Proceedings of the 2024 TENNESSEE WATER RESOURCES SYMPOSIUM

April 2-4, 2024

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Keynote Speakers

Tuesday, April 2nd

Michael McCall
TVA Vice President of Environment and Sustainability

"Making Decisions for a Sustainable Future: TVA's Management of the Tennessee River System"

Wednesday, April 3rd

Lacey Thomason
U.S. Army Corps of Engineers Silver Jackets Deputy Program Manager

"Help Build a Resilient America: Reduction of Flood Risk and other Natural Disasters Through Technical Assistance and Collaboration"

PRESENTATIONS

SESSION 1A

GROUNDWATER
(Moderator: Wade Kress, USGS)

AQUIFERS
(Moderator: Scott Schoefernacker, Protect Our Aquifer)

SESSION 1B

FLOODING
(Moderator: Alfred Kalyanapu, TTU)

STREAM AND WETLAND QUALITY
(Moderator: Andrea Ludwig, UTK)

SESSION 2A

WATER QUALITY (PART I)
(Moderator: Laura Ruhl-Whittle, USGS)

WATER QUALITY (PART II)
(Moderator: Daniel Saint, TVA)

SESSION 2B

MITIGATION
(Moderator: John Schwartz, UTK)

GREEN INFRASTRUCTURE
(Moderator: Karina Bynum, TDEC)

SESSION 2A

HARPETH RIVER
(Moderator: Rich Cochran, TDEC)

NUTRIENTS
(Moderator: Drew Westerman, USGS)

SESSION 2B

STORMWATER
(Moderator: Paul Davis, PE)

INFRASTURE
(Moderator: Adrian Ward, Barge Design Solutions)

SESSION 3A

ALGAE
(Moderator: Forbes Walker, UTK)

SESSION 3B

TECHNOLOGY
(Moderator: Brandy Hayes, RES)

POSTERS

SESSION 1-A

Tuesday, April 2nd at 1:30pm - 3:00pm
GROUNDWATER
(Moderator: Wade Kress, USGS)

Beyond the Arbitrary Radius: Unraveling Wellhead Protection Areas and Regulations Discrepancies
R. Villalpando-Vizcaino, B. Waldron, D. Larson, M. DuBose

Variability in the Recharge Potential of Soil Moisture in West Tennessee Crop Fields
M. Yaeger

Advancing Groundwater Management and Infrastructure Assessment in Western Tennessee through Airborne Geophysics
R. Adams, A. McVay, B. Minsley

Tuesday, April 2nd at 3:00pm - 5:00pm
AQUIFERS
(Moderator: Scott Schoefernacker, Protect Our Aquifer)

A Tale of Two Aquifers: Comparing Aquifer Management in Central Texas and West Tennessee to Sustain the Memphis Sand Aquifer
S. Houston

Water Resource Integration Plans (WRIP): A Method of Comprehensive Infrastructure Plannin
B. England

Monitoring ambient groundwater quality of Tennessee aquifers
M. Gratzer, L. Ruhl-Whittle, J. Kingsbury, B. Ham, K. Hill, A. Hourigan

BEYOND THE ARBITRARY RADIUS: UNRAVELING WELLHEAD PROTECTION AREAS AND REGULATIONS DISCREPANCIES

Rodrigo Villalpando-Vizcaino[1,2,*], Brian Waldron[1,2], Daniel Larsen[1,3], and Mary DuBose[1,2]

Wellhead Protection Plans (WHPP) for groundwater sources have existed since 1986, emphasizing the importance of preventing contamination rather than remediating it. In Tennessee, these plans categorize wellheads based on service connections and water extraction. However, a potential discrepancy arises when legal classifications diverge from the actual groundwater dynamics, especially if a public water system is deemed non-community despite significant groundwater withdrawal. This presentation explores synthetic examples illustrating diverse methods (mathematical, analytical, numerical) for delineating wellhead protection areas under various scenarios with increasing hydrocomplexity (multiple wells, hydraulic gradients, withdrawal regimes, hydraulic properties). The goal is to address the possibility that regulatory-defined zones might underestimate real groundwater capture zones. This is crucial, as oversight could compromise the regulation, protection, and supervision of areas vital for maintaining clean groundwater resources and ensuring the integrity of public supply systems. The findings underscore the limitations of relying on arbitrary radius zones, revealing the potential for significant underestimations, with zones five to ten times smaller than numerically modeled groundwater capture zones after 25 years' time of travel, while maintaining an overly simplified circular shape. The implications are substantial, emphasizing the need for a more sophisticated approach to regulate, protect, and supervise areas susceptible to contamination. The results prove valuable for public supply systems aiming to exceed regulatory standards, offering a better understanding of the anticipated groundwater capture zones. Embracing a "water steward" mindset aligns with the proactive principles that inspired WHPP decades ago, guaranteeing the ongoing success of groundwater resource preservation and the dependable operation of public supply systems.

[1] Center for Applied Earth Science and Engineering Research (CAESER), University of Memphis, Tennessee

[2] Department of Civil Engineering, University of Memphis, Tennessee

[3] Department of Earth Sciences, University of Memphis, Tennessee

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VARIABILITY IN THE RECHARGE POTENTIAL OF SOIL MOISTURE IN WEST TENNESSEE CROP FIELDS

Mary Yaeger

Estimating annual groundwater recharge is an important question to answer for planning sustainable growth in West Tennessee. The rolling landscape is crossed by five rivers and their tributaries, many deeply-incised due to the region's highly-erodible, water-retentive silt-loam soils. Drainage properties range from relatively well-draining in uplands to very poorly-draining in lowlands, with root-zone restrictive layers present on hillslopes. Discontinuous low-permeability layers in the deep subsurface can inhibit vertical recharge from better-draining soils but may also direct the infiltrated moisture along the topographical gradient to lowlands. Row-crop agriculture is the main regional land-use, only 18% of which is irrigated by center pivots according to the latest USDA Irrigation Census. Agricultural practices are designed to slow surface runoff and discharge subsurface excess.

Annual potential recharge rates were obtained by applying recession fluctuation methods to in-field deep-soil water content and nearby well levels at a non-irrigated, better-draining upland field and an irrigated, poorly-draining lowland field. For water year 2022 (rainfall 153cm), the upland field yielded 57cm potential recharge by soil moisture and 70cm by water table, while the lowland field yielded 3cm by soil moisture and 110cm by water table fluctuations, respectively. Shallow lowland groundwater fluctuated much more than the lowland deep-soil layer, which is at or near saturation most of the year. These results suggest highly-variable potential recharge rates dependent on landscape position, soil drainage, and thickness of silt-loam layer. Subsurface fines layers may further redistribute potential recharge from uplands to lowlands, and ultimately, to incised stream bottoms.

ADVANCING GROUNDWATER MANAGEMENT AND INFRASTRUCTURE ASSESSMENT IN WESTERN TENNESSEE THROUGH AIRBORNE GEOPHYSICS

Ryan F. Adams[1], Angel N. McVay[2], and Burke J. Minsley[3]

Airborne electromagnetic (AEM) surveys are a powerful geophysical technique to rapidly generate millions of models of the electrical properties of the subsurface that can be correlated with hydrologic and geologic groundtruth to produce rich datasets detailing entire landscapes. In 2019-22, the U.S. Geological Survey (USGS) acquired airborne electromagnetic geophysical survey data in western Tennessee as part of the Mississippi Alluvial Plain (MAP) groundwater study. Surveys were conducted along west-to-east trending flight lines with an even, three kilometer spacing. More targeted surveys were flown along the Mississippi River levee and in the New Madrid seismic zone in Western Tennessee. By synthesizing traditional hydrologic and geologic information with geophysical measurements, collected on a regional scale, we aim to refine existing groundwater models and contribute valuable insights for groundwater resource availability, infrastructure assessment, and seismic hazard analysis.

The airborne geophysical data collected in this region was integrated into existing hydrogeologic frameworks and models to greatly enhance their ability to characterize and understand the subcropping geology, aquifer and confining units, and water availability. Subsurface lithological variations were delineated continuously and at high resolution to facilitate the identification of potential windows within confining units and aid in the development of targeted strategies to mitigate risks to those underlying units.

AEM survey lines flown adjacent to levees along the Mississippi River determined the hydrogeologic properties of the units underlying the levees. The data were then categorized into groups based on their modeled permeability using a machine learning model. These categories were then used to optimize the locations of geotechnical investigations. Additionally, targeted survey lines were collected in the New Madrid Seismic Zone to identify faults and provide crucial data for seismic hazard assessment.

The results obtained from the airborne geophysical surveys have also contributed to the construction of high-resolution hydrogeologic frameworks and groundwater models, which support informed decision-making processes for sustainable water resource management. This study highlights the multifaceted applications of airborne geophysics in addressing groundwater dynamics and infrastructure risk in Western Tennessee.

