm) and the concentration of pollutants is low (Hillis and Bellis, 1971). Because of their dependence upon clean streams and their unique life history, the status of Hellbender populations is often viewed as a valuable indicator of aquatic ecosystem health. Unfortunately, Hellbender populations are declining in Tennessee and they are currently listed as State Endangered (TWRA, 2018). Habitat fragmentation as a result of large-scale dam construction by the Tennessee Valley Authority is one major reason for these declines in Southeastern Tennessee (Freake *et al.*, 2018). These impoundments have isolated Hellbender populations, leaving many remaining "at risk" populations comprised of mature individuals in relatively larger (and presumably older) age classes with limited signs of recruitment and connectivity to genetic diversity from nearby populations. In response to these Hellbender declines, translocations from sustainable healthy populations to isolated "at risk" populations have been proposed as a possible conservation strategy for Hellbenders in Tennessee. This is the first study to date completed with the goal of understanding the viability and effects of these types of translocations on Hellbenders in Tennessee. The results of this study will be informative for future Hellbender translocation plans in Tennessee and across the range of the species.

APPROACH

We evaluated the short-term success of translocation on wild Hellbenders by comparing the spatial ecology of individuals pre- and post-translocation using radio-telemetry. In May/June 2018, 27 Hellbenders were captured from within two sustainable populations (Tumbling Creek and Hiwassee River; Fig.1) and a trained veterinarian surgically implanted a radio-transmitter into their body cavity. Once recovered, they were released at the original capture site. For one year we studied the home range sizes, movements and multi-scale habitat use of these individuals, by locating them between 1-3 times a week depending on the season and stream conditions. Habitat use was evaluated using a discrete choice use-availability approach, by comparing habitat data from locations used by Hellbenders to randomly selected available habitats in that area. Following one year, we subsequently collected similar data from a portion of these individuals (N =17) that were translocated (May-July 2019) into two nearby streams with declining populations (Rough Creek and Citico Creek, respectively). Translocation sites were selected from various streams in the region that are isolated from main-stem populations, based on the overall habitat suitability, their genetic similarity to the source streams, and a known history of declining Hellbender

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populations. Tracking at the translocation sites was carried out until the first hard frost of the season, in mid-November 2019.

RESULTS AND DISCUSSION

We collected over 1,500 location data points (869 prior to translocation and 715 post-translocation) from our four study sites. Individuals that had less than 15 locations per season were excluded from our analysis. Survival rates of translocated individuals increased when moved from Tumbling to Rough Creek (80% to 100%), while they decreased when moved from Hiwassee to Citico Creek (76% to 33%). Long distance movements (>100 m) were observed in 58% of translocated individuals (7/12) at Citico Creek, compared to only 20% (1/5) at Rough Creek. Hellbenders at Citico Creek had the largest home ranges of the four sites, with median kernel density estimated core usage areas of 3951 m^2, while the smallest median home ranges were recorded at the Hiwassee River (25.37 m^2). This indicates large differences in behavior for this cohort of animals before and after being moved. In contrast, the core home ranges of Tumbling Creek (median =90.45 m^2) were only slightly smaller than those for animals translocated to Rough Creek (median = 266.83 m^2). We report medians here, because we did have some individuals at both Citico and Tumbling Creek that made very large movements, influencing site averages. One young male Hellbender at Tumbling Creek traveled over 3 km upstream over the course of the first year, and the most mobile male at Citico Creek moved a total of over 5 km in both upstream and downstream directions within a period of 4 months. We examined the "settling rate" of the animals by looking at average sedentariness, or the proportion of times an animal was found in the same location in successive tracking sessions. Sedentariness was high for the animals translocated to Rough Creek (80% ± 2.94%) compared to an average of (49% ± 4.72%) for animals translocated to Citico Creek.

The greater rate of "exploration" amongst individuals in Citico Creek could be due to increased competition for prey items with other predators (e.g. large fish, otters), and likely led to the increased predation by otters. Preliminary crayfish count surveys revealed much less crayfish at Citico Creek than Rough Creek, and further work will be done in the spring to evaluate the differences between these two streams. Our results show that translocations of Hellbenders can be successful, but site selection matters. Hellbender translocations at Rough Creek were more successful than those at Citico Creek, based on metrics such as settling rates and survival. We recommend that future translocations evaluate the presence of predators (e.g. otters) and the density of prey items (i.e. crayfish) before selecting translocation sites for wild Hellbenders.

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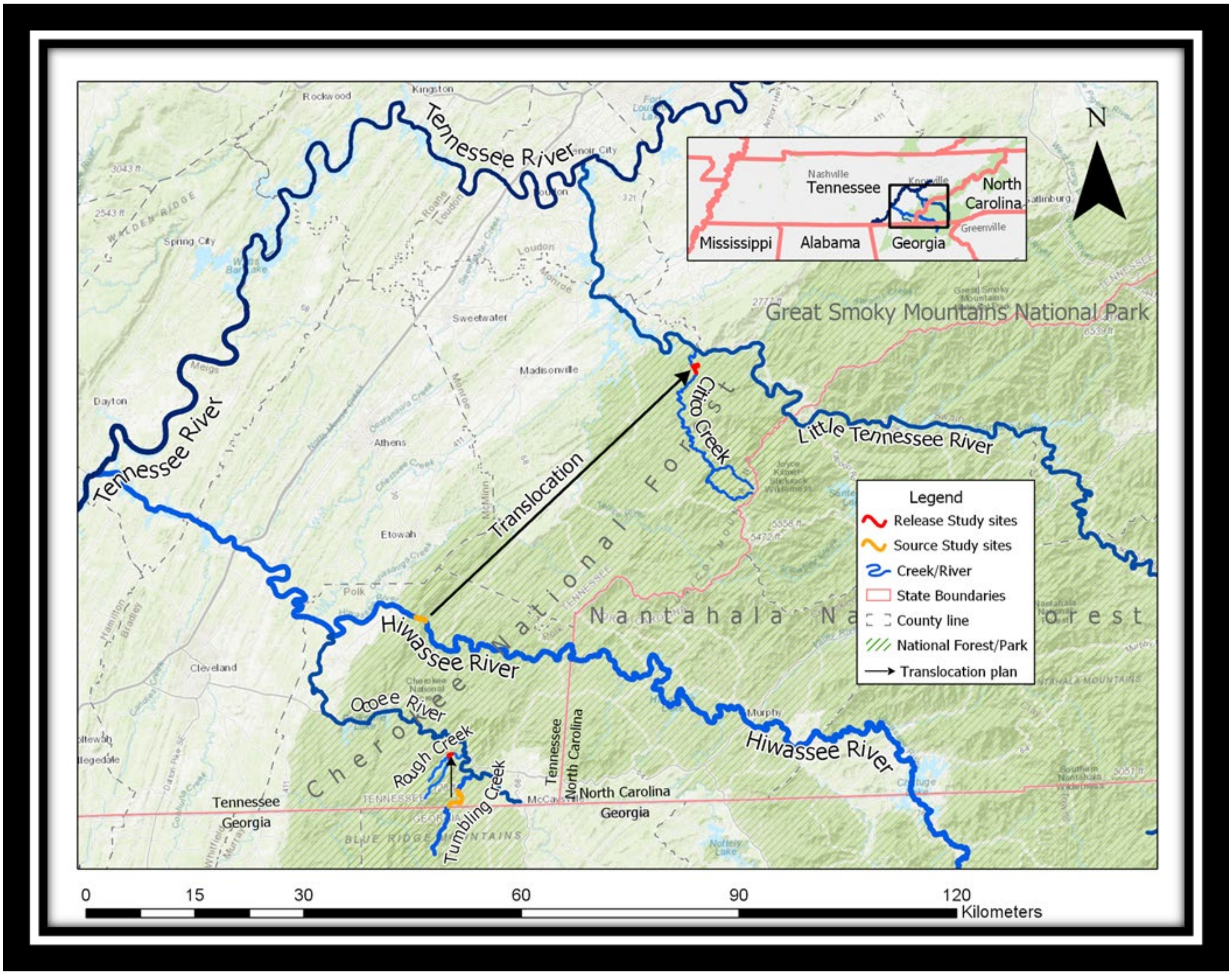
Figure 1. Map of study sites, with source streams and translocation sites indicated.



THE RETURN OF NUTRIENT RETENTION IN RESTORED AGRICULTURAL WETLANDS

Justin Murdock, Robert Brown, Spencer Womble, Shrijana Duwadi, Morgan Michael and Alfred Kalyanapu

Tennessee Technological University, Cookeville, TN

Agricultural watersheds contribute a substantial proportion of nutrients exported by rivers in the Lower Mississippi River Basin (LMRB). These excess nutrients can degrade local aquatic habitats and ultimately contribute to Gulf of Mexico hypoxia expansion. Several factors in LMRB watersheds contribute to increased nutrient export, including channelization and levee construction that create a disconnect between the river and its floodplain, and the conversion of riparian floodplain wetlands into agricultural production. The USDA Natural Resources Conservation Service (NRCS) established the Wetlands Reserve Program (WRP) more than 20 years ago in order to restore marginal agricultural land back to functional wetland ecosystems. The goal of our research is to assess whether restoration, implemented through the WRP program, enhances essential wetland functions in western Tennessee and Kentucky. We are measuring WRP easement nutrient reduction performance as a function of time in the program (i.e. wetland successional stage) and the effectiveness of specific restoration practices such as hydrology modifications and tree plantings across 40 easements. This presentation will detail results from the first year of a four-year study, including how NRCS restoration practices alter nitrogen and phosphorus uptake rates, as well as denitrification potential. The ecosystem services provided by these restored easements appears to reach far beyond that of just the creation of wildlife habitat, and includes the potential for substantial water quality improvement in local and downstream agroecosystems.

INFLUENCE OF TOPOGRAPHY AND PHYSICAL PROPERTIES ON HYDRIC SOILS IN DEVIL'S KITCHEN BRANCH BOG, GREENEVILLE, TN

William Jarvis[1], Joshua Welty, Dr. Ingrid Luffman, and Dr. Arpita Nandi

INTRODUCTION AND BACKGROUND

Devil's Kitchen Branch Bog is a mountainous bog located in Greene County, TN within the boundary of the Cherokee National Forest. Forest wetlands play an important environmental role by improving water quality, mitigating flood severity, and providing critical habitats for threatened species (USEPA, 2020). Mountain wetlands are formed by distinctive hydrology, soils, and ecology leading to fragile environments. Unfortunately, wetlands like this have shown a significant decline from anthropogenic activities; less than half the wetlands existing before settlement were still extant in 1980 (Dahl, 1990). Devil's Kitchen (Figure 1) follows the trend; primitive roads crossing the wetland, existing since before 1900, have led to damages from off-highway vehicles (OHV). The US Forest Service (USFS) has selected this particular wetland for restoration efforts. The aim of this research is to correlate topographic characteristics and soil physical properties to hydric soil character to help determine the potential for expansion and restoration of the bog. Within the study area, locations with latent wetland conditions are assumed to have similar characteristics to existing wetland locations.

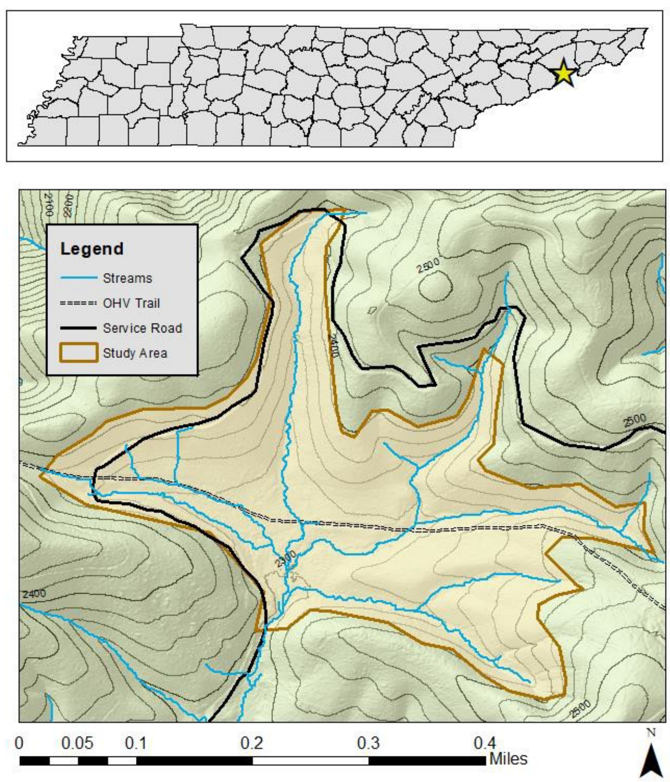


Figure 1: Locator Map of the study area showing OHV trail and drainage.

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METHODS

A proposed area outline was provided by the National Forest Service based on previous work from rangers. Using a grid, the area was divided into 58 sampling cells. Soil cores 0.4 m in length were extracted from each cell and evaluated in situ for hydric soil indicators using the United States Army Corps of Engineers Wetland Determination Form (United States Army Corps of Engineers, 2012). In the field, samples were sealed in sterile plastic bags and transported to the East Tennessee State University Department of Geosciences Soils Lab for physical testing. Soil moisture content was tested by comparing sample masses before and after oven drying. GPS data recorded in the field was used in conjunction with TN LiDAR digital elevation models to determine topographic properties at each sampling point. Slope, elevation, and distance to streams were calculated in ArcMap 10.7.1 (ESRI, 2019). Logistic regression models were developed in SPSS version 25 (IBM, 2017) for the presence of hydric soil using topography and soil physical properties described above.

RESULTS

Hydric soils were present in 20 of the 58 sampling locations (Figure 2). Hydric soils generally had a higher moisture content, lower elevation, lower slope, and were closer to streams (Table 1). Each of these variables is significantly correlated ($p < 0.05$) to the presence of hydric soils. Using 70% of the data, a binary logistic regression model was created. Despite correlation in all variables, the model retained only distance to stream and elevation as significant predictors ($p=0.097$ and $p=0.028$, respectively). The model had a Nagelkerke R square of 0.444, correctly categorizing 81.8% of the data used to build it. Testing the model against the remaining 30% of the data produces a receiver operating characteristic (ROC) curve of area 0.810.

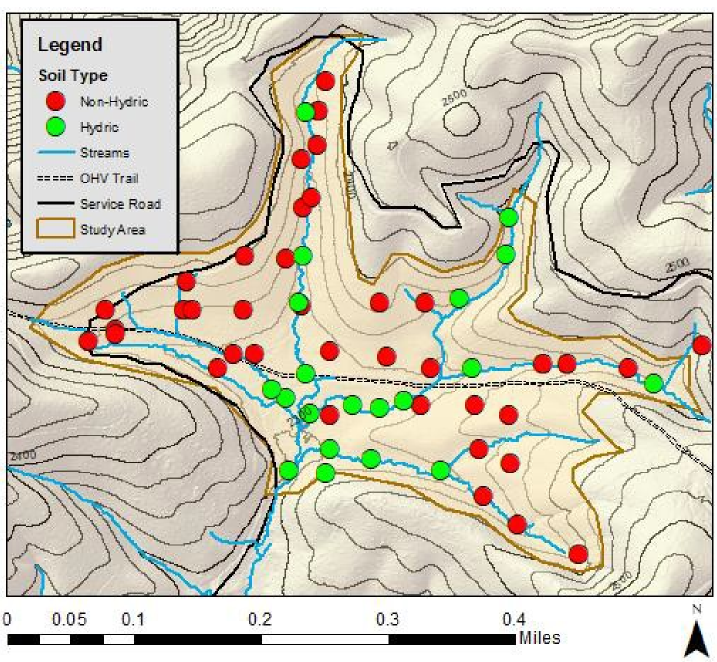

Figure 2: Sampling map of the study area.

Table 1. Mean values of explanatory variables for hydric and non-hydric soils

Soil Type	Elevation (ft)	Slope (% grade)	Distance to Stream (m)	Average Moisture (% weight)
Hydric Soils	2326.9	24.9	3.6	53
Non-Hydric Soils	2384.7	58.3	15.2	22

DISCUSSION

The low proportion of hydric to non-hydric soils indicates that the current extent of the Devil's Kitchen Bog is smaller than the outline provided by the USFS (Figure 1). Trends in the data reflect the known determinants of wetland formation. Generally, factors that increase water retention lead to more favorable wetland conditions. In basins, lower elevations are more frequently inundated than higher ones. Areas with lower slope allow for less runoff, therefore increasing water retention. The distance to stream likewise indicates areas that are in favorable hydrologic conditions. As a direct result of water retention, soils become more saturated; increasing moisture content (Richardson & Vepraskas, 2001)

Because the explanatory variables are linked by a common factor, water retention, there is high correlation between each variable. This can be seen in the limited list of variables retained in the logistic regression model. Still, the model is reasonably accurate; the high area (0.810) underneath the ROC curve indicates a low false-positive rate. Future work will incorporate other variables including chemical and soil texture data in efforts to improve the model. Following this, explanatory variables will be interpolated using ordinary kriging and a hydric soil probability surface will be generated using these variables and the model equation.

Results from this study can be extrapolated to similar mountain bogs in the southeast United States. The field, laboratory, and statistical modeling methods described in this study may be useful to develop a wetland restoration boundary in other locations.

CONCLUSION

This study indicates that the topographic factors of elevation and the distance to a stream are useful for predicting the presence of hydric soils within Devil's Kitchen Branch Bog. While soil moisture and surface slope showed a significant correlation to hydric soils, they were not a useful predictor. By combining these results with geospatial methods, wetland delineation may be refined.

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INTRODUCTION TO THE SANITARY SEWER ACCESS SYSTEM IN THE CITY OF MEMPHIS

(Louie) L. Yu Lin[1]

The City of Memphis Division of Public Works Sewer Department (City) is responsible for the operation and maintenance of the City sanitary sewer system. As part of regular operation and maintenance programs, the Sewer Department needs access to the sanitary sewer system, much of which is located adjacent to and crossing over streams or wet weather conveyances because sewers have to maintain gravity flow as much as possible. Access to the sanitary sewer system and inspection of sanitary sewer systems can be complicated when the Tennessee Department of Environment and Conservation (TDEC) water quality regulations and permits are applied. Inadequate inspection and maintenance of the sanitary sewer system may cause serious environmental damage. To facilitate the ease and speed of access to the sanitary sewer system in the event of an emergency, as well as for on-going maintenance, the City plans to develop a system, whereby administrative, legal, and physical access to the sewer system have been identified to provide for sanitary sewer access.

The Surface Water Institute (SWI) in the Department of Civil and Environmental Engineering (CEE) at Christian Brothers University (CBU) supports on-going and emergency access to the sanitary sewer system under the order of WPC 16-0054 and develops a demonstration plan for the City of Memphis. The project is planned to be a pilot demonstration program within specific sewer segments to establish the look and approach of the system prior to roll-out of coverage for the entire sewer system. The preliminary study site is focused on the Nonconnah Interceptor from the T. E. Maxson WWTP to I-55 (in Figure 1). The pilot program to be completed over 2 years will initially cover the gravity mains of 84" in diameter and larger but will also include the 4 barrel 48" siphon at the I-55/I-240 junction. The pilot program will be disseminated, so that all parts of the Sanitary Sewer system in the City of Memphis can be integrated at a later date as needed. This paper is going to present the concepts and planning stage of the sanitary sewer access road program.

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IDENTIFICATION OF WATER FEATURES FOR SANITARY SEWER ACCESS

Thomas B. Lawrence[1]

BACKGROUND

The gravity flow sanitary sewer interceptors in the City of Memphis tend to be located adjacent to three major watercourses that cross the City, generally from east to west. They are Nonconnah Creek, the Wolf River, and the Loosahatchie River. Each of these waterways terminates by flowing into the Mississippi River within the Memphis city limits. The interceptors are now over a half century old, requiring on-going inspections, along with possible repairs. Moreover, since they are located adjacent to the waterways, they are in some of the most difficult areas to access for the entire sanitary sewer system, due in part to regulatory restrictions, heavy vegetation, and high-water flooding.

To help address the sanitary sewer access issues, TLE worked with the Christian Brother University (CBU) Surface Water Institute (SWI) and other consultants to identify access restrictions, then to determine the information that could help achieve access to the sanitary sewer system. Without a method for effective access, the city is restricted in its ability to readily reach sanitary sewer infrastructure for preemptive inspections to reduce the risk of system failure. Additionally, when an issue arises, the City needs quick access. To address possible access issues, the SWI developed the City of Memphis "Environmentally Sustainable Sewer System Access Project (SSAP)".

One of the roles that TLE performed for the project was to identify possible areas where water quality permitting may be needed (called "Areas of Concern - AOCs), so that the City could get permit applications developed and submitted as soon as possible. Development of the AOC database required a desktop analysis, compilation of data from many resources, and the physical inspection of the area along the sanitary sewer lines.

PRESENTATION

The presentation will discuss how the AOCS were identified and how the information is presented, so as to be of the best use to the City and its contractors when performing on-going maintenance and when responding to emergency repairs.

ABOUT THE SPEAKER

Thomas B. Lawrence, PE has been active in the field of environmental engineering for over 25 years, including work as a regulator, as a manager for a regulated entity complying with water quality permits, and as a consultant helping to protect and restore water quality. As a registered professional engineer in Tennessee, California and Illinois, he has led the investigation of water

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pollution issues and developed solutions to address the water quality concerns that are specifically tailored to the situation, ranging from public education to the design and implementation of mechanical remediation systems. He has worked with regulators throughout the country to negotiate permit conditions to ensure that water quality remediation and water pollution efforts can proceed in the most efficient and cost-effective manner. Mr. Lawrence is an excellent speaker and has spoken on water quality issues and project management at conferences throughout the country, including the California Stormwater Quality Association (CASQA) Annual Conference, the International Erosion Control (IECA) Annual Conference and the Tennessee Engineers' Conference. Additionally, he is particularly adept at explaining complex water quality issues to the general public, neighborhood groups and school children.