[1] United States Geological Survey, Lower Mississippi-Gulf Water Science Center, Nashville, TN

[2] United States Geological Survey, Lower Mississippi-Gulf Water Science Center, Little Rock, AR

[3] United States Geological Survey, Geology, Geophysics, and Geochemistry Science Center, Denver, CO

A TALE OF TWO AQUIFERS: COMPARING AQUIFER MANAGEMENT IN CENTRAL TEXAS AND WEST TENNESSEE TO SUSTAIN THE MEMPHIS SAND AQUIFER

Sarah Houston[1]*

Shelby County, Tennessee remains the only county in the state with the delegated authority to manage groundwater, although most management programs exist on paper only. New research has revealed the Memphis Sand Aquifer is vulnerable to legacy pollution that will continue to degrade the high quality water used by all residents, industry, and some agricultural users. Efforts are underway to revitalize groundwater management in West Tennessee and the Edwards Aquifer Authority (EAA) in Central Texas is often cited as a great model for governance. Drawing from diverse sources such as reports, scientific publications, governmental records, and legal reviews, this presentation compares the hydrogeological structures, historical management approaches, political frameworks, and protection programs of the Edwards and Memphis aquifers. Highlighting the disparities, it underscores the Edwards' rapid and interconnected water system, leading to early awareness of management needs and strong state legislative involvement. In contrast, the slower movement of the Memphis aquifer, coupled with limited geological mapping and regulatory programs, presents distinct challenges in governance. By understanding the conditions that spurred effective legislation and the transparent data sharing of the EAA, this presentation proposes ways for Memphis aquifer stakeholders to bridge the knowledge implementation gap and enhance aquifer management in the West Tennessee region.

[1] Protect Our Aquifer, 1910 Madison Ave. #130, Memphis, TN 38104 sarah@protectouraquifer.org

WATER RESOURCE INTEGRATION PLANS (WRIP): A METHOD OF COMPREHENSIVE INFRASTRUCTURE PLANNING

Brady England

The recent allocation of government funding for drinking water and wastewater infrastructure improvements has led to the increased need for infrastructure planning. However, information on existing systems is often lost throughout the years, particularly through increased employee turnover affecting all parts of the water industry. This loss of in-depth system knowledge makes choosing critical infrastructure improvements difficult, as needs become harder to identify. One solution to this issue is the development of a Water Resource Integration Plan (WRIP). A WRIP acts as a repository of existing system information and a planning document for future infrastructure improvements. WRIPs are intended to be a living document, updated at regular intervals to provide up to date information and adapt to future needs. Using the WRIP developed for Murfreesboro's Water Resource Department (MWRD) by Smith Seckman Reid, Inc. as an example, this presentation aims to guide attendees through the creation of a WRIP, including information gathering, infrastructure planning, potential uses, and advice for WRIP development. With public utility funding sources, such as ARPA, requiring asset management plans, WRIPs offer a comprehensive way to plan for the future.

MONITORING AMBIENT GROUNDWATER QUALITY OF TENNESSEE AQUIFERS

Michael C. Gratzer, Laura S. Ruhl-Whittle, James A. Kingsbury, Brian Ham, Kristi L. Hill, Amy M. Hourigan

The Tennessee Department of Environment and Conservation (TDEC) and the U.S. Geological Survey (USGS) have collaborated to establish a network of wells and springs for monitoring the ambient groundwater quality of Tennessee's nine principal aquifers. Groundwater accounts for about 21 percent of the water used in Tennessee for public, domestic, and industrial supply as well as agriculture. The new groundwater quality monitoring network will provide the groundwater-quality data necessary for evaluating the suitability of Tennessee's groundwater resources for these uses, building upon other groundwater quality networks in the state to provide greater spatial coverage. The network consists of about 120 wells and springs in the nine principal aquifers of the state. The number of sites sampled in each principal aquifer will be based on the amounts of groundwater withdrawn from and the areal extents of the aquifers. Site selection also involves consideration of well depths, well types, and whether sites had historical water-quality data. Samples will be analyzed for major ions, trace elements, nutrients, dissolved organic carbon, volatile organic compounds, and tritium. Samples from a subset of sites will be analyzed for E. coli, pesticides, and radionuclides; these sites will be selected based on hydrogeologic conditions that increase the likelihood of groundwater containing these constituents. This year (2024), samples will be collected from about 30 sites in western Tennessee, 20 sites in the Western Highland Rim and Central Basin regions, and 22 sites in the Eastern Highland Rim and Cumberland Plateau regions. In 2025, about 24 sites will be sampled in the Valley and Ridge region and Blue Ridge Mountains. Each site is planned to be resampled every five years.

SESSION 1-B

Tuesday, April 2nd at 1:30pm - 3:00pm
FLOODING
(Moderator: Alfred Kalyanapu, TTU)

Combating the Hazard Creep: Implications of a Rapidly Developing Area
M. Miro, J. Naughton, K. Chapman

Rising Above: Navigating Harpeth River Challenges
A. Ward, S. Abdulrahman

Extreme Precipitation in the Southeastern United States: Are We Underestimating Depth-Duration-Frequency Values because of Low Rain-Gauge Density and Temporal Resolution?
N. Kafle, F. Dell'Aira, D. Burnette, C. Meier

Tuesday, April 2nd at 3:00pm - 5:00pm
STREAM AND WETLAND QUALITY
(Moderator: Andrea Ludwig, UTK)

Karst Controls on Jurisdictional Status of Low-order Streams in Tennessee
D. Jackson

Measuring the trajectory of ecosystem functional return in restored agricultural wetlands: When is a wetland restoration goal reached?
J. Murdock, R. Brown, S. Duwadi, S. Womble

Seasonal and Diurnal Variations of Stream Metabolism in a Middle TN Headwater Stream
M. Chen, J. Ayers

COMBATING THE HAZARD CREEP: IMPLICATIONS OF A RAPIDLY DEVELOPING AREA

Kate Naughton, Kevin Chapman, Madi Miro

The community of Wesley Chapel, FL has experienced growth in population of over 150% between 2001 and 2021, during which areas surrounding the Boyette Road Reclaimed Water Reservoir have seen rapid, high-density residential construction. The reservoir has a maximum storage capacity of 500 MG and is impounded entirely by an earthfill dam. Inundation modeling required to identify at-risk areas downstream of the reservoir in the event of a breach was completed in 2023. The effort updated inundation mapping completed in 2015 and highlighted this hazard creep, revealing impacts to emergency response and challenges on how to effectively educate people moving into these downstream locations.

During an emergency planning exercise following creation of the inundation maps, emergency responders were introduced to the new tools and encouraged to discuss their use in the event of an emergency. Emergency responders used the maps to guide creation of a notification extent, questioning how they would determine potentially impacted populations. The exercise revealed the presence of critical facilities within the inundation zone that were not previously included in the county's emergency action plan. The exercise included extended discussion on the unintended consequences of land development and how to properly educate new and future property owners located within the inundation zone.

This presentation will outline the implications of positioning a reservoir within a landscape currently or potentially evolving due to human development. We will use this dam as a case study to further discussion on hazard creep around dams and potential ways to combat it.

RISING ABOVE: NAVIGATING HARPETH RIVER CHALLENGES

Adrian Ward and Shahad Abdulrahman

The city of Franklin owns a 200-acre tract of land that is bordered on three sides by the Harpeth River and its fourth side by Interstate 65. The Harpeth River is notorious for flooding at frequent flood events making development of the site difficult and expensive. In 2018, the city of Franklin decided to move forward with the design of a public facility that will consist of 10 sports fields, an inclusive playground, a regional maintenance facility and an adjacent area for a future water reclamation facility. Design of the site required a hydraulic model to be developed for the Harpeth River as a large portion of the existing site was in the floodplain. This model was used to evaluate bridge openings for the access road required to enter the site. While a No-Rise condition was possible, it required the bridge design to be approximately 1,000 feet long which drastically exceeded the estimated bridge costs. Further evaluation revealed that a smaller bridge opening could be justified that reduced the bridge length to approximately 300 feet but required a conditional letter of map revision (CLOMR) to be obtained. This was a great cost savings for the project. The plans are now complete, and the project is due to begin construction in spring of 2024.

This presentation will provide attendees with an understanding of hydraulic modeling and floodplain management issues associated with the development of the site as well as other stormwater features designed to mitigate the impacts of runoff.

[1] Barge Design Solutions

[2] City of Franklin, Engineering

EXTREME PRECIPITATION IN THE SOUTHEASTERN UNITED STATES: ARE WE UNDERESTIMATING DEPTH-DURATION-FREQUENCY VALUES BECAUSE OF LOW RAIN-GAUGE DENSITY AND TEMPORAL RESOLUTION?

Nischal Kafle, Francesco Dell'Aira, Dorian J. Burnette, and Claudio I. Meier

We investigate the impacts of rain gauge station density and temporal resolution on extreme precipitation in the southeastern United States, focusing on the shorter rainfall durations of interest to urban hydrologists. The existing US rain gauge network is characterized by coarse temporal (most stations totalize over 15-minute clock periods) and spatial resolutions, which may potentially cause underestimation of extreme rainfall events. We use two different datasets to explore these issues: (i) 13 years of concurrent data at 862 German rain gauges operating at a high (1-minute) temporal resolution, with a much (17 times) denser weather station network than the SE US, and (ii) 473 stations in the Southeastern US, with varying record lengths, of which about a third has gauges that measure every 1 minute.

The analysis for the effects of station density uses the German data; it involves generating various realizations of lower-density rain gauge networks to assess biases and uncertainties in extreme rainfall estimates, specifically in regionally derived Depth-Duration-Frequency (DDF) values. This allows us to infer whether the US may be underestimating the severity of such events. The effects of the gauges' temporal resolution are elucidated by using all 1-minute data, from both Germany and the SE US. Actual maxima are extracted from the 1-min records, from which "true" DDF values are computed, which are then compared to biased values obtained from aggregated records (for example, the 1-min records can be aggregated to 15-min windows, to simulate the data one would have from a typical US gauge). Concurrently, the study explores trends in sub-hourly precipitation extremes in the southeastern US, employing event-based methodologies and statistical tests on precipitation data.

We find that: (i) a lower station density significantly increases the uncertainty in regionally-derived DDF, and may also result in underestimation, (ii) rainfall data totalized every 15 minutes cause relevant negative biases in our DDF estimates which depend on duration and gauge location, but more importantly, exhibit an at-a-station variability (uncertainty) that is much larger than has been recognized heretofore, and (iii) a large proportion of rain gauges in the Southeastern US display significant increasing trends in the frequency of extreme sub-hourly precipitation events. Overall, this research contributes crucial insights into the underestimation of current DDF values in the southeastern United States, and can be used to optimize rain-gauge networks for enhanced extreme precipitation predictions and trend detection in the face of changing climate patterns.

[1] Department of Civil Engineering, The University of Memphis

KARST CONTROLS ON JURISDICTIONAL STATUS OF LOW-ORDER STREAMS IN TENNESSEE

David E. Jackson, P.G., P.H.[1]

Sinking stream hydrology commonly is encountered throughout significant portions of Middle Tennessee where substrate materials may consist of karst bedrock. In such terrane, low-order streams and those draining small watersheds may not ever receive base flow, with surface flow entirely absent except during or immediately following precipitation events. These hydrologic conditions are among those comprised in Tennessee's statutory definition of a Wet-weather Conveyance, and, under Tennessee's Hydrologic Determination process, may constitute one or more Primary Indicators of a Wet-weather Conveyance.

Accordingly, it is important to recognize the role of karst formations that may deprive streams of base flow, with a resulting effect on these streams' jurisdictional status under Tennessee's Water Quality Control Act of 1977 and related regulations. Similarly, and with regard to the recent Sackett vs. EPA SCOTUS decision, the elimination of stream flow by karst conditions may result in the ephemeral hydrology characteristic of non-Relatively Permanent Waters.

Multiple instances of stream channels with sinking flow have been documented as Wet-weather Conveyances, despite these channels exhibiting strong geomorphology, "sorting", or other Secondary Indicators of jurisdictional streams. These examples support further consideration by practitioners and regulators alike of karst geomorphology as an agent of base-flow elimination and its potential effect on jurisdictional status.

[1] Davey Resource Group, Nashville, Tennessee

MEASURING THE TRAJECTORY OF ECOSYSTEM FUNCTIONAL RETURN IN RESTORED AGRICULTURAL WETLANDS: WHEN IS A WETLAND RESTORATION GOAL REACHED?

Justin Murdock[1], Robert Brown[1,2], Shrijana Duwadi[1,3], and Spencer Womble[1,4]

Determining if or when a wetland has been successfully restored is difficult and depends on specific restoration goals. Restorations have historically centered on returning wetland soil, hydrology, vegetation, and wildlife to a pre-disturbed state, but there is increasing interest in reestablishing ecosystem services such as nutrient retention and carbon storage. However, as pre-disturbed functional rates are often unknown, goals often default to maximizing processing rates, especially in wetlands adjacent to eutrophic waters. We conducted an intensive space-for-time assessment of the maximum nutrient retention potential of 35 restored floodplain agricultural wetlands enrolled in the USDA Natural Resources Conservation Service's Wetlands Reserve Program in Tennessee and Kentucky. Wetland ages ranged from 0 to 23 years post restoration. Higher nitrogen and phosphorus retention were generally associated with increased age, but there were distinct recovery trends among wetland sub-habitats and hydrology regimes, particularly within the first 10 years post-restoration. Younger floodplain wetlands had the potential to be substantial nutrient sinks when flooded, but several were nutrient sources. Soil moisture, pH, and nutrient content were positively correlated with nutrient retention potential, but more work is needed to determine mechanisms driving these differences. Despite high variation within the first decade, nutrient retention rates stabilized within and across all wetlands, coalescing into a state of consistent, but much lower removal from 10 – 23 years post-restoration. Results suggest that evaluating wetland restoration success in terms of nutrient retention goals may be misleading if assessed during the first decade because early estimates may not reflect longer-term functional benefits.

[1] Department of Biology, Tennessee Technological University, Cookeville, TN

[2] Oak Ridge Institute for Science and Education, US Environmental Protection Agency, Corvallis, OR

[3] Department of Life and Environmental Sciences, University of California, Merced, CA

[4] Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA

SEASONAL AND DIURNAL VARIATIONS OF STREAM METABOLISM IN A MIDDLE TN HEADWATER STREAM

Ming Chen, John C. Ayers

Three to five-day long field campaigns were conducted almost every month from May 2022 to May 2023 at East Fork Creek, a rural headwater stream in middle TN, to characterize diel variations and stream metabolism. Measurements of dissolved oxygen (DO concentration (mg L-1), irradiance (PAR = photosynthetically active radiation in umol m-2 s-1), water temperature (°C), atmospheric pressure (atm), and salinity (ppt = parts per thousand) were made every five minutes. With those parameters, stream metabolism variables Gross Primary Productivity (GPP) and Ecosystem Respiration (ER) were calculated based on a Bayesian model. Up to now, 44 daily averages and 5904 instantaneous values of GPP and ER have been measured.

Among the 44 days of measurements, there are only 4 days such that GPP exceeds ER (3 in winter and 1 in summer), indicating that EFC is usually heterotrophic throughout the year and emitting CO_2 to the atmosphere. GPP shows strong seasonal variation, peaking in July and staying low in winter. ER does not vary seasonally except for a slight increase in Fall which might be caused by decomposition of leaves. Net ecosystem production (= GPP ER is usually negative since ER is the dominant process in EFC, indicating net consumption of O2 and production of CO2.

A more extensive field campaign was set up from July 2-5 in 2022 to collect 150ml water samples from East Fork Creek every four hours using an ISCO auto sampler. Conductivity, depth, dissolved oxygen, fluorescent dissolved organic matter (fDOM), pH, total algae, and turbidity were measured every 5 minutes using a YSI EXO_2 sonde. Diel signals were observed for temperature, pH, turbidity, and concentrations of Ca, Mg, K, Se, Fe, Ba, chloride, nitrate, DIC, DO, DOC, and total algae (TAL). GPP was found to be positively correlated with pH, DO, light intensity, concentration of Ca and nitrate, and negatively correlated with DOM and TAL. ER is found to be positively correlated with temperature, pH, DO, and negatively correlated with salinity, conductivity, and TAL Measured DO concentrations ranged from 5.7 to 11.1 ug/L (67% to 143% local saturation) saturation), indicating an aerobic environment, and the mean P concentration of 18 ug/L indicates the stream is mesotrophic. No analyzed species exceeded U.S. regulatory limits. East Fork Creek serves as a model unpolluted headwater stream in middle TN.

SESSION 2-A

Wednesday, April 3rd at 8:30 am - 10:00 am
WATER QUALITY (PART I)
(Moderator: Laura Ruhl-Whittle, USGS)

Occurrence and distribution of cyanotoxins using microcystin concentrations and water quality in under-investigated urban locations in Middle Tennessee
K. Hill, D. Moore, T. Byl

Identification of Contaminants in Well Water through the Tennessee Well Water Program, 2022-2023
K. Dunaway

Identifying contributing areas for Tennessee community drinking-water springs with dye tracing: preliminary results
A. Hourigan, B. Miller, B. Ham

Wednesday, April 3rd at 10:30 am - 12:00 pm
WATER QUALITY (PART II)
(Moderator: Daniel Saint, TVA)

The Geography of Watershed Toxicity in Shelby County, Tennessee
R. Banai, G. Amankwaa

Investigation and Management of Microseira (Lyngbya) wollei Infestations Source Water Reservoirs
T. Goldsby, T. Goldsby

Stephens Lake: a model unpolluted pond in middle TN
J. Ayers, M. Chen, J. Wei

Wednesday, April 3rd at 1:30 pm - 3:00 pm
HARPETH RIVER
(Moderator: Rich Cochran, TDEC)

"Integration of High Definition Stream Survey (HDSS) Data for QUAL2K Modeling: A Case Study on the Harpeth River
J. Parham, B. Connell

Water Quality Monitoring of the Harpeth River
D. Jones

Quantitative Fluorescent Dye Tracing to Determine Low Flow Travel Times for Water Quality Protection of the Harpeth River
J. Ponzio

Wednesday, April 3rd at 3:30 pm - 5:00 pm
NUTRIENTS
(Moderator: Drew Westerman, USGS)

From subsidies to stressors: shifting ecological baselines alter biological responses to nutrients in highly modified agricultural streams
S. DeVilbiss, J. Taylor, M. Hicks