During his career, Mr. Lawrence has been the President of Tennessee Section of the American Society of Civil Engineers (ASCE), the Chair of the Tennessee Chapter of the Environmental and Water Resources Institute (EWRI), President of the Engineers' Club of Memphis, a member of the Tennessee Stormwater Association (TNSA) board, a member of the Memphis Area Geographic Information Council (MAGIC) board, and the President of the Memphis Chapter of the Tennessee Society of Professional Engineers. In 2013, Mr. Lawrence won the prestigious ASCE "Daniel B. Barge, Jr. Distinguished Service Award" for his contributions to ASCE and the engineering field.

DEVLOPMENT OF INSPECTION AND MAINTENANCE OF SANITARY SEWER ACCESS SYSTEM PROGRAM FOR THE CITY OF MEMPHIS

(Louie) L. Yu Lin[1] and J.T. Malasri[2]

ABSTRACT

All sanitary sewer systems deteriorate over time. In order to keep the current systems in optimum condition and effectively perform their objectives, maintenance of the sanitary sewer line is necessary. Sewer lines are one of the main aspects of drainage systems that need regular inspection. If the sewer line instillation is less than ten years old, a yearly inspection is required. If the instillation is older than ten years, however, an inspection and cleaning of the sewer line should happen every six months. Maintenance is required to maintain the optimal capacity of the sanitary sewer line. Without maintenance, the sanitary sewer line could fail to operate. Consequently, major environmental damage affecting the environment, including soil, water and people could follow. The inspection of the sanitary sewer line is difficult due to several restrictions including land use, heavy vehicles, wetland restriction, hydrological conditions, and hydraulics conditions. Some physical barriers and land use can also make inspections difficult. As an example of previous environmental damage, in 2017 the City of Memphis sanitary sewer leaked around the McKellar Lake area that caused aquatic damage of approximately 350 million gallons of sewage to flow into the lake and consequently, the Mississippi River. The Tennessee Department of Environment and Conservation and the U.S. Environmental Protection Agency fined the City in 2017 due to this damage. The City used this fine to establish a Sustainability Environmental Program (SEP). Under this program, the Surface Water Institute at Christian Brothers University assisted the City to develop a maintenance and inspection program. This paper is going to present the outcomes of the program.

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SESSION 3A

WASTEWATER (Moderator: Tania Datta, TTU)
8:30 a.m. – 10:00 a.m.

Specific Involvement of Syntrophobacter in the Anaerobic Syntrophic Degradation of Propionate
Liu Cao and Qiang He

Co-Occurrence and Exclusion Patterns of Microbial Populations in Anaerobic Treatment of Dairy Wastewater
Yabing Li, Si Chen, and Qiang He

An Evaluation of Nashville Metro EQ Biosolids as a Forage Fertilizer and Soil Amendment
Shawn A. Hawkins and Forbes Walker

SPECIFIC INVOLVEMENT OF *SYNTROPHOBACTER* IN THE ANAEROBIC SYNTROPHIC DEGRADATION OF PROPIONATE

Liu Cao*[1] and Qiang He[1]

ABSTRACT

Methanogenesis is widely exploited for the treatment of various wastewater and production of methane as a renewable source of energy. Methanogenic processes carry out the degradation of organic matter with a network of complex metabolic pathways by diverse microbial trophic groups under anaerobic conditions. It is of great significance to understand the underlying mechanisms of this process. Propionate is one of the essential intermediates during the anaerobic digestion process; yet the degradation of propionate is known to be difficult owing to unfavorable thermodynamics under anaerobic conditions. Better understanding of the syntrophic propionate degradation is crucial to enhance the stability and efficiency of anaerobic treatment processes. This study developed several groups of propionate enrichment cultures to identify the syntrophic propionate oxidizers and to investigate the effect of inoculum source and substrate concentration on the microbial populations involved in propionate metabolism. Findings from this study demonstrated *Syntrophobacter* as the specific syntrophic proton-reducing acetogenic bacteria while its associated methanogen partners were non-specific. *Methanoculleus* populations tended to be dominant under more extreme conditions, suggesting that the introduction of enriched *Syntrophobacter* and *Methanoculleus* might be a strategy for effective bioaugmentation in unstable anaerobic processes with propionate accumulation.

* Presenter

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CO-OCCURRENCE AND EXCLUSION PATTERNS OF MICROBIAL POPULATIONS IN ANAEROBIC TREATMENT OF DAIRY WASTEWATER

Yabing Li[1*], Si Chen[1], Qiang He[1,2]

*Presenting author

ABSTRACT

Anaerobic digestion processes are characterized by the complexity of interactions between populations that are required for proper process functions. To gain an understanding of these important interactions, we investigated the anaerobic microbiomes in the anaerobic treatment of dairy wastewater in triplicates over a 118-day period. The treatment processes remained stable throughout the study period. However, the microbial populations involved in this process exhibited significant temporal dynamics. Analyses of microbial community composition indicated that the top five most abundant bacterial genera at the beginning of the study were affiliated with *Firmicutes* and *Bacterordetes*. In contrast, the top five most abundant bacterial genera at the end of the study were instead affiliated with *Synergistetes*, *Verrucomicrobia*, *Lentisphaerae* and *Chloroflexi*. The most abundant archaeal genus remained unchanged as the acetoclastic *Methanosaeta* during the study, with its relative abundance ranging between 46.4% and 65.7%. Following *Methanosaeta*, two hydrogenotrophic methanogens, *Methanospirillum* and *Methanobrevibacter*, were the most abundant. Population co-occurrence analyses based on spearman correlation revealed the top 5 strongest correlated pairs were all represented by populations of the same phylum, i.e. *Firmicutes*. In comparison, results from co-exclusion analyses indicated that strong negative correlations were more frequently observed between populations that had remote phylogenetic relationships. This observation is evident in the top 5 strongest negative correlations, i.e. ASV1020 (*Firmicutes*) and ASV1853 (*Chloroflexi*), ASV1853 (*Chloroflexi*)and ASV1019 (*Firmicutes*), ASV0266 (*Actinobacteria*) and ASV0014 (*Firmicutes*), ASV0355 (*Synergistetes*) and ASV0661 (*Firmicutes*), ASV1853 (*Chloroflexi*) and ASV1080 (*Proteobacteria*). Strong positive correlation relationships between intra-taxa populations and negative correlation relationships between inter-taxa populations imply both high levels of redundancy between closely related populations and competition between microbial populations with greater phylogenetic distance. The validity of these observations needs to be further investigated in other anaerobic treatment processes.

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AN EVALUATION OF NASHVILLE METRO EQ BIOSOLIDS AS A FORAGE FERTILIZER AND SOIL AMENDMENT

Shawn A. Hawkins and Forbes Walker

ABSTRACT

Nashville Metro employs a state-of-the-art, sustainable process to manage biosolids employing an anerobic digestor to reduce pathogens and provide odor control, followed by a thermal dryer to destroy remaining pathogens and remove moisture for facilitate beneficial reuse as a fertilizer and soil amendment. The anaerobic digestors are heated and the thermal dryers are fueled with combustible gases recovered from the anaerobic digester. Prior and ongoing plots studies conducted by University of Tennessee Institute for Agriculture are evaluating forage yield and quality using four spring application rates of Nashville Metro Exceptional Quality (EQ) biosolids (0.75, 1, 1.5, and 3 tons/acre). The average analysis of the Metro EQ biosolids equates to a 5:5:0 fertilizer, therefore the study augmented the EQ biosolids with supplemental potassium as recommend by soil tests. Fescue yield and forage quality were compared with chemical fertilizer applied at UT Extension recommended rates based on soil tests (60 lbs/acre of nitrogen in the spring and fall with supplemental phosphate and potassium as recommended by soil tests) as well as a no fertilizer control. Both the moderate (1.5 tons EQ biosolids/acre) and high (3 tons EQ biosolids/acre) spring applications of increased spring hay yields and forage quality compared to the negative control and were equivalent to the results obtained with chemical fertilizer. Spring nitrogen availability was 32±7%. Fall hay yield and forage quality were similar for all treatments, so carryover and release of nitrogen from the spring applied biosolids was negligible. Metro EQ biosolids clearly provided plant available micronutrients because spring forage concentrations of both copper and zinc increased significantly as the biosolids application rate increased.

SESSION 3B

WEATHER AND CLIMATE (Moderator: Md Nowfel Bhuyian, TDEC)
8:30 a.m. – 10:00 a.m.

Recalibration at Sinking Pond: Climate Extremes and Hydroperiod Change in a Tennessee Karst Wetland
Jennifer Cartwright and William Wolfe

Evaluation of Recharge and Evapotranspiration Estimation Methods for the Mississippi Embayment with Examples from West TN
David E. Ladd

Modeling of Climate Change Induced Flood Risk in the Conasauga River Basin
Tigstu Dullo, Sudershan Gangrade, Md Bulbul Sharif, Mario Morales- Hernández, Alfred J. Kalyanapu, Sheikh Ghafoor, Shih-Chieh Kao, and Katherine Evans

RECALIBRATION AT SINKING POND: CLIMATE EXTREMES AND HYDROPERIOD CHANGE IN A TENNESSEE KARST WETLAND

Jennifer Cartwright[1]* and William Wolfe[2]

Karst depression wetlands throughout the eastern United States are important to regional and global biodiversity but may be threatened by hydrologic shifts under climate change. For example, increased ponding duration since 1970 in Sinking Pond—a 35-acre seasonally flooded karst depression wetland on the Highland Rim of Tennessee—has been implicated in recruitment failure of overcup oak (*Quercus lyrata*). Hydrologic models based on rainfall and temperature records from 1854 through 2002 successfully simulated observed inundation patterns in Sinking Pond and showed that prolonged inundation (more than 200 days per year) was considerably more common after 1970 than before. However, model calibration and validation datasets did not include extreme climatic events such as droughts. A subsequent severe drought in 2007 and 2008 provided an opportunity to recalibrate the Sinking Pond hydrologic model to better represent the drivers of pond inundation across a wider range of climate conditions. Although recalibration of published hydrologic models is relatively rare, this study demonstrates its importance for ecohydrologic studies, as climatic extremes (droughts and intense storms) may become more common under climate change than they were in historical records. This study has potential relevance for a variety of karst-dependent ecosystems in which ecological shifts may be driven by changing hydrologic conditions.

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EVALUATION OF RECHARGE AND EVAPOTRANSPIRATION ESTIMATION METHODS FOR THE MISSISSIPPI EMBAYMENT, WITH EXAMPLES FROM WEST TENNESSEE

David E. Ladd[1]

Recharge and evapotranspiration (ET) are critical components of the water budget for the Mississippi Alluvial Plain (MAP) and are important inputs to the groundwater flow model developed for the Mississippi Embayment Regional Aquifer System (MERAS) used to simulate flow in the MAP area. Different estimation methods for these components produce results that vary from each other in space and magnitude, and determining which method produces the most accurate results can be difficult. The U.S. Geological Survey Lower Mississippi - Gulf Water Science Center is currently using multiple estimation methods to refine estimates of recharge and ET for the MERAS area. These refinements should improve model-simulation results and the quantification of available groundwater in the Mississippi River Valley alluvial aquifer beneath the MAP. A comparison of recharge estimates from PRISM-based calculations used in the original MERAS model with the Soil-Water-Balance (SWB) model and with long-term Empirical Water Budget (EWB) estimates illustrates this variability. While water-budget estimation methods will be compared throughout the MAP, water-budget estimation in West Tennessee and surrounding areas will be a primary focus of the presentation.

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MODELING OF CLIMATE CHANGE INDUCED FLOOD RISK IN THE CONASAUGA RIVER BASIN

Tigstu Dullo[1], Sudershan Gangrade[2], Md Bulbul Sharif[3], Mario Morales-Hernández[4], Alfred J. Kalyanapu[5], Sheikh Ghafoor[6], Shih-Chieh Kao[7], and Katherine Evans[8]

The goal of this study is to evaluate the potential impacts of climate change on flood regimes and critical energy infrastructures at a high-spatial resolution through coupled hydrologic-hydraulics models. The hydrologic simulations are conducted using a 90m resolution Distributed Hydrology Soil Vegetation Model (DHSVM) driven by (1) 1981–2012 Daymet meteorologic observation, and (2) eleven sets of downscaled Coupled Model Intercomparison Project (CMIP5) global climate model projections for 40 years in the historical period (1966–2005), and 40 years in the future (2011–2050). Flood simulations are performed using a graphic processing unit (GPU)-accelerated TRITON (previously named Flood2D-GPU) hydraulic model that solves the full 2D-shallow water equations using a new finite-volume numerical scheme. The TRITON model is first evaluated for its sensitivity to several model parameters, namely, the digital elevation model, Manning's roughness, and initial conditions. Then, the TRITON model performance is assessed by comparing to the existing Federal Emergency Management Authority flood inundation maps. Finally, the verified flood model is used to simulate 912 annual maximum streamflow events at 10m spatial resolution for an ensemble-based flood risk evaluation. The flood simulation results are used to evaluate changes in flood regimes and to assess the vulnerability of critical energy infrastructures in a changing climate.

Key Words: Flood Modeling; TRITON; Climate Change; Substation; Flood Regime

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SESSION 3C

AGRICULTURAL STUDIES (Moderator: Jenny Dodd, TDEC-DWR)
8:30 a.m. – 10:00 a.m.

Potential Effects of Pasture Conversion from Cool Season to Warm Season Grasses on Hydrologic Parameters in the Oostanaula River Watershed
Bahareh Shoghli, John Schwartz, Shawn Hawkins, Forbes Walker, and Chris Clark

Fenceline Hay Feeders: A New BMP for Water Quality in Tennessee
Forbes Walker and Shawn Hawkins

Water Availability in the Mississippi River Alluvial Plain: Initial Assessment of Agricultural Water Management Scenarios in the Mississippi Delta
Connor J. Haugh and Jeannie R.B. Barlow

POTENTIAL EFFECTS OF PASTURE CONVERSION FROM COOL SEASON TO WARM SEASON GRASSES ON HYDROLOGIC PARAMETERS IN THE OOSTANAULA RIVER WATERSHED

Bahareh Shoghli, John Schwartz, Shawn Hawkins, Forbes Walker, and Chris Clark

Agricultural lands with pasture grasses may be more sustainable and profitable by a farm allocating a portion of existing cool season grasses to warm season grasses. Warm season grasses are characterized by higher biomass yields annually, and relatively lower nutrient and management requirements therefore improving water quality. In this study, the effects of pasture conversion from cool season to warm season grasses were assessed using the USDA Soil and Water Assessment Tool (SWAT) in the Oostanaula Creek watershed of East Tennessee. The model output variables to be assessed included evapotranspiration, percolation and surface water. Model output included long-term simulations for current land uses (0% conversion), and two potential conversion projections at 25% and 40% from existing cool-season grass Tall Fescue to warm season grasses (Big bluestem). In addition, model outcomes were assessed for differences in climate conditions (wet/normal/dry years) and seasons. The general hypothesis is during drought years, cattle farms with a portion of warm season grasses will be more resilient hydrologically and biomass productive.

FENCELINE HAY FEEDERS: A NEW BMP FOR WATER QUALITY IN TENNESSEE

Forbes Walker[1] and Shawn Hawkins[1]

Hay and pasture systems for beef cattle are a dominant agricultural land use in Tennessee, covering an estimated 2.5 to 3 million acres. Hay is typically fed to cattle during the winter months (November to March). Most hay is fed outside, either in hay rings or by rolling out the bales of hay directly onto the field. Depending on the weather conditions, these systems can result in significant losses of hay, and create denuded areas that can be sources of non-point pollution from runoff and erosion.

In early 2019 the University of Tennessee Extension initiated a series of on-farm demonstrations to evaluate the use of different fenceline feeding systems at the Middle Tennessee Research and Education Center in Lewisburg. These hay feeding systems are a new best management practice for improving animal performance, reducing hay losses and improving water quality for Tennessee. This presentation will give an overview of the work that has been conducted and plans for expansion of the program to other counties in middle Tennessee.

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WATER AVAILABILITY IN THE MISSISSIPPI RIVER ALLUVIAL PLAIN: INITIAL ASSESSMENT OF AGRICULTURAL WATER MANAGEMENT SCENARIOS IN THE MISSISSIPPI DELTA

Connor J. Haugh[1] and Jeannie R.B. Barlow

Water for agricultural irrigation in the Mississippi River alluvial plain in northwestern Mississippi (the Delta) is supplied primarily by the Mississippi River Valley alluvial aquifer. Although the aquifer has significant storage capacity, there is evidence that the current rate of water use is exceeding the available supply from the aquifer. In an effort to better understand the impacts of different water-management scenarios on water availability and to identify additional monitoring needs in the Delta, the U.S. Geological Survey and the Mississippi Department of Environmental Quality are collaborating to update and enhance an existing regional groundwater-flow model. The model has been updated through March 2014 with the most recent water-use data, precipitation and recharge data, and streamflow and groundwater-level data. Selected alternative water-supply scenarios have been evaluated to assess impacts to the alluvial aquifer and identify data needs for future groundwater management modeling. Alternative water-supply options assessed to date include: 1) increased irrigation efficiency; 2) tailwater recovery and on-farm storage; 3) surface-water augmentation; 4) inter/intra-basin surface-water transfers; and 5) groundwater transfer. A relative comparison approach was used to calculate the simulated water-level response due to each scenario. Water-level response is the difference between water-levels simulated by the alternative-supply scenario and the water levels simulated by a base case or "no action" scenario. Water-level response in the alluvial aquifer varied for each scenario based on the location and magnitude of the implemented alternative-supply option. The groundwater transfer and injection scenario showed the largest water-level response.
These initial model results serve as a starting point to develop and assess conjunctive water-management-optimization scenarios, as well as to improve and enhance current and future monitoring activities within the Delta. Model limitations and data needs identified during the scenario analysis will help inform data collection and model refinement efforts as part of the Mississippi Alluvial Plain project.

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STUDENT POSTERS

Mapping and Measuring Lampenflora Along Mammoth Cave's Frozen Niagara Tour Route
Jonathan Alford

Data Collection Towards Understanding Stormwater Management and Flooding Issues in the Town of Gainesboro, Jackson County, TN
Maci M. Arms

Trends in Forest Throughfall Deposition in the Great Smoky Mountains National Park
Taylor S. Blackstone

Correlations Between Microcystin Toxin and Environmental Variables in the Tennessee State University Wetland
Rodney Blackwell Jr., Jacob Byl, De'Etra Young, and Thomas Byl

Effects of Didymosphenia on Larval Chironomids: Assemblage Changes, Taxa Specific Feeding and Wearing of Mouthparts
Peter W. Blum, IV

Evaluation of Tropical Cyclone Flood Discharges Estimated with Rainfall from Parametric Models for Flood Risk Studies
John T. Brackins and Alfred Kalyanapu

Performance Evaluation of Existing Highway Vegetated Swales in Tennessee for Stormwater Runoff Reduction
Joseph Brockwell, Tania Datta, and Alfred Kalyanapu

Nitrogen Removal in a Riparian Wetland with Constraining Restoration Strategies
Robert Brown

Dissolved Organic Carbon Fate and Acidification Behavior in the Great Smoky Mountains National Park
Jason Brown

Improving the Excess Shear Stress Equation Erosion Rate Estimates for Streambanks by Adjusting the Empirical Exponent Based on Bank Type
Justin C. Condon

Hydrologic Models to Evaluate Pollutant's Impacts on Microbiology
Preyanka Dey and Jejal Bathi

Development of GIS-Based Watershed Vulnerability Assessment (GAVA) Tool for HUC-12 Level Watershed in Tennessee
Vinay A. Dhanvada, Alfred J. Kalyanapu, and Tania Datta

Allelopathic Effects of Cyanotoxin Microcystin-LR in Greater Duckweed, Spirodela polyrhiza (L.) Schleid
Shrijana Duwadi and Justin Murdock

Evaluation and Identification Microplastics in Fresh Water
Chioma Ekechi and Tammy H. Boles

Quantifying Tree Canopy Contributions to Stormwater Runoff Reductions in Urban Watersheds
Matthew C. Howard

Development of GIS-Based Vegetated Swale Algorithm for TDOT Highways (GV-SwATH) of Putnam County
Minhazul Islam, Alfred Kalyanapu, and Tania Datta

Karst Groundwater: Monitoring Tools and Emerging Pathogens
Rachel Kaiser, Jason Polk, and Getahun Agga

Influence of the Cumberland River on Groundwater Flow Direction in a Fuel-Contaminated Aquifer in Nashville, Tennessee
Darrius Lawson, Chris Vanags, De'Etra Young, Jessica Oster, and Tom Byl

Beaver Creek Restoration Project at Powell: A Case Study
Grace Long

Watershed Comparison of the Effects of Land Use on Water Quality
Adam McLerran

Characterizing the Pigments in Lampenflora in Mammoth Cave National Park, Kentucky
Nakana'ela Morton, Brittaney Hogan, Rickard Toomey, De'Etra Young, and Thomas Byl

Terrestrial Cyanobacteria Produce Microcystin Toxin
Shakarah Nelson, De'Etra Young, Rickard Toomey and Tom Byl

Hydrologic Monitoring to Assess Restoration Success of WRP Easements in Tennessee and Kentucky
Collins Owusu, Nusrat Jannah Snigdha, Mackenzie T. Martin, Alfred J. Kalyanapu and Justin Murdock

Impacts of the Chimney Tops II Wildfire on Soil and Stream Chemistry within the Great Smoky Mountains National Park
Salley Reamer

Investigating Sewage Influence on Nitrate $\delta^{15}N$ and $\delta^{18}O$ values in Baker Creek in Knoxville, TN
Victoria Rexhausen

Hydrodynamic Modeling of Tennessee River Using a Novel Grid Generator

Shuvashish Roy and Jejal Bathi

Nanomaterial Quantification Towards Their Treatment
Steven C. Sawyer

Harmful Algal Blooms: Microcystin Toxin and Nutrient Analysis in the TSU Wetland
Tyrese Stanford

Understanding the Fate of Engineered Nanoparticles in the Environment
Syed Mohammed Tareq

Didymosphenia Geminata Cells and Mats are Regulated by Different Environmental Factors in Southern Appalachian Streams
Spencer Womble

Impacts of Biomethane Potential Test Variability on Specific Methane Yield
Tyler Wright and Tania Datta

Can Cover Crops Increase Infiltration to Assist Agricultural Producers to Adapt to Climate Change Impacts?
Adam A. Zimmerman, Forbes R. Walker, Neal S. Eash, and Hannah A. McClellan

PROFESSIONAL POSTER

Estimated Groundwater Withdrawals for Irrigation and Aquaculture in the Mississippi Delta, 2014-2017
John A. Robinson, Jordan L. Wilson, Wade H. Kress, and Jeannie R. Barlow

MAPPING AND MEASURING LAMPENFLORA ALONG MAMMOTH CAVE'S FROZEN NIAGARA TOUR ROUTE

Jonathan Alford
Faculty Mentors: Tom Byl, Rickard Toomey* and De'Etra Young
*Tennessee State University, *National Park Service*

Algae can be beneficial to the environment, providing oxygen and food in aquatic systems. But algae can also be detrimental when it grows too fast and produces toxins. Algae have adapted to live in a variety of terrestrial environments, even in the cave passages at Mammoth Cave National Park. Cyanobacteria (blue-green algae) and chlorophyta (green algae) are the two main algae that grow along lit cave passages. These cave-adapted algal growths are called lampenflora. The objective of this research was to map the lampenflora along a cave tour route, develop quick, reliable tools that could be used to characterize the lampenflora, provide an estimate of biomass and differentiate between cyanobacteria and chlorophyta. Lampenflora sites that represented communities of cyanobacteria and chlorophyta were characterized using a dual-channel fluorescence-based sensor (sensors for chlorophyll a and phycocyanin). The ratio of chlorophylla to phycocyanin provided a quick method to estimate if the algal community is dominated by cyanobacteria or chlorophyta. Preliminary readings show a correlation between phycocyanin pigment concentrations and cyanotoxin production.