The effects of nutrients on stimulating cyanobacterial dominance and microcystin production in the Cumberland River, Tennessee
J. Li

Accounting for the ecological relevance of nutrient loads in urban water quality interventions
V. Rexhausen

OCCURRENCE AND DISTRIBUTION OF CYANOTOXINS USING MICROCYSTIN CONCENTRATIONS AND WATER QUALITY

in under-investigated urban locations in Middle Tennessee

Kristi L. Hill[1,2], Devin M. Moore[1,2], Thomas D. Byl[1,2]

Cyanotoxins (CTs) are a type of algal toxin produced by cyanobacteria during harmful algal blooms (HABs) and their effects on freshwater bodies are of growing concern for public and environmental health. The mechanisms for distribution and release of CTs in freshwater systems are poorly understood, but ingestion and contact with toxin in water has caused sickness and death in humans, pets, and wildlife. Nutrient rich waters and warm temperatures provide conditions conducive to HAB growth. In addition to Tennessee's long and hot summers, nutrient rich run-off from continued land development is causing ideal conditions for HAB growth in the greater Nashville area. Middle Tennessee also has abundant surface water and is composed of primarily unconfined karst limestone bedrock. Thus, surface water and groundwater resources may interact despite bodies appearing isolated at the surface. The U.S. Geological Survey, in collaboration with the Tennessee Department of Environment and Conservation, are investigating potential threats to drinking water and recreational reservoirs due to CT by collecting ambient water samples and deploying passive samplers near water utility intakes in Middle Tennessee and some of their tributaries. The CT concentrations found in reservoirs with hydrologic connections are being compared to identify whether toxin is moving through unconfined hydrologic units in the subsurface, and to determine whether they could enter public supply and recreational water bodies. Additionally, water-quality data are being collected to explore correlations with algal toxin to better understand relationships between water-quality and algal toxin production.

[1] U.S. Geological Survey, 640 Grassmere Park, Ste. 100, Nashville, TN 37211 (klhill@usgs.gov)

[2] Tennessee State University - Department of Agriculture & Environmental Sciences, 3500 John A. Merritt Boulevard, Nashville, TN 37209

IDENTIFICATION OF CONTAMINANTS IN WELL WATER THROUGH THE TENNESSEE WELL WATER PROGRAM, 2022-2023

Kristin Dunaway

Well or spring water is the primary source of drinking water in Tennessee (TN) but there are few regulations for well or spring water testing. These water sources may contain biological and chemical contaminants that may have medical and economic implications. To identify and quantify the presence of biological and chemical contaminants within residential wells, the TN Department of Health (TDOH) initiated a free pilot program for Tennessee residents utilizing grant funds. From September 2022 to June 2023, 95 well water samples were tested for total coliform/Escherichia coli, Lead, Copper, Arsenic, Fluoride, Nitrate/Nitrite, and Total Dissolved Solids (TDS) using EPA-certified or A2LA certified methods. Results for each analyte were compared to federal acceptable limits and used to inform appropriate remediation steps.

Of the 95 wells tested, 46% (44/95) were positive for total coliforms, 10% of which were positive for E. coli. Of the wells tested, the following contaminants were detected above federal acceptable limits: TDS (11%, 10/95), Lead (4%, 4/95), and Copper (3%, 3/95). Fluoride, Arsenic, Copper, and Nitrate/Nitrate were detected below the federal acceptable limits in 94% of wells. Of the 95 wells tested, all of them had some of the contaminants of concern. For this reason, testing should continue and be expanded because if the initial data trend continues, there is a potential for 126,500 of the estimated 275,000 wells to be contaminated with total coliforms alone.

95 citizens with wells volunteered for the program in its first year. Due to 35 percent of the wells being in one county and the majority of the rest of the wells being in one region of the state, data is unlikely to be truly representative of the whole state. However, with some of the analytes showing large representation in the wells tested, it is likely that these contaminants are present throughout the state.

Contaminated wells lead to a multitude of medical and economic impacts and the only way to begin to understand how the public is affected by the water they drink is through continued expansion of the well water testing program. Our findings demonstrate that both biological and chemical contaminants are present at various levels in TN residential wells. This study also serves as a starting point to potentially expand the TN well water program. Next steps would be to expand testing to all 95 counties to have better representative data for the whole of the state. Further goals are to make the testing standard for wells as it is for public drinking water, as well as expand to emergency response. This data supports a need to test for contaminants to inform remediation practices for residential wells.

IDENTIFYING CONTRIBUTING AREAS FOR TENNESSEE COMMUNITY DRINKING-WATERSPRINGS WITH DYE TRACING: PRELIMINARY RESULTS

Amy M. Hourigan[1], Benjamin V. Miller[1], Brian Ham[2]

Karst aquifers and springs are highly susceptible to contamination but are an important drinking-water resource in Tennessee. To protect these resources, public water system managers are required to identify the area that contributes to the water supply and delineate a source water protection area (SWPA), which is difficult to estimate in karst landscapes. The U.S. Geological Survey (USGS) and Tennessee Department of Environment and Conservation (TDEC) have completed the second of a five-year investigation to evaluate contributing areas to karst springs used for drinking-water. Since 2021, multiple dye traces have been conducted in seven communities. Work in Cowan, Jasper, Vanleer and Woodbury is complete, while studies are ongoing in Caryville, Lafayette, and Morristown. On average, 14 dye injections are conducted per community, revealing groundwater flowpath directions. Contributing areas, both inside and outside current SWPAs have been identified in nearly all communities. Several positive dye traces highlighted examples of unexpected hydrologic interaction between topographically separate basins. Other interesting finds observed throughout the study include longer than normal dye path lengths and rapid transport times. The results will be provided to water system managers to help manage and protect their drinking-water resources.

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[2] Tennessee Department of Environment and Conservation, 312 Rosa L. Parks Ave., 11th Floor, Nashville Tennessee 37243

REVISITING THE FIGHT AGAINST BAD DATA MANAGEMENT

Gerald Burnette

A presentation at last year's AWRA Symposium identified deficiencies in adherence to sound data management principles, examined effects of bad data management on science, and offered suggested ways to increase awareness of the problem and improve outcomes. This presentation will expand on the topic by offering more examples and exploring their implications. We will also identify any progress made in the proposed plan for addressing this problem.

INVESTIGATION AND MANAGEMENT OF MICROSEIRA (LYNGBYA) WOLLEI INFESTATIONS SOURCE WATER RESERVOIRS

Troy Goldsby and Terry Goldsby

Many of the source water reservoirs in the United States were impounded more that 60 years ago and are now experiencing the effects of reservoir aging. Some of these effects include advanced nutrient loading with subsequent eutrophication, sedimentation, and a decrease in species diversity. Additionally, introductions of non-native invasive flora have exacerbated these conditions, and some have greatly accelerated the aging processes. Many of these introductions are well known, e.g. Eurasian watermilfoil (Myriophyllum spicatum), Florida elodea (Hydrilla verticillata), and curly-leaf pondweed (Potamogeton crispus). However, there are many other algae and cyanobacteria species that are not as well known, but still contribute to degradation of our reservoirs. In particular, Lyngbya (Microseira wollei) has been spread to many reservoirs during the past 3 decades and poses serious problems for these water bodies. Lyngbya is a large-celled, filamentous, mat-forming cyanobacterium. Creating both benthic and surface mats, it can cover entire ponds and coves and be several feet deep. Mats can impede navigation and recreation, cover and smother submersed plants, and clog water intakes. In addition, they emit a strong and unpleasant earthy or musk-like odor (Speziale, Turner and Dyck, 1988). In addition to these degrading effects, reservoir aging is accelerated and the taste and odor of source waters can be impacted. During the past 15 years, many products and techniques have been investigated for control and management of Lyngbya infestations. The purpose of this presentation will be to present a history of Lyngbya management efforts; highlighting the most effective approaches that have been utilized so far.

[1] Jones Lake Management, Waynesboro, Tennessee

[2] Jones Lake Management, Guntersville, Alabama

STEPHENS LAKE: A MODEL UNPOLLUTED POND IN MIDDLE TN

John C. Ayers, Ming Chen, Jialei Wei

Stephens Lake (SL) is a 0.026 km^2 pond in Franklin, TN formed by damming the headwaters of East Fork Creek (EFC), a rural headwater stream in middle TN. We characterized the pond in preparation for in-situ experiments. A depth survey in 11/23 found depth < 1.6 m in most places, being most shallow where the stream enters and deepest near the original channel. In-situ measurements were made in 10/24/22-10/26/22 and 3/27/23-4/3/23. Functional dissolved organic matter fDOM, optical dissolved oxygen ODO, pH, total algae TAL, and temperature showed diel signals in 2023, and ODO, pH, specific conductivity SpC and temperature showed strong diel signals and fDOM a weak signal in 2022. Diel signals showed variable time lags compared with light intensity and were muted compared with diel signals measured simultaneously in EFC 2,240 meters downstream of the dam.

Water samples were collected every four hours for 96 hours in 2023 and analyzed for 25 species. All samples were Ca-HCO3 type water. Se and Mn showed strong (+) correlations with DOC suggesting complexation. No species exceeded regulatory limits except for Mn in 7 of the 24 samples. Based on P concentrations the pond is oligotrophic, consistent with ODO ranging from 6.7-13.2 in 2022 and 8.3-11.7 mg/L in 2023. Average TDS (mg/kg) increased from 107 in SL to 198 in EFC downstream, consistent with progressive mineral dissolution. Stephens Lake is a model unpolluted pond in middle TN that can be used to monitor ecosystem response to environmental change.

INTEGRATION OF HIGH DEFINITION STREAM SURVEY (HDSS) DATA FOR QUAL2K MODELING: A CASE STUDY ON THE HARPETH RIVER

James Parham Ph.D.[1] and Brett Connell[1]

A comprehensive High Definition Stream Survey (HDSS) spanning 50 miles of the Harpeth River, Tennessee, was conducted to gather physical habitat and water quality parameters. Collaborating with Hazen & Sawyer and Crawford Hydrology Lab, the initiative aimed to support the development of a QUAL2K model, specifically designed to assess water quality requirements for a proposed treatment facility servicing Franklin, TN, with discharge of purified water into the Harpeth River.

The data collection involved continuous HDSS video, water quality metrics, physical algal samples, spot water-quality grab samples, and 15 cross-sectional discharge transects at major tributary sites. The HDSS assessment generated a continuous 1-meter resolution output, delivering a georeferenced, high-resolution dataset applicable for analyses from microhabitat to watershed levels. Information encompassed water depth, surface elevation, bottom elevation, physical habitat details, and water quality data, forming the foundational dataset for the QUAL2K model. After the initial survey, channel dimensions were gathered from side-scan sonar data and percent channel shading was determined from the video data to further describe important model variables.

This project highlights the pivotal role of integrating HDSS data into water quality modeling, promoting evidence-based decision-making for effective river management. The Harpeth River HDSS stands as a valuable resource, contributing crucial insights for informed and collaborative initiatives in the realm of river management.

[1] Trutta Environmental Solutions, LLC

WATER QUALITY MONITORING OF THE HARPETH RIVER

Danielle Jones

The City of Franklin (COF) owns and operates a Water Reclamation Facility (WRF) that has a permitted capacity of 16 MGD. However, wastewater demand is estimated to be 24 MGD by 2050, necessitating a new 8 MGD Clean Water Facility (CWF).

Water quality modeling must be employed to evaluate the impact of CWF discharge of purified water into the Harpeth River to support the NPDES permitting process. Hazen conducted comprehensive river monitoring in 2022 and 2023 to support the development of a QUAL2K model in the absence of EPA's updated WASP model. In late 2023, EPA released an updated and calibrated WASP model for the Harpeth River. As a result, Hazen employed the WASP model to evaluate the impact of an 8 MGD discharge from the CWF.

Almost 50 river miles were evaluated during Hazen's two sampling periods at multiple locations along the Harpeth River. Efforts to complete the study included support for Trutta Environmental to complete a High-Definition Stream Survey, development of sampling procedures and protocols, selection of sampling locations, water quality grab sampling, continuous water quality monitoring and equipment support, benthic biomass sampling, chlorophyll-a sampling and filtration, cross sectional and velocity measurements and dye tracking for time of travel.

Results from the intensive monitoring that occurred were used to validate the results from the EPA's updated WASP model with a new 8 MGD source of purified water.

QUANTITATIVE FLUORESCENT DYE TRACING TO DETERMINE LOW FLOW TRAVEL TIMES FOR WATER QUALITY PROTECTION OF THE HARPETH RIVER

John Ponzio

The City of Franklin (COF) owns and operates a Water Reclamation Facility (WRF) that has a permitted capacity of 16 MGD. However, wastewater demand is estimated to be 24 MGD by 2050, necessitating a new 8 MGD Clean Water Facility (CWF). As the receiving stream, the Harpeth River is listed for impairment of dissolved oxygen in the segment of interest for a new purified water source.

Hazen teamed with Crawford Hydrology Laboratory (CHL) from Western Kentucky University to implement a quantitative dye trace study during low flow conditions in the river. Rhodamine WT dye was selected for use during the study as water quality monitoring stations were equipped with rhodamine WT sensors. Background fluorescence in the river was evaluated using both charcoal receptor packets and rhodamine WT sensor data collected prior to dye introduction to inform dye dosing. The dye mass was calculated using an empirical regression equation developed by Worthington and Smart (2003) to reach dye concentrations that would overcome observed background fluorescence and be detected at the furthest downstream Hazen-operated water quality monitoring station. [LB1]

The dye injected at river mile 92.40 traveled for almost 12 days for a total of 43.15 river miles with a calculated speed of 0.155 river miles per hour based on the peak concentration at each water quality monitoring station. This time of travel enabled Hazen to further understand how potential pollutants traverse the river during low flow conditions as well as dissolved oxygen.

FROM SUBSIDIES TO STRESSORS: SHIFTING ECOLOGICAL BASELINES ALTER BIOLOGICAL RESPONSES TO NUTRIENTS IN HIGHLY MODIFIED AGRICULTURAL STREAMS

Stephen E. DeVilbiss, Jason M. Taylor, Matt Hicks

Subsidy-stress gradients provide a useful framework for understanding ecological responses to perturbation. In highly modified systems, tolerant organisms that typically increase in response to environmental stressors may shift to stress responses at higher concentrations due to shifting ecological baselines that are positively skewed. As a result, patterns in biological tolerance in these more altered ecosystems may differ from less modified regions, creating significant challenges for detecting biological improvements resulting from restoration efforts. Using the agriculturally-dominated Mississippi Alluvial Plain (MAP) in Mississippi, USA as a case study, we demonstrate that numerous macroinvertebrate taxa that responded negatively to higher nutrient concentrations in the MAP were either unresponsive or responded positively to lower nutrient concentrations in less modified MS ecoregions, providing evidence for a subsidy response in less modified regions and a stress response in the MAP where concentrations are substantially elevated. Further, MAP-specific tolerant and intolerant taxa responded predictably and consistently to increasing nutrient concentrations across space and time. Thus, establishing regionally-specific biological tolerance can provide meaningful interpretations of biological community data and inform long-term stream health in highly modified ecoregions where widespread perturbation may limit representation of traditional intolerant taxa in regional species pools. Lastly, we demonstrate the efficacy of this approach with bacterial communities characterized with amplicon sequencing, which lack sufficient life history characteristics necessary for the development of multi-metric indices. Both macroinvertebrate and bacterial communities responded similarly to increasing nutrient concentrations suggesting that DNA-based approaches may provide an additional, efficient biological assessment tool for using a weight of evidence approach when monitoring water quality improvements in highly modified watersheds. While our approach may not be appropriate for defining criteria, redefining regional biological tolerance, or using less traditional assemblages could be useful for tracking ecological responses to nutrient reduction efforts in highly modified watersheds.

THE EFFECTS OF NUTRIENTS ON STIMULATING CYANOBACTERIAL DOMINANCE AND MICROCYSTIN PRODUCTION IN THE CUMBERLAND RIVER, TENNESSEE

Jingjing Li[1], Dalton Tryba[1], Justin Murdock[1]*

Riverine cyanobacterial blooms have become a worldwide environmental concern; however, our understanding of the mechanisms driving algal blooms in rivers remains limited. This study investigated the impact of nutrient conditions on dominant algal genera and microcystin production in large rivers. Water sourced from the Cumberland River, Tennessee, underwent a 36-day incubation, exploring four distinct nutrient scenarios of nitrogen (N) and phosphorus (P) limitation. When N was limiting, the proportion of nitrogen-fixing cyanobacteria (Dolichospermum sp.) increased with rising P and dominated when P exceeded 0.1 mg/L. Conversely, with excessive N, the cyanobacteria Microcystis sp. increased with higher P and became dominant. When P was low, eukaryotic algae increased with rising nitrogen levels, and green algae and diatoms jointly became dominant when N surpassed 5 mg/L. However, when P was in excess, green algae dominated when N exceeded 5 mg/L. These results indicate that both N and P are potentially limiting algae growth in the Cumberland River. Specifically, high N increases eukaryotic algae dominance, but green algae require a higher P level than diatoms. Nitrogen stress serves as a key trigger for the dominance of nitrogen-fixing cyanobacteria, and adding N when cyanobacteria dominate shifts communities to another toxin-producing cyanobacteria. Furthermore, the production of the cyanotoxin microcystin increased with higher N/P ratios, indicating a close relationship between toxin synthesis and nitrogen availability. This study advances our understanding of how nutrient thresholds influence the selection of dominant algal genera and microcystin production in large rivers.

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ACCOUNTING FOR THE ECOLOGICAL RELEVANCE OF NUTRIENT LOADS IN URBAN WATER QUALITY INTERVENTIONS

Victoria Rexhausen

Understanding complex biogeochemical processing and transport phenomena is one of the crucial problems facing the field of water resources today. Streams located in urban areas are at increased risk for nitrogen pollution due to the increased risk of anthropogenic inputs, and urban stormwater runoff drives the transport of pollutants to receiving streams. To mitigate risk to urban ecology and downstream bodies, it is critical to accurately assess the timing and volumetric proportion of runoff from different surfaces within the urban watershed. It is equally important to understand the ecological relevance of seasonal nutrient loads resulting from microbial activity in the soil and the decomposition of particulate organic matter.