DATA COLLECTION TOWARDS UNDERSTANDING STORMWATER MANAGEMENT AND FLOODING ISSUES IN THE TOWN OF GAINESBORO, JACKSON COUNTY, TN

Maci M. Arms[1]*

The Town of Gainesboro of Jackson County, Tennessee has recently experienced significant flooding and stormwater management issues. Located in an economically distressed county, it does not have the resources necessary to determine the cause of the issues. Speculated causes include the age and condition of the Town's stormwater management infrastructure, overgrown vegetation present in Doe Creek, a stream that drains much of the runoff from Gainesboro, and increased runoff due to land use change in the draining locations since 2010. However, prior to this project, limited data was available to determine the factors contributing to flooding. Therefore, this project aimed to collect data to provide a true understanding of the problem and hopefully lead to a more effective solution. In order to achieve this objective, information was gathered concerning: historic weather data, historic land-use data, topographical information, soil data, data on Doe Creek and its tributaries, water quality data, flood maps, storm drain and sewer maps with details on invert elevation and sizes, and socio-demographic data. Overall, none of the speculated causes were proven. The speculated cause of the Town's poor stormwater management infrastructure was identified as a data gap and is to be resolved in the future steps of this project.

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TRENDS IN FOREST THROUGHFALL DEPOSITION IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Taylor S. Blackstone[1]*

Abstract: Atmospheric deposition of acid pollutants have declined substantially in the past decade and is reflected in the trends in throughfall chemistry. Limited data exists for throughfall chemistry in the Great Smoky Mountains National Park (GRSM), and there is a need to characterize the changes that have occurred. Of particular interest in the GRSM is the combined effects of forest vegetation structure and elevation on deposition chemistry. This study examines the long-term changes in deposition chemistry that has occurred at Noland Divide, a high-elevation research monitoring station. In addition, this site will be compared with a low-elevation NADP monitoring site at Elkmont in the GRSM.

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CORRELATIONS BETWEEN MICROCYSTIN TOXIN AND ENVIRONMENTAL VARIABLES IN THE TENNESSEE STATE UNIVERSITY WETLAND

Rodney Blackwell, Jr.[1]*, Jacob Byl[2], De'Etra Young[3], and Thomas Byl[1,4]

ABSTRACT

Cyanobacteria capable of producing microcystin toxins flourish in the wetland at the Tennessee State University (TSU) research farm in Nashville, Tennessee, and the cyanobacteria pose a danger to humans, livestock and wildlife. The objective of this research was to measure microcystin and water chemistry to determine trends through time. Samples were collected at four locations in the TSU wetland between the summer of 2017 through early winter of 2020 and analyzed for nitrogen, phosphorous, iron, sulfur, Secchi depth (turbidity), type of algae present, and microcystin. Continuous water-quality instruments were also installed at the inlet and outlet of the wetland to document dissolved oxygen, pH, temperature, specific conductance and turbidity (NTU). Seven cyanobacteria genera capable of producing microcystins were identified in the wetland. Microcystin concentrations ranged from less than 0.15 to 25.1 µg/L.The peak microcystin concentrations were well above the U.S. Environmental Protection Agency's health advisory concentration of 0.3 µg/L. The highest microcystin concentrations occurred in June and were located near a livestock access point. Correlations were run using the environmental variables and microcystin concentrations to determine which variables best predicted harmful algal blooms (defined as microcystin concentrations greater than 1 microgram per liter). The environmental variables that predicted harmful algal blooms were: turbidity, with an increase in probability of 0.002 for each increase in NTU (significant at 1%); total phosphate, with an increase in probability of 0.045 for each additional milligram per liter of phosphate (significant at 1%); and the nitrate to phosphate ratio, with a decrease in probability of 0.0087 for each increase of 1 in the ratio (significant at 10%).

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EFFECTS OF *DIDYMOSPHENIA* ON LARVAL CHIRONOMIDS: ASSEMBLAGE CHANGES, TAXA SPECIFIC FEEDING AND WEARING OF MOUTHPARTS

Peter W. Blum, IV

ABSTRACT

Didymosphenia geminata (didymo) mats alter the biotic diversity and distribution of freshwater invertebrates, including reduced abundances of many mayfly, stonefly and caddisfly taxa. However, some macroinvertebrate taxa increase in abundance after didymo mat formation. Non-biting midges (chironomids) of the sub-family Orthocladiinae experience the greatest increase in abundance, possibly aided by their consumption of didymo. These dietary changes potentially impact larval feeding structures. This study examined the differences in genus-level diversity of larval chironomids in streams impacted by didymo, the contributions of didymo frustules (hardened silica cell walls) to their diet, and the impact of dietary changes to the wear on chironomid feeding structures. Preliminary results suggest that the majority of chironomid assemblages in streams with didymo mats are composed of primarily a few genera that consume didymo frustules. Further, feeding structure wearing was most prevalent in chironomid taxa that consumed didymo frustules. The benefits of consuming didymo frustules may outweigh the increased wearing of these chironomid's feeding structures, potentially increasing their abundance over other insect taxa.

EVALUATION OF TROPICAL CYCLONE FLOOD DISCHARGES ESTIMATED WITH RAINFALL FROM PARAMETRIC MODELS FOR FLOOD RISK STUDIES

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

ABSTRACT

From 1960 through as recent as 2018, tropical cyclones (TCs) have produced greater than 1000-year rainfalls over time periods ranging from 1 to 5 days for the states in Federal Emergency Management Agency Region IV (except Kentucky, where the TC rainfall of record produced between a 200- and 500-year rainfall event). Therefore, TC rainfall events have the potential to affect the tail of flood risk statistical distributions, even for inland states. For flood risk modeling purposes, it is important to be able to simulate expected TC rainfall from a joint distribution of parameters like TC track, size, and intensity. Four existing parametric models already attempt to predict rainfall hyetographs from these variables, and an evaluation of the storm-total precipitation fields produced by these models was completed in Brackins and Kalyanapu (2020). In this study, the rainfall from the parametric models serves as the precipitation forcing to a Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model of the Swannanoa River (HUC10 0601010506), a tributary of the French Broad in western North Carolina. The objective of the current study is *to perform a case study using a HEC-HMS model of the Swannanoa River to determine if rainfall produced by four parametric TC rainfall models allows for sufficient representation of TC flood discharge*. While Brackins and Kalyanapu (2020) demonstrated that the IPET (2006) model was the most skillful at reproducing storm-total precipitation for thresholds above 75 millimeters (3 inches), preliminary HEC-HMS results indicate that the IPET model suffers from serious limitations for weakening TCs which are sufficiently far inland.

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PERFORMANCE EVALUATION OF EXISTING HIGHWAY VEGETATED SWALES IN TENNESSEE FOR STORMWATER RUNOFF REDUCTION

Joseph Brockwell[1], Tania Datta[1], Alfred Kalyanapu[1]

Vegetated swales are stormwater control measures designed to reduce peak flow volumes, and promote infiltration and evapotranspiration. Within most highway systems today, the use of simple drainage ditches in the medians and right of ways are implemented to convey the stormwater runoff from the roadways to a storm drain outlet. However, these simple drainage structures could, to some capacity, perform as vegetated swales. The extent of this performance, however, is unknown, especially for Tennessee's highway systems. Therefore, this research work aims to evaluate the stormwater runoff reduction potential of two existing drainage ditches located on State Route 111 and Interstate 40, in Putnam County, Tennessee. The evaluation of these ditches will be based on their site characteristics and meteorological influences. A predictive model that estimates the runoff reduction potential based on site characteristics and meteorological factors is also proposed to be developed. The selected site characteristics for the study include the soil infiltration rates, initial soil moisture content, site geometry, and the land cover. As for the meteorological factors, rainfall intensity, rainfall volume, antecedent dry period, air temperature, relative humidity, solar radiation and wind speed are selected to assess the performance of the runoff reduction potential of these ditches.

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NITROGEN REMOVAL IN A RIPARIAN WETLAND WITH CONTRASTING RESTORATION STRATEGIES

Robert Brown

Floodplain connections enhance nitrogen (N) retention in riparian wetlands by promoting soil inundation and anaerobic conditions where N is permanently removed by denitrification. Nitrogen and carbon (C) removed through denitrification can come from floodplain soil or be delivered by floodwater. As rivers are disconnected from floodplains by construction of agricultural ditches, restoration practices can improve floodwater-soil interactions and nitrogen removal within impacted watersheds. We will investigate how different wetland restoration strategies influence overall denitrification rates and removal of N from floodwater. Sources of reactive N for denitrification will be evaluated using flow-through soil core incubations with $Na^{15}NO_3^-$ additions to inflowing water. Isotopically labeled ^{15}N allows measurement of denitrification fueled by "floodwater" ($^{15}NO_3^-$) and coupled nitrification-denitrification within soil ($^{14}NO_3^-$) for each core. Flux of methane and SRP will be measured for each core as both may be released under anoxic conditions. Dissolved gas concentrations (CH_4,$^{28}N_2$,$^{29}N_2$, $^{30}N_2$, and O_2) will be measured using membrane inlet mass spectrometry (MIMS). Nitrate and dissolved organic C will be measured to account for changes in denitrification fuel sources. Soil organic matter, N, and P content will be measured at the time of core collection and after one-week incubation to relate changes in soil composition with N removal and release of methane and SRP. This study will link specific restoration strategies with N removal from stream water, and may elucidate potential ecosystem disservices (i.e., methane and SRP release) during wetland restoration.