Baker Creek is a 6.7 km2 urban watershed with forested headwaters in East Tennessee that has been identified on the 303(d) list of impaired streams for containing elevated nitrate loads. In a case study focused on Baker Creek, we seek to understand seasonal patterns of nitrate sources and transport related to land use gradients measured by percent impervious surfaces and percent forested area. The study employs stable isotope analysis of dissolved nitrate and dissolved sulfate and microbial source tracking (MST) using microbial community “fingerprints” extracted using 16 rRNA gene amplicon sequencing of both water column and runoff samples. The results are used to estimate the relative contribution of runoff from landscape types (roads/impervious, grass/lawns/parks, and forests) to various concentric drainage points. The results also give indications of the major contributing sources of nitrate from 4 major literature-derived endmembers (atmospheric deposition, organic processes, fertilizers, and manure/septic waste).

This investigation into sources and delivery of nitrate to Baker Creek presents evidence that the dissolved nitrate is primarily spruced from soil microbial processes, and that stormwater runoff from impervious surfaces such as roads and sidewalks contributes insignificantly to nitrate concentrations in the watershed. This is critical, as the intervention strategies to treat streams listed as impaired with elevated nutrient loads generally focus on slowing stormwater runoff. In the future, general water quality criteria may be adapted in order to account for factors such as land use, season, and climate in determining the nutrient load which is ecologically relevant to the watershed. Future work is necessary in order to properly estimate the effects of these factors and to understand the nuanced influences of hillslope through-flow on both hydrology and biogeochemical cycles.

SESSION 2-B

Wednesday, April 3rd at 8:30 am - 10:00 am
MITIGATION
(Moderator: John Schwartz, UTK)

A Framework for Applying Stormwater Control Measures as Compensatory Mitigation for Stream Restoration
C. Parks Oliver

Evaluation of Bioengineered Bank Stabilization Methods for Use in Stormwater Mitigation Programs
J. Armitage

A New Connectivity Based Urbanization Index for Hydrological Applications
F. Dell'Aira, C. Meier

Wednesday, April 3rd at 10:30 am - 12:00 pm
GREEN INFRASTRUCTURE
(Moderator: Karina Bynum, TDEC)

Investigation of Microbiological Water Quality during Rooftop Rainwater Harvest
C. Swanson, T. Anaya, Q. He

Managing Your City's Trees Can Help to Reduce Stormwater Runoff Volume
E. Kuehler

Utilizing A Watershed Priority Model to Expand Riparian Planting Efforts Across Tennessee
M. Johnson

Wednesday, April 3rd at 1:30 pm - 3:00 pm
STORMWATER
(Moderator: Paul Davis, PE)

City of Redbank Infrastructure Planning
C. Foster, L. Johnson

Viewing the Regulatory Landscape for Approvals of Proprietary Manufactured Treatment Devices for Stormwater Quality
M. Miller

Redefining Permit Compliance: Harnessing Qualitative Insights and School Partnerships
G. Judkins

Wednesday, April 3rd at 3:30 pm - 5:00 pm
INFRASTURE
(Moderator: Adrian Ward, Barge Design Solutions)

Response of Anaerobic Digestion to Temperature Fluctuation in Wastewater Treatment
X. Zhao, C. Swanson, Q. He

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

Developing and Implementing Water Infrastructure Grant Programs to Support Community Water Infrastructure
J. Tribble

A FRAMEWORK FOR APPLYING STORMWATER CONTROL MEASURES AS COMPENSATORY MITIGATION FOR STREAM RESTORATION

Ceara Parks Oliver[1]

With the introduction of the 2008 Mitigation Rule, stream restoration is now a burgeoning industry within the United States. Although the ruling allows for a range of restoration practices to apply for compensatory mitigation, there are few incentives to pursue alternative methods. However, innovation is attainable when utilizing the ruling's watershed approach to its full potential. As greater emphasis is placed on strategic site selection for mitigation, the watershed approach aims to promote ecological recovery with compensatory efforts. Although not widely used for compensatory mitigation, stormwater control measures (SCMs) are known for improving water quality and returning a watershed to a more natural state. This presentation will focus on developing a framework to apply SCMs as compensatory mitigation for stream restoration. To measure an SCM's ability to improve water quality within a stream, both sediment and habitat will be treated as currency. Sediment is supplied via in-stream erosion and catchment sources. With advancements in hydromodification, sediment is one of the most reported stressors of stream health. Considering that sediment is frequently utilized when determining compensatory mitigation for stream restoration, applying sediment as a currency for SCMs makes this a readily applicable approach. The second currency, habitat, is inspired by stream restoration's primary goal of providing ecological uplift. Although biology is seen as a driving force in stream evolution, stream restoration doesn't always result in biological recovery. This framework will dive into modeling SCMs in software such as River2D to reflect habitat potential for specific fish species. This currency provides a biological approach to ecological uplift for compensatory mitigation efforts. Ultimately, the objective of this framework will be to foster innovation and uncover the 2008 Mitigation Rule's full potential.

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EVALUATION OF BIOENGINEERED BANK STABILIZATION METHODS FOR USE IN STORMWATER MITIGATION PROGRAMS

Jaimie Armitage

Streambank erosion is a growing concern due to changes in climate patterns and increased land development, among other factors. Erosion can have detrimental effects on humans and aquatic organism life, but there are limited significant incentives to stabilize eroding shorelines. The Tennessee Department of Environment and Conservation (TDEC) recently approved the use of bioengineered shoreline stabilization as a possible application for stormwater mitigation in stormwater management programs across the state. In an effort to strengthen the protocol, a methodology based in the prevention of sedimentation will be created for stormwater professionals to effectively and more accurately credit bank stabilization in their stormwater mitigation programs. To strengthen TDEC's decision to allow credits for bioengineered bank stabilization as an alternative to hard armoring, a published process of ecosystem service quantification will be tested on both bioengineered and hard armored. Additionally, the accuracy of erosion rates produced by the Bank Stability and Toe Erosion Model (BSTEM) and remote monitoring of historical aerial photography analysis will be compared to results produced from field monitoring methods (two-dimensional surveying and erosion pin monitoring).

A NEW, CONNECTIVITY-BASED URBANIZATION INDEX FOR HYDROLOGICAL APPLICATIONS

Francesco Dell'Aira and Claudio I. Meier

The percentage of impervious area (IA) is a well-established measure of the level of urbanization in developed watersheds, used in a variety of applications ranging from assessing the impacts of land development activities on water quality, to deriving regional models for flood prediction in ungauged basins. In the last 20 years, however, multiple studies have pointed out the limitations of using IA as an indirect descriptor of the hydrological impacts of urbanization, because it is not able to account for spa□al patterns in the urbanized patches. Specifically, IA cannot distinguish between paved areas that are directly connected to the stream network (quickly contributing most of their precipitation input) from those that are disconnected, due to the presence of pervious areas along the runoff path from an impervious patch to the stream. Several alternative methodologies have been proposed in the literature to obtain more informative measures of the level of urbanization, but they all present some disadvantages. For example, some require information on the stormwater drainage network, which is rarely available, especially in the case of large-scale studies. Other methods analyze patterns in concurrent flow and precipitation series, attempting to implicitly determine the proportion of directly connected impervious area, under the assumption that it is this component of the basin's surface that governs its hydrologic response when smaller storms occur. But this approach comes with major uncertain□es related to the potentially variable contributions from pervious areas, depending on their antecedent soil moisture conditions. We propose here a new lumped, connectivity-based urbanization index, defined from the digital elevation model and the land-use map of a watershed. We analyze its correlation to other, established urbanization measures, and test its predictive power in regionalization approaches. Our new index improves the predictive power of regional models, when used in place of the traditional percentage of impervious areas, indica□ng that it can enhance the accuracy in flood predictions for ungauged basins.

INVESTIGATION OF MICROBIOLOGICAL WATER QUALITY DURING ROOFTOP RAINWATER HARVEST

Clifford S. Swanson, Tabitha Anaya, and Qiang He

With increasing impacts of climate change on water resources, there is a growing demand for sustainable practices of water management. One such option growing in popularity is the harvesting of rainwater during storm events, particularly runoff from rooftops. With the potential of rainwater harvest as a sustainable strategy to alleviate water shortage, it is imperative to characterize the quality of harvested rainwater and the factors that impact water quality. Therefore, the goal of this study was to gain a better understand of the quality of rainwater harvested from rooftop runoff. In this study, 8 different types of rooftops were examined across 6 different storm events of various intensity. A suite of water quality parameters were measured, including chemical oxygen demand (COD), total nitrogen (TN), alkalinity, total coliforms, and E. coli. Additionally, the microbiological water quality was assessed through 16S rRNA amplicon sequencing to analyze the microbial community of rainwater harvested from rooftop runoff. Storm characteristics, roofing materials, and age of roofing were considered as potential factors impacting water quality of rooftop runoff.