DISSOLVED ORGANIC CARBON FATE AND ACIDIFICATION BEHAVIOR IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Jason Brown

Stream acidification has long been a concern to aquatic habitats, agricultural operations, and community water supply sources. The result of decades of pollution neglect, stream and soil acidification has inspired monitoring practices of atmospheric chemical deposition which has, in turn, played a role in the regulation of polluters. These improved regulations and advancements in technology function to manage and reduce outputs from certain point-source polluters, such as power plants, although other known non-point levels of pollution are exceptionally difficult to suppress. As a result, the reduced pollutant deposition has developed cause for concern over internally-produced acidic sources. Previously regarded as inconsequential due to large amounts of inorganic acid deposited across landscapes, organic acids have recently been suspected of playing a larger role in these internal soil and surface water chemical processes. As such, enhancements in the understanding of carbonic interactions will assist in remediation activities necessary to counteract this contamination. It is exceptionally important to define this knowledge to avoid future ecological and economical losses and other unforeseen consequences. With that in mind, presumptions exist that reductions in strong acid deposition has potentially allowed increased solubility of weak organic acids. Others observed impacts on pH and/or dissolved organic carbon (DOC) as well as sometimes increasing toxic inorganic aluminum concentrations. Obviously, further research is necessary to define this relationship in a variety of potential situations. This research addresses the following: 1) What is the overall concentrations of DOC found in the GRSM; 2) What influences the fate and transport of DOC; and 3) How much is dissolved organic carbon affecting the toxicity of monomeric Al. To fully understand the necessary steps to ensure a continued and improved status, the chemical interactions that are occurring as a result of the dynamics of soil and water conditions are a critical component of study. Given the conditions of today, organic acids have become a primary point of interest and will be effectively addressed through this research project.

IMPROVING THE EXCESS SHEAR STRESS EQUATION EROSION RATE ESTIMATES FOR STREAMBANKS BY ADJUSTING THE EMPIRCAL EXPONENT BASED ON BANK TYPE

Justin C. Condon

The erosion rate of streambanks is modeled using the excess shear stress equation $e = k_d(\tau_a - \tau_c)^a$ The equation contains 4 parameters and an empircal exponent (a) assumed to be unity. Erosion pins have been used to quantify the amount of material deposited or lost from streambanks. 127 erosion pins were placed at 7 different streams sites in the Knox County, Tennessee area at the lower, middle, and upper bank to determine the rate of erosion (e). The pins were placed at 4 different bank types: straight with no vegetation, straight with vegetation, bend with no vegetation, and bend with vegetation. On average the pins showed a .1 feet of material loss during the measurement period. Jet testing devices have been used to measure the erodibility coefficient (k_d) and the situ critical shear stress (τ_c) for streambanks. A mini-jet test device was used at the same 7 streams sites to quantify the k_d and τ_c using the three analytical procedures: the iterative approach (IP), the scour depth approach (SDP), and the Blaisdell method (BM). Generally, the k_d values were lower and τ_c values were higher at the lower bank compared to the upper bank. HEC-RAS is used to model the flow and the sediment transport to determine the boundary shear stress (τ_a). The objective of this research is to improve erosion rate estimates of streambanks by adjusting the (a) value in the excess shear stress equation based on the 4 bank type catergories previously discussed.

HYDROLOGIC MODELS TO EVALUATE POLLUTANT'S IMPACTS ON MICROBIOLOGY

Preyanka Dey[1]* and Jejal Bathi[2]

INTRODUCTION

Over recent years, much progress has been made in hydrologic modelling strategies to understand the processes affecting the microbial diversity of a watershed. Lots of models, for example, AQUATOX, PLOAD, HSPF, SWAT, EPA's WASP, EPA's SWMM, etc. developed particular aim to predict pollutant load and understand pollutant impact on ecosystem. However, it is very important to realize individual model's capability in delineating pollutant fate and its impact on microbiology for better management of a watershed. By selecting and reviewing most probable models, here we attempted to describe overall hydrologic model development trend, extent and limitations of available models in portraying the health of an aquatic microbial ecosystem.

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DEVELOPMENT OF GIS-BASED WATERSHED VULNERABILITY ASSESSMENT (GAVA) TOOL FOR HUC-12 LEVEL WATERSHED IN TENNESSEE

Vinay A Dhanvada[1], Alfred J Kalyanapu[2], and Tania Datta[3]

The objective of this project is to develop a HUC-12 level watershed scale vulnerability index for watershed vulnerability assessment using Multi-Criteria Decision Making (MCDM) approach and geographic information system (GIS) based algorithm. The study area chosen is Loosahatchie watershed, a 742 sq. mi. drainage area in western Tennessee region. The project comes under the purview of the Mississippi River Basin Initiative (MRBI) and National Water Quality Initiative (NWQI) which identifies and addresses impaired water bodies through voluntary conservation. The proposed model will be designed based on a list of factors which influence the watershed vulnerability using MCDM methodology implemented in a GIS interface. A vulnerability map will be produced by means of a weighted overlay analysis that combines all the influencing factors derived from the MCDM. Model results will be categorized into three vulnerability classes: Low Vulnerability Zone (LVZ), Moderate Vulnerability Zone (MVZ), and High Vulnerability Zone (HVZ). This GIS-based Algorithm for watershed Vulnerability Assessment (GAVA) approach can provide useful information to guide local governments and decision makers in watershed prioritization and selection of suitable structural and nonstructural remedies for countering impairment of water bodies in the region.

Keywords: Watershed Vulnerability, Multi-Criteria Decision Making, Geographic Information System, National Water Quality Initiative, Mississippi River Basin Initiative

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ALLELOPATHIC EFFECTS OF CYANOTOXIN MICROCYSTIN-LR IN GREATER DUCKWEED, *SPIRODELA POLYRHIZA* (L.) SCHLEID

Shrijana Duwadi[1] and Justin Murdock[1]

Microcystin-LR is the most toxic microcystin produced by the cyanobacteria *Microcystis aeruginosa* Kützing. Although it has widely been known that this toxin is hepatotoxic to animals, its effect on plants is still unclear. Given that this toxin acts as a protein phosphatase inhibitor, an allelopathic effect on aquatic plant growth is also possible. For our study, greater duckweed, *Spirodela polyrhiza* (L.) Schleid was grown in a gradient of Microcystin-LR concentrations (control, 0.1, 1, 2, 3, 4, and 5 µg/L) for four weeks. Although the results showed that final frond numbers and plant growth rates were significantly different ($p= 0.0017$ and $p=0.0138$ respectively) among different concentrations, no clear concentration-dependent effects of Microcystin-LR were observed on final frond number and plant growth rate. Some plants exposed to higher concentrations had chlorotic spots and marginal necrosis. However, no significant difference ($p=0.9679$) was noticed for the final dry biomass of plants among different concentrations. Therefore, Microcystin-LR does not appear to have allelopathic effects on the growth of *S. polyrhiza.*

Keywords: allelopathy; cyanotoxin; *Microcystin aeruginosa*; Microcystin-LR; *Spirodela polyrhiza*

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EVALUATION AND IDENTIFICATION MICROPLASTICS IN FRESH WATER

Chioma Ekechi[1] and Tammy H. Boles[1]

Global demand for single use plastics is at an all-time high because of the versatility, durability and affordability of synthetic polymers, resulting in increasing concerns about the end of life treatment of used plastics. Plastics in the environment can be broken down into such smaller fragments as microplastics, with diameters measuring five millimeters (5mm) or less. Microplastics are very light and buoyant; as a result, they can easily be transported across different environmental compartments and trophic levels. The aim of this study is to determine the microplastic content of a select body of fresh water. Samples will be collected from Center Hill Lake, Smithville, TN, via plankton net trawling and run through three metal sieves of different mesh sizes. Residual solids will be digested by wet peroxide oxidation to remove all biological material and separated according to their densities using a saturated sodium chloride solution. Particles will be oven dried, weighed and identified using Fourier Transform Infra-red Spectroscopy. Particle sizes will be measured using a laser diffraction particle size analyzer.

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QUANTIFYING TREE CANOPY CONTRIBUTIONS TO STORMWATER RUNOFF REDUCTIONS IN URBAN WATERSHEDS

Matthew C. Howard

Urban stormwater is a major contributor to surface water degradation in the United States, prompting cities to invest in ways to naturally capture, store, and slowly release runoff through "Green Infrastructure" (GI) such as urban trees. Interception describes a tree's ability to capture and store rainfall, reducing the volume of stormwater that degrades urban streams during storm events. While rainfall interception for full canopy environments is well studied, limited research is available that characterizes the interception of open-grown trees commonly found in urban areas. Nine trees from three common, urban, native species planted in three Knoxville-area parks were studied to quantify interception. Continuous measurements of interception were made using several automatic rain gauges positioned underneath tree canopies. When compared to gross precipitation, the measurements quantify interception, throughfall (rainfall that passes through the canopy) and stemflow (rainfall that travels down the trunk) of each tree. Data was collected for one year to account for seasonal variations in canopy cover and precipitation patterns. Results demonstrate the effect of event duration, rainfall intensity, and seasonal variations on the interception potential of each species as well as intra-event dynamics of precipitation transport through canopies, allowing them to be properly credited as part of urban watershed restoration efforts.

DEVELOPMENT OF GIS-BASED VEGETATED SWALE ALGORITHM FOR TDOT HIGHWAYS (GV-SWATH) OF PUTNAM COUNTY

Minhazul Islam[1]; Dr. Alfred Kalyanapu[2]; and Dr. Tania Datta[3]

ABSTRACT

Stormwater management is becoming highly important in recent days because of growing development around the urban areas and its impact on nearby stream impairment. According to the 303(d) list of 2018, there are 11 natural water bodies in Putnam County which are impaired (TDEC, 2018). Among these water bodies, four streams are impaired by municipal discharges which are falling under the MS4 permit. In Tennessee, the Tennessee Department of Transportation (TDOT) is responsible to comply with the MS4 permit before discharging highway runoff to a nearby stream. In Putnam County, State Route 111 (SR111) and Interstate 40 (I40) are the two existing highways. There are some stormwater control measures such as highway vegetated swales, conveyance pipe, etc. The vegetated swale is contributing as a stormwater conveyance system as well as onsite runoff reduction which is yet to be investigated. For this investigation, extensive surveying in necessary to get the geometric properties of these swales. However, surveying over 13 miles (approx.) for SR111 and 37 miles (approx.) for I40 will be cumbersome and time-consuming. In order to ease the study in a larger scale, the purpose of this study was set to develop a GIS-Based tool in ArcMap which will be able to delineate the swale polygon using highway road centerline data from US Census Bureau and LiDAR (Light Detection and Ranging) data from TNGIS website. Python programming language will be used to develop the tool. A user manual will be developed for guidance along with the tool.