The results from this study found significant variations in water quality parameters of harvested rooftop runoff, including pH, turbidity, alkalinity, COD, and TN. It was revealed that pH (7.87±0.83), turbidity (2.34±2.02 NTU), and TN (0.81±0.89 mg/L-N) were parameters highly correlated with the preceding antecedent dry period, with spearman correlation coefficients of 0.59, 0.51, and 0.43, respectively. The storm intensity was most impactful on COD (26.57±20.45 mg/L), with a spearman correlation coefficient of 0.310. Additionally, it was found that roofing material had significant impact on water quality where shingle roofs contributed to significantly higher alkalinity and turbidity than metal and tile roofs. As a measure of microbiological water quality, elevated E. coli levels were observed in rooftop runoff from both metal and shingle roofs, with concentrations reaching 277 CFU/100mL and 1,335 CFU/100mL, respectively. Nonetheless, it was revealed that many of the bacteria isolated from the rooftop runoff are not known to be pathogenic, with the dominant bacteria coming from populations including Massilia, Duganella, Methylobacterium, and Burkholderiaceae, as well as many other environmentally associated taxa. Further analysis showed that roofing material and age of roofing were the most important determinants of microbiological water quality.

These results revealed that stormwater characteristics are important for the physical and chemical quality of harvested rain water, whereas roofing materials and age are key determinants of microbiological water quality. It is evident that harvested rooftop runoff is not directly suitable for potable uses due to elevated levels of E. coli. However, with the finding that the microbiological water quality of harvested rooftop runoff is mostly shaped by the roof itself, the potential to enhance the microbiological water quality of harvested rooftop runoff through roof design needs to be explored.

MANAGING YOUR CITY'S TREES CAN HELP TO REDUCE STORMWATER RUNOFF VOLUME

Eric Kuehler[1]

Urban trees provide an abundance of benefits to residents including increased water quality. Leaves and branches intercept and retain rainfall to keep a portion of that volume from becoming runoff. Rainfall intensity under canopy is dampened thus helping to delay peak flow to storm drains. Trees also transpire water from the soil thus allowing for increased water storage in the soil between rainfall events. Using urban forest management tools developed by the USDA Forest Service (i-Tree Canopy and i-Tree Eco), Metro Nashville was able to quantify the stormwater benefits that the trees provide in a small (221 acres) combined sewer system with 28% tree canopy cover. Based on local, 2020 meteorological data, the trees in the Boscobel CSS retained approximately 4 million gallons of rainfall and transpired about 12 million gallons of water. An estimated 31,000 gallons of rainfall is retained per rainfall event during the growing season when trees are in leaf. With this information Metro Water Services can better calculate treatment costs, develop strategies to help further reduce peak flow of stormwater runoff into the combined sewer system, and manage its urban forest resource to maximize stormwater benefits.

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UTILIZING A WATERSHED PRIORITY MODEL TO EXPAND RIPARIAN PLANTING EFFORTS ACROSS TENNESSEE

Maddy Johnson

Riparian forests are unique ecosystems that act as transitional areas between land and water, and are a vital part of a healthy and functional stream ecosystem. Riparian forests are increasingly threatened by urban development, agriculture, and invasive species. This issue is further exacerbated by the lack of awareness among the public of the connection between native riparian vegetation and water quality. As our landscape changes rapidly, it is becoming increasingly essential to preserve functional riparian zones, increase riparian and urban tree plantings, and lead interdisciplinary educational programs for various public and private audiences to facilitate state-wide restoration initiatives. The Community Riparian Restoration Program for Tennessee (CRRP) is funded by the Tennessee Division of Forestry, and aims to drive community involvement in riparian restoration through applied research. Spatial analysis using water quality indicators and watershed land cover were performed to develop a data-driven watershed prioritization model for riparian restoration. The CRRP uses this model to connect with organizations across Tennessee to map and strategically plan future tree planting and bank repair projects to maximize water quality benefits. The model is also used to identify and connect with entities in high-need communities to organize interactive and educational workshops focused on riparian buffer establishment, management, and expansion. The prioritization model is an effective communication tool that will help organize, visualize, and strategically plan future riparian restoration initiatives across the state.

CITY OF RED BANK INFRASTRUCTURE PLANNING

Clayton Foster and Leslie Johnson

The City of Red Bank (City) is located within the City of Chattanooga. While other City services are maintained by the City of Chattanooga, the City maintains all stormwater infrastructure within its 4,700 acre service area. The City does not have any existing maps of their stormwater assets and a stormwater master plan has not been performed.

The City is located between two ridge lines which drain to a single stream, Stringers Branch. Stringers Branch follows the main commercial corridor and most developed sections of the City. A large portion of Stringers Branch is a concrete lined creek with few natural components and has approximately 2,600 linear feet of completely encapsulated stream draining under the foundations of businesses, parking lots, churches, roads, and restaurants. As this corridor developed, the City's aging stormwater infrastructure has become stressed which will ultimately create flooding in areas which never previously had issues or worsen existing areas. In 2023, the City decided to establish a plan to collect data of the previously unmapped system and to evaluate problem areas along Stringers Branch. Additionally, a master plan to document the existing stormwater infrastructure and to prioritize stormwater drainage system improvement projects will be proposed.

This presentation will review the early stages of the master planning process through the pilot study which will be completed in Spring 2024. We will present (1) a review of existing data, (2) key decisions made when selecting inventory and modeling requirements, (3) basin prioritization, (4) schema creation for data collection, and (5) condition assessment metrics. We will review unique data collection techniques including 360-degree cameras for condition assessment and 3D laser scanning technologies for the encapsulated portions of Stringers Branch. For the pilot study area, we will review the (6) existing conditions hydraulic model, (7) alternatives development and evaluation process, and (8) final recommendations. Additionally, we will review project-specific tools created for data management. This is an important project to City's ongoing efforts to protect their investments, respond to aging and undersized infrastructure, and prepare for the future growth of the City.

VIEWING THE REGULATORY LANDSCAPE FOR APPROVALS OF PROPRIETARY MANUFACTURED TREATMENT DEVICES FOR STORMWATER QUALITY

Mark B. Miller, P.G.[1]

The implementation of post-construction, permanent proprietary manufactured treatment devices (MTDs) has matured significantly over the past 25 years. Water quality treatment standards for site developments commonly specify an amount of pollutant to be removed by stormwater control measures (SCMs) with a treatment goal of 80% TSS removal. Some states apply their MTD approval standards statewide while other states allow local authorities having jurisdiction (AHJs) to apply their own MTD approval standards. Furthermore, some states only provide a narrative standard for stormwater management and offer no guidance for MTD approvals. A series of maps will illustrate the geographic distribution of MTD approval standards according to: (a) statewide approval programs in 10 states, (b) select AHJs that administer their own MTD approval programs and the basis for those approvals, and (c) 12 states with narrative standards in their stormwater manuals.

Statewide MTD approvals rely either on laboratory-testing or field-testing protocols that include the New Jersey Department of Environmental Protection (NJDEP) laboratory test, the NJDEP TARP Tier II field test (inactive), the Washington State Department of Ecology TAPE field test, or the California Water Resources Control Board approval process specifically for Trash Treatment Control Devices that target particles ≥ 5 mm (5,000 microns). Local AHJs typically, with some notable exceptions and deviations, approve MTDs based on the NJDEP laboratory test, TARP, or TAPE. A spirited debate continues pertaining to the merits and pitfalls between laboratory-testing and field-testing. AHJs should consider the pros and cons of these testing venues given their fundamental differences and MTD performance data they yield. Note that for states and AHJs that include phosphorus as a pollutant of concern, TAPE is the only protocol for total phosphorus treatment. A map will also illustrate the distribution of 10 states that include an MTD approval provision that addresses phosphorus removal.

An example pertaining to MTD model sizing resulting from different particle size distributions (PSDs) between laboratory- and field-testing will be explored. When a laboratory test uses a coarse-grained PSD when compared to a field test, or vice versa, the coarse-grained PSD typically results in a higher maximum treatment flow rate (MTFR) for the same MTD. In that case a smaller MTD model could be sized having a smaller footprint compared to an MTD test having a fine-grained PSD and lower MTFR (larger footprint). A sizing and consequences comparison for the same MTD having two different PSDs will be presented.

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REDEFINING PERMIT COMPLIANCE: HARNESSING QUALITATIVE INSIGHTS AND SCHOOL PARTNERSHIPS

Gretchen Judkins

The Clean Water Act of 1972 prohibits the discharge of pollutants through a point source into waters of the United States unless done so within parameters set forth by a National Pollution Discharge Elimination System (NPDES) Permit. To protect water quality from polluted runoff, NPDES permit holders must use structural and non-structural controls to reduce and filter stormwater. The Metropolitan Government of Nashville and Davidson County holds a Phase I municipal separate storm sewer system (MS4) permit, managed by the NPDES Section of Metro Water Services, Stormwater. Nashville's permit requires a public education program targeting people living and working in the county to prevent point source pollution before it occurs.