Keywords: ArcMap, Python, TDOT, LiDAR, Stormwater Management

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KARST GROUNDWATER: MONITORING TOOLS AND EMERGING PATHOGENS

Rachel Kaiser[1], Jason Polk[2], and Getahun Agga[3]

In urban karst areas, such as the City of Bowling Green, Kentucky (CoBG) and the Tampa Bay Metropolitan Area (TBMA), groundwater quality faces a variety of threats. The development of residential, commercial, and industrial landuse types allows for a wide variety of groundwater pollutants to enter the karst groundwater systems. Various different models and indices, including the Karst Disturbance Index (KDI), Karst Aquifer Vulnerability Index (KAVI), and the Karst Sustainability Index (KSI), have attempted evaluative approaches to identify issues in urban karst areas, but the methods vary by location and lack a focus on urban karst groundwater quality, as well as a lack of a data-driven approach that is able to capture short- and long-term changes in threats to urban groundwater quality. The overall purpose of this study was to develop a holistic, data-driven threat, vulnerability, and monitoring toolbox for urban karst groundwater systems to ensure groundwater quality is maintained in urban karst regions for both human and environmental health. This study focused on: 1) determining what indicators, parameters, and data quality need to be prioritized to create an effective, holistic toolbox for urban karst groundwater monitoring, and 2) developing effective tools for assessing urban karst groundwater quality. The outcomes include the Urban Karst Aquifer Resource Evaluation (UKARE) toolbox, the application of the threat, vulnerability, and monitoring tools in CoBG and TBMA, and primary data collection in the CoBG and TBMA on water quality parameters. The final results of this study were used to create a data-driven UKARE toolbox that can be used universally.

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INFLUENCE OF THE CUMBERLAND RIVER ON GROUNDWATER FLOW DIRECTION IN A FUEL-CONTAMINATED AQUIFER IN NASHVILLE, TENNESSEE

Darrius Lawson[1], Chris Vanags[2], De'Etra Young[1], Jessica Oster[2], and Tom Byl[1,3]

The Tennessee State University research farm in Nashville, Tennessee is located along the Cumberland River and has nine 250-foot deep wells that can be used to monitor groundwater levels and quality. The wells have 6-inch steel casings to the top of bedrock (20-40 feet below land surface) and the lower part of the wells are open boreholes in limestone bedrock. The upper limestone is the Hermitage Formation which extends approximately 100 feet below surface. Below the Hermitage Formation is the Carters Limestone. The research well located adjacent to the northern property line is contaminated with trace concentrations of benzene, ethyl-benzene, and extractable petroleum hydrocarbons. Several potential sources of fuel contaminants occur adjacent to the site, making it important to understand groundwater flow direction to identify the source of the contaminants. Another unique feature of the water from the contaminated well is the high concentration of dissolved iron (greater than 5 mg/L of ferrous iron). High levels of dissolved iron can be toxic to groundwater bacteria, which raised the concern that there may not be many indigenous bacteria capable of biodegrading fuel compounds. The objectives of this study were to determine groundwater flow direction and determine if there were viable bacteria capable of biodegrading hydrocarbon compounds. To accomplish the first objective, groundwater levels were measured every 15 minutes in 3 research wells using water-level transducers. The water levels were confirmed with electrical tape measurements every 2-4 weeks in 2018-2019. The U.S. Geological Survey Cumberland River gage (USGS 03431514) located a quarter mile upstream of the farm provided river water-surface elevation for the same time period. The location and water elevations for the 3 wells and Cumberland River were entered into the Environmental Protection Agency's Groundwater Flow Model 3PE to triangulate the groundwater flow direction. The modeled groundwater hydraulic gradient fluctuated approximately 90-degrees in response to changing river and groundwater elevations. In addition to calculating flow direction, actively growing bacteria were measured using Biological Activity Reaction Tests (BART) assays. Denitrifying, iron-related and sulfur-related bacteria were present at 10,000 or more bacteria per milliliter in the contaminated well during 3 sampling events. Previous studies in contaminated karst aquifers found these bacteria types were capable of biodegrading petroleum compounds, but the rates varied depending upon the terminal electron acceptors present in the aquifer.

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BEAVER CREEK RESTORATION PROJECT AT POWELL: A CASE STUDY

Grace Long

A stream restoration project in Beaver Creek near Powell has been designed using an ecohydraulic engineering approach. Multiple assessments were completed to determine what restoration practices would be effective with a focus on bank stability. Assessment included hydrological modeling, 2D hydraulic modeling, physical habitat modeling, BSTEM (bank stability modeling), and a functional traits analysis. Results will be presents on the proposed design for construction in late 2020.

WATERSHED COMPARISON OF THE EFFECTS OF LAND USE ON WATER QUALITY

Adam McLerran[1]

A comparison of water quality was conducted during October 2019 on an agricultural watershed and a forested watershed, both located in northern middle Tennessee and a small portion of one in southern Kentucky. The Little Trace Creek watershed (HUC-12-051100020101) is approximately 25,426 acres and 61% agriculture, mostly cattle and poultry operations. The Jennings Creek watershed (HUC-12-051301060302) is approximately 36,075 acres and 84% forested. The land use data was collected from the Multi-Resolution Land Characteristics Consortium Website. Conductivity and dissolved oxygen were measured using a YSI® Professional Plus Multiparameter Meter on three separate occasions on three separate streams within each watershed. The data indicates a noticeable difference in water quality between these two watersheds. The dissolved oxygen measurements showed more variation in the agricultural watershed (SD of 2.2) than in the forested watershed (SD of 0.5). The forested watershed showed a higher average dissolved oxygen level at 7.61 mg/l than the agricultural watershed at 7.23 mg/l. The conductivity was also more variable for the agricultural watershed (SD of 14.1) than the forested watershed (SD of 7.4). The agricultural watershed had an overall average conductivity of 276.2 µs/cm as opposed to the forested watershed at 253.4 µs/cm. One stream in the agricultural watershed stream had a lower average dissolved oxygen at 5.21mg/l, which is close to the minimum value of 5.0 mg/l necessary for good water quality. Further research could determine the causation of the lower dissolved oxygen.

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CHARACTERIZING THE PIGMENTS IN LAMPENFLORA IN MAMMOTH CAVE NATIONAL PARK, KENTUCKY

Nakana'ela Morton[1]*, Brittaney Hogan[1], Rickard Toomey[2], De'Etra Young[1], and Thomas Byl[1,3]

ABSTRACT

Algae have adapted to live in a variety of terrestrial environments, even in the cave passages at Mammoth Cave National Park. Cyanobacteria (blue-green algae) and chlorophyta (green algae) are the two main algae that grow close to the tour lights installed along the cave passages. These cave-adapted algal growths are called lampenflora. The lampenflora are considered a nuisance because they are not a natural cave flora and can detract from a natural cave experience. Additionally, it is unknown how the presence of lampenflora affects cave biota. Some cyanobacteria have been shown to produce cyanotoxins such as microcystin that present a danger to cave fauna and tourists. The objective of this research was to develop quick, reliable tools that could be used to characterize the lampenflora, provide an estimate of biomass and differentiate between cyanobacteria and chlorophyta. Lampenflora sites that represented communities of cyanobacteria and chlorophyta were characterized using a dual-channel fluorescence-based sensor (sensors for chlorophyll a and phycocyanin). The ratio of chlorophyll a to phycocyanin provided a quick method to estimate if the algal community is dominated by cyanobacteria or chlorophyta. The intensity of the reading provided some indication of lampenflora coverage on the rock but maxed out when the cave wall was above 60% covered with lampenflora. Additional research will look at the correlation between cyanotoxin and pigment concentrations to determine if the chlorophyll a or phycocyanin is an indicator of toxin levels.

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TERRESTRIAL CYANOBACTERIA PRODUCE MICROCYSTIN TOXIN

Shakarah Nelson[1]*, De'Etra Young[2], Rickard Toomey[3], and Thomas Byl[1,4]

ABSTRACT

Cyanobacteria are prokaryotes with photosynthetic capabilities commonly found in marine and freshwater environments. Fossil evidence indicates they were prolific in the Precambrian oceans 3.5 billion years ago and helped to give rise to the oxygen-rich atmosphere. Microcystis, Oscillitoria, Leptolyngbya, Planktothrix, Nostoc, Dolichospermum and Hapalosiphon are types of cyanobacteria that have continued to thrive and have adapted to grow near lights used for tours in the cave passages at Mammoth Cave National Park. During preliminary cyanotoxin testing, 10 out of 11 cave sites with visible algal growth tested positive for microcystin (total concentration range was below detection to 3.67 µg/L analyzed using Enzyme Linked Immuno-Sorbent Assays). No microcystins were detected at control sites in Mammoth Cave where algae were not visible. Another common terrestrial cyanobacterium, *Nostoc commune*, found growing along the surface of gravel paths had microcystin concentrations ranging from 0.0 to 16.6 µg/L. The difference in toxin concentrations between the cyanobacteria growing near the lights and the growth along the gravel paths may be due to differences in algal community structure, light intensity, subtle geochemical variances, moisture, or some other environmental factor. These preliminary findings raise interesting questions, such as: what percent of the terrestrial cyanobacteria are capable of producing toxins, what toxins are they capable of producing, and, what are the environmental signals that trigger the production of toxins in this environment?

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HYDROLOGIC MONITORING TO ASSESS RESTORATION SUCCESS OF WRP EASEMENTS IN TENNESSEE AND KENTUCKY

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The Wetland Reserve Program (WRP) by the Natural Resources Conservation Service (NRCS) evaluates the performance of restoration practices implemented on the easements enrolled in the program to restore the degraded wetland health. The current project is a part of this initiative, with team members from multiple universities, focusing on sites across Kentucky and Tennessee. This WRP assessment will be performed by developing hydrologic and nutrient budgets for selected sites. The objective of our project *is to develop hydrologic budgets of the study easements that can be used for performing nutrient retention analysis*. The hydrologic conditions will be monitored through the installation of HOBO MX2001 water-level loggers at the study sites to determine inflows and outflows. Data related to precipitation, groundwater, evapotranspiration and soils are being collected through readily available data repositories such as NRCS Web Soil Survey, USGS and NCDC. The drainage potential of each easement is being assessed by processing a high-resolution LIDAR dataset and other available data through GIS and remote sensing analysis. Currently, the MX2001 loggers are installed in 16 easements in West Tennessee with more to be installed in Kentucky and other parts of West Tennessee in the coming months. A GIS-based decision support tool will be developed to predict easement specific nutrient rates and results will be published in peer-reviewed journals.

IMPACTS OF THE CHIMNEY TOPS II WILDFIRE ON SOIL AND STREAM CHEMISTRY WITHIN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Salley Reamer[1]

ABSTRACT

The Chimney Top 2 (CT2) fire began in November 2016 and burned nearly 18,000 acres, with 11,000 acres burned within the Great Smoky Mountains National Park (GRSM). The fire spread due to strong, dry winds in the area and extreme drought conditions. Within the burn area, 55 stream miles were affected; it is typical to see a pulse of sediment move into waters after a fire. This study analyzed the impacts within the Park and surrounding area for impacts to water quality and soil response. The impacts of wildfire are typically short term; monitoring efforts and sample collection began within one week of the fire and have been analyzed temporally and at different levels of burn intensity.

A soil and water characterization of the burn area will be produced, with a battery of parameters being tested. These parameters will be tested on soils collected in 2018 and 2019, at locations in all levels of burn: no burn, low/medium and high burn. Additionally, samples will be collected at sites near the burn, that were not impacted as a control.

Sites will be selected away from major roads in the park to avoid contamination from sources such as road chat applied in the winter and exhaust from vehicles. The data will be compared to soil and stream data of the same parameters obtained before the fire in sites within and around the burn area.

Wildfire is closely studied in the western United States, with far more area burned annually on the west coast. The Chimney Tops II fire offers a unique opportunity to analyze the impacts of wildfire on a natural landscape in the eastern United States. Additionally, biweekly monitoring efforts within the park for the past 25+ years have given the group pre-fire data, offering a comparison for post-fire data.

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INVESTIGATING SEWAGE INFLUENCE ON NITRATE $\Delta^{15}N$ AND $\Delta^{18}O$ VALUES IN BAKER CREEK IN KNOXVILLE, TN

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Urban development can result in elevated nitrate concentrations from a number of nonpoint sources including manure and sewage. Previous indication of leaky infrastructure coupled with elevated nitrate loading in Baker Creek Watershed in Knoxville, TN suggested potential contribution of sewage to nitrate loading in this watershed. This study employs nitrate isotopic tracers to investigate the likelihood of pollution from human septic tanks in Baker Creek. Dry weather samples were taken from throughout Baker Creek Watershed and analyzed for the isotopic composition of nitrate molecules. This study did not find conclusive evidence of such pollution, but it did explore useful applications of nitrate isotopic tracers in hydrologic studies. The study recommends future research using nitrate isotopes as tracers in surface waters, as well as ways to improve environmental modeling using stable isotope geochemistry.

HYDRODYNAMIC MODELING OF TENNESSEE RIVER USING A NOVEL GRID GENERATOR

Shuvashish Roy and Jejal Bathi, Ph.D., P.E.

Environmental Protection Agency's (EPA) Environmental Fluid Dynamics Code (EFDC) is a state of art hydrodynamic model used for three-dimensional simulation of rivers and lakes for improved water resources management. A MATLAB based novel grid generator is developed for EFDC to facilitate the complex grid generation process and applied for the urban stretch of Tennessee River near Chattanooga. In this poster, we present an updated current progress of our research in an effort to develop and apply the grid generator for hydrodynamic and water quality modeling of the Tennessee river under extreme flow (both high and low) conditions. Results from our study will help decision makers and watershed managers to prepare for possible extreme conditions that may cause devastating impacts on public health and the existing critical infrastructures along the river.

NANOMATERIAL QUANTIFICATION TOWARDS THEIR TREATMENT

Steven C. Sawyer

Engineered nanomaterials (ENMs), are extremely prevalent in the environment as they are in about 1800 different common consumer products. ENMs are classified as being between 1-100 nanometers and have proven extremely hard to track and treat throughout the environment. ENM tracking and treatment is vital because of the threat they pose to both living and non-living objects within the environment. The primary aim of our research nano-pollutant control in urban stormwater runoff, specifically non point source runoff. We will be looking at the differences in data of properties between environmental samples both before and after vacuum filtration through a 0.45 micron filter, thus far experiments show that vacuum filtration reduces the concentration of suspended solids but does not remove dissolved solids. Currently, the Total Dissolved Solids (TDS) concentration in urban stormwater runoff is where the majority of our efforts are aimed. In order to measure the efficacy of our column test methods it will be compared against standard filtration methods. At present our data shows TDS concentrations between 5 mg/L and 70 mg/L in our collected samples. Dynamic Light Scattering tests have also been run on our environmental samples after vacuum filtration and the results show that the particle size distribution within the dissolved portion of pollutants is between 171 nm and 266 nm. This research is aimed at characterizing these ENPs by Source Area and treating them using bioretention systems.

HARMFUL ALGAL BLOOMS: MICROCYSTIN TOXIN AND NUTRIENT ANALYSIS IN THE TSU WETLAND

Tyrese Stanford
Faculty Mentor: Tom Byl and De'Etra Young
Tennessee State University

Cyanobacteria capable of producing microcystin toxins flourish in the wetland at Tennessee State University in Nashville, TN posing a danger to livestock and wildlife. The objective of this research was to measure microcystin and water chemistry to determine trends through time. Samples were collected at 4 locations in the wetlands between 2017 – 2019 and analyzed for nutrients (nitrogen, phosphorous), iron, sulfur, Secchi depth, type of algae present, and microcystin. Continuous water-quality instruments were also installed at the inlet and outlet to document dissolved oxygen, pH, temperature, specific conductance and turbidity. Seven cyanobacteria genera capable of producing microcystins were identified. Microcystin concentrations ranged from less than 0.15 to 25.1 μg/L, and peak microcystin concentrations were well above the US EPA's health advisory concentration of 0.3 μg/L. The highest concentrations of toxin were located near the livestock access point. Additional work includes correlations between water chemistry parameters and microcystin concentrations.

UNDERSTANDING THE FATE OF ENGINEERED NANOPARTICLES IN THE ENVIRONMENT

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Due to the complexity of environmental samples and the limitation of available analytical techniques, study of the fate of the Engineered Nano Particles (ENPs) in real environmental samples is challenging. However, synthetic samples prepared with standard ENPs in distilled water is an alternative to understanding the fate behavior of the ENPs under the controlled matrix of aquatic chemistry. With a view to understanding the ENPs aquatic fate, we have studied the dispersion dynamics of prominent ENPs in distilled water. The ENPs studied include iron, silver, titanium, silicon, copper, and nickel. All the samples with known concentrations were studied subjected to sonication. Then the study of dispersion and aggression was carried out using DLS (direct light scattering) as well as induced coupled plasma (ICP) – atomic emission spectroscopy (AES) at discrete times of sonication. Results clearly showed that dispersion of the ENPs is very small but increased with time of sonication. Copper had better dispersion when compared to the rest of the ENPs studied. In general, aggregation of the particles increased initially, but later after 3 hours of sonication, it started decreasing.

DIDYMOSPHENIA GEMINATA CELLS AND MATS ARE REGULATED BY DIFFERENT ENVIRONMENTAL FACTORS IN SOUTHERN APPALACHIAN STREAMS

Spencer G. Womble

Tailwaters of hypolimnetic release dams in the southeastern U.S. are often cooler and have less nutrients than unregulated streams in the region. These differences allow tailwaters to function as important recreational trout fisheries; however, some tailwaters also support *Didymosphenia geminata* mats that can cover substrata, alter benthic food webs, and may degrade fish habitat. *Didymosphenia geminata's* distribution in the Southeast has not been extensively delineated as reports often only come when mats have developed. This diatom can go unnoticed if only cells are present. Recent studies suggest multiple environmental variables may be facilitating its presence in the Southern Appalachians. Surveys of select southern Appalachian streams were conducted from May to September of 2014, 2015, and 2018 to determine *D. geminata* presence. Random Forest analysis was used to relate water chemistry and habitat characteristics to *D. geminata* distribution and form (i.e., cells or mats). Nitrate, sulfate, wetted width, temperature, and conductivity had the strongest relationship with *D. geminata* presence. Turbidity, conductivity, nitrate, temperature, and wetted width had the strongest relationship with *D. geminata* form. These findings suggest that cell survivorship and mat production may be facilitated by different environmental factors. Understanding what environmental conditions initiate both cell colonization and mat development will improve natural resource agencies' ability to identify streams susceptible to nuisance mats and reduce *D. geminata* biomass in streams affected by mats.

IMPACTS OF BIOMETHANE POTENTIAL TEST VARIABILITY ON SPECIFIC METHANE YIELD

Tyler Wright[1], Tania Datta[1]

Anaerobic digestion is a well-established technology for the stabilization of wastewater residuals and energy recovery in the form of biogas. Yet, according to the EPA, currently only 600 water resource recovery facilities in the United States implement this technology, leaving much potential for growth. However, in order for a facility to begin using anaerobic digestion, the waste streams must be evaluated for their methane producing potential. This is commonly accomplished through the biomethane potential (BMP) test. First developed in 1979, the BMP test is quite simple to undertake. It can be achieved by adding a known quantity of organic substrate to an active anaerobic inoculum in an air-tight serum bottle where the biogas produced is measured, and its methane content is determined. Although it remains a powerful, simple and inexpensive tool, the test often suffers from several variabilities in experimental parameters and data reporting, which leads to inconsistent and irreproducible results reported in literature. Many researchers have performed studies on the parameters such as substrate particle size, mixing method, and temperature, and their impact on specific methane yield. However, to date, certain parameters and their effects on specific methane yield have not been fully evaluated. Therefore, the overall aim of this study is ***to evaluate the individual impacts reactor volume, headspace volume, nutrient addition, and inoculum source have on the specific methane yield of the biomethane potential test***. ***Preliminary results show around two times difference in specific methane yield (NL/kg VSS added) with changing headspace and reactor volumes.***

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CAN COVER CROPS INCREASE INFILTRATION TO ASSIST AGRICULTURAL PRODUCERS TO ADAPT TO CLIMATE CHANGE IMPACTS?

Adam A. Zimmerman, Dr. Forbes R. Walker, Dr. Neal S. Eash, Hannah A. McClellan

ABSTRACT

Rationale	Water infiltration rates in Tennessee no-till corn (Zea mays L.)-soybean (Glycine max L.) rotation systems may be impacted through the use of cover crops.
Objectives or hypothesis	This study will evaluate changes in water infiltration under common cover crops of a no-till corn-soybean rotation system.
Methods	Cover crop treatments will be compared against a control (no cover crop) in a no-till corn-soybean cropping rotation at The University of Tennessee's Middle Tennessee Research & Education Center in Spring Hill, Tennessee (Maury County). The soil series is predominantly a Maury silt loam (fine, mixed, active, mesic Typic Paleudalf). Saturated hydraulic conductivity (K_{sat}) will be measured using a SATURO Infiltrometer from METER Group (Pullman, Washington).
Results	Preliminary results will be presented at the meeting.
Conclusions	We hypothesize that cover crop use will increase the infiltration rate of this no-till corn-soybean rotational cropping system. This would be helpful to producers in increasing the amount of soil water and mitigating some drought-stress effects.

ESTIMATED GROUNDWATER WITHDRAWALS FOR IRRIGATION AND AQUACULTURE IN THE MISSISSIPPI DELTA, 2014–2017

John A. Robinson[1], Jordan L. Wilson[2], Wade H. Kress[3], and Jeannie R. Barlow[4]

The Mississippi Delta region, one of the most productive agricultural regions in the Nation, depends largely on groundwater for irrigation and aquaculture. To provide stakeholders with tools to better understand and manage the water resources, the U.S. Geological Survey (USGS), through cooperative studies with the Mississippi Department of Environmental Quality (MDEQ) and the USGS Mississippi Alluvial Plain Water Availability Project, is developing a common hydrologic framework for describing and predicting highly variable interactions among surface-water and groundwater within the Mississippi Delta region.

In February 2014, the MDEQ implemented a voluntary metering program. Under the MDEQ's voluntary metering program, groundwater wells screened in the Mississippi Delta region were metered, and annual reports of metered water use for these wells were submitted to the MDEQ. In 2014, 2015, 2016, and 2017, meter readings from each growing season were submitted, and selected measurements determined to have sufficient information were used to assess regional water use in the Delta.

Groundwater withdrawals for each growing season were estimated for 1-square-mile grid across the Mississippi Delta by using the voluntary meter program dataset to determine representative groundwater withdrawal rates by beneficial use, geographic region, and precipitation zone. For each 1-square-mile grid, water use was determined for each crop and aquaculture by multiplying the acreage irrigated by groundwater by the representative withdrawal rate for that crop based on its respective region and precipitation range. Total water use for each grid was computed by adding water use for each crop that was irrigated as well as aquaculture.

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