While Nashville's public education program covers a wide range of topics, from MS4 permit compliance in other Metro departments to Tennessee Multi Sector Permit compliance at industrial facilities, most education focuses on residential pollution. When reporting the accomplishments of the program to its regulator, the Tennessee Department of Environment and Conservation, the norm consists of providing quantitative data such as the number of brochures distributed or people spoken to at an event. However, NPDES now invests resources in collecting qualitative research to determine the efficacy of its public education program to provoke behavior change causing a reduction in water pollution throughout Metro Nashville and the barriers that may prevent this change. This presentation will explore the expansion of NPDES partnerships with various schools to facilitate the evolution of the public education program while continuing to maintain MS4 permit compliance.

RESPONSE OF ANAEROBIC DIGESTION TO TEMPERATURE FLUCTUATION IN WASTEWATER TREATMENT

Xinghan Zhao[1]*, Clifford S. Swanson[1], and Qiang He[1]

Anaerobic digestion (AD) is a microbially-catalyzed wastewater treatment technology capable of simultaneous pollutant removal and production of a renewable biofuel in the form of methane gas. Despite the advantages of anaerobic digestion, the broader adoption of this technology for waste treatment has been hindered by concerns of potential process instability resulting from the susceptibility of methanogenic microbial populations to changes in process conditions. Fluctuation in temperature represents one of the most common disturbances in AD operation. To gain an understanding of how microbial communities involved in AD respond and adapt to sudden temperature fluctuations, two sets of triplicate anaerobic digesters, sharing a common inoculum, were examined over a 4-month period. These bioreactors were initially operated at 35°C, when the temperature of one set of triplicate bioreactors (treatment) were dropped to 32°C, maintained for 14 days, and then returned to the initial operating temperature at 35°C. The performance of both sets of triplicate bioreactors was monitored with parameters including biogas production, removal of chemical oxygen demand reduction (COD), volatile fatty acids (VFA) concentration, and pH. Responses of the microbial communities were characterized by 16S rRNA amplicon sequencing.

Results from the monitoring of AD process performance indicate that a significant change in pH was observed in response to the temperature down shift, decreasing from 6.80 in control bioreactors to 6.50 in treatment bioreactors. This corresponded with a reduction in methane production from 140 to 120 mL/L/Day in the treatment bioreactors. The 16S rRNA gene amplicon sequencing showed that the species richness decreased in treatment bioreactors as compared to the control bioreactors. Further microbial community analysis showed significant and persistent shifts in the methanogen populations in response to the temperature down-shift. In treatment bioreactors, the relative abundance of Methanoregula increased from 14% to 39% while Methanosaeta, Methanosarcina and Methanospirillum decreased significantly from 5% to 1%, from 40% to 18% and from 18% to 1%, respectively. Process performance in the treatment bioreactors, measured as biogas production, recovered to a large extent after the initial disruption. However, the changes in anaerobic microbial community persisted. Results from this study demonstrate the robustness of anaerobic digestion process in response to fluctuations in temperature, providing insight for the development of effective operational practices. Further studies are needed to investigate the significance of the lack of correlation between process performance and the underlying microbial community.

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* Presenting author

INTORDUCTION 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. 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 purpose of this project is to implement a Supplemental Environmental Project (SEP) for the City of Memphis to resolve the Settlement Agreement and Order of the Case WPC16-0054 and to develop the sanitary sewer inspection program along Nonconnah Creek. The goals of the project are to improve water quality, to protect the environment, and to prevent any environmental damage in the future.

The project was divided into two phases; Phase I from Nonconnah Creek between the confluence of the Mississippi River and Highway I-55 (later revised to Getwell Road), and Phase II from Getwell Road to Forest Hill Irene Road. During the course of the first phase study, thirteen access roads were planned and one demonstration site at New Horn Lake Road was constructed. The SSAP was continued and extended to Phase II. A total of thirty-six access roads was identified and planned. During 2021 and 2023 forty-nine planned access roads were inspected three times. The inspection data including field inspection routes, photos/videos, and inspection forms were collected and built into an SSAP-GIS Viewer. The data were analyzed and published on the ESRI website.

Several major conclusions were drawn from this study: (1) Currently the City of Memphis does not have sufficient access roads to support sanitary sewer inspection and maintenance; (2) the construction of a sanitary sewer access system along the streams has a number of barriers that need to be considered and carefully evaluated before and after construction; (3) the City of Memphis needs to have a formal database to record all access road information; and (4) the inspection and the maintenance of the sanitary sewer access system needs to be well maintained to prevent any catastrophic failures.

[1] Professor, Surface Water Institute, and Department of Civil and Environmental Engineering, Christian Brothers University

DEVELOPING AND IMPLEMENTING WATER INFRASTRUCTURE GRANT PROGRAMS TO SUPPORT COMMUNITY WATER INFRASTRUCTURE

Jennifer Tribble

Since 2021, the Tennessee Department of Environment and Conservation (TDEC) has been developing and implementing water infrastructure grant programs to support community water infrastructure through funding under the American Rescue Plan Act (ARPA). This historic investment of $1.35 billion toward Tennessee's drinking water, wastewater, and stormwater infrastructure required a balance of expediency to program due to ambitious federal deadlines and strategic thought to promote long-term improvements in water infrastructure. As a part of this program, TDEC's Division of Water Resources worked alongside the Tennessee Association of Utility Districts to develop the Tennessee Infrastructure Scorecard, which aggregates financial, operational, and environmental data from water systems and provides them a snapshot of potential areas for investment and improvement. TDEC required all water systems participating in the ARPA-funded grants to complete the Tennessee Infrastructure Scorecard, which gives TDEC a holistic overview of water systems statewide. In this presentation, TDEC will discuss the context and approach to the Tennessee Infrastructure Scorecard and ARPA-funded grants and share early data and takeaways from the results of scorecard completion.

SESSION 3-A

Thursday, April 4th at 8:30 am - 10:00 am
ALGAE
(Moderator: Forbes Walker, UTK)

Composition of Epilithic Soft-Algal Assemblages in Infralittoral Zones of Tennessee Reservoirs and Correlations of Composition to Trophic State
J. Lebkuecher, D. Redwine

Effects of the Nuisance Alga Didymosphenia Geminata on Benthic Macroinvertebrate and Fish Communities
N. Burger, J. Murdock

Managing Algal Challenges in Southeastern Source Water Reservoirs
M. Huddleston, T. Goldsby

COMPOSITION OF EPILITHIC SOFT-ALGAL ASSEMBLAGES IN INFRALITTORALZONES OF TENNESSEE RESERVOIRS AND CORRELATIONS OF COMPOSITION TO TROPHIC STATE

Jefferson Lebkuecher[1] and Daniel Redwine

ssemblages of infralittoral periphytic algae are understudied due partially to the historical emphasis on phytoplankton and other water-column characteristics to evaluate the integrity of lentic systems. We tested the null hypothesis that characteristics of epilithic soft-algal assemblages at infralittoral sites in reservoirs of Middle and East Tennessee do not infer trophic state. One infralittoral site in five mesotrophic and five eutrophic reservoirs in Middle and East Tennessee was sampled to determine the relative abundance of epilithic soft algae, concentrations of epilithic chlorophyll (chl) a, and water concentrations of chl a, total phosphorus (TP), and total nitrogen (TN). The concentration of epilithic chl a correlates significantly to the concentration of TP but not to TN. The water concentration of chl a does not correlate significantly to concentrations of TP, TN, or epilithic chl a. Trophic-state indicator values for 102 epilithic soft-algal taxa are calculated as the abundance-weighted average of the concentration of epilithic chl a normalized between 0 and 100. The trophic-state indicator values indicate the relationship of the abundance of algal taxa to trophic state and contribute to our limited knowledge of the effects of eutrophication on infralittoral soft-algal taxa. Trophic-state indices are calculated as the mean abundance-weighted average of trophic-state indicator values for algal taxa of an assemblage. The index values infer the trophic state of the sites and are the first to use epilithic concentrations of chl a as opposed to water-column characteristics to indicate trophic-state optima for periphytic algae of lentic systems. The indices are easy to calculate and provide novel tools to help evaluate and monitor the trophic state of infralittoral sites in reservoirs of Middle and East Tennessee.

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EFFECTS OF THE NUISANCE ALGA *DIDYMOSPHENIA GEMINATA* ON BENTHIC MACROINVERTEBRATE AND FISH COMMUNITIES

Natalie E. Burger[1,2] and Justin N. Murdock[2]

Didymosphenia geminata (Didymo) is a stalk-forming diatom that can change benthic community structure by blanketing stream bottoms with thick mats, which have reduced fish production in several countries. Mats were first documented in eastern Tennessee streams in 2004; however, trout biomass in these heavily managed streams remains high. We investigated the effects of Didymo mats on macroinvertebrate community structure and macroinvertebrate and trout resource use in the Clinch, South Holston, and Watauga rivers in Tennessee to ascertain how these systems maintain energetic input into fishes that rely on benthic foods. Pre-Didymo and two years of post-Didymo macroinvertebrate data demonstrate limited mat effects on macroinvertebrate community structure. Macroinvertebrate stable isotopic signatures suggested slight shifts in resource use from biofilms to macrophytes with high Didymo coverage (>50%). Brown and rainbow trout in both high and low Didymo sites primarily assimilated turbellarians and Didymo stalks. Lipid analyses supported isotope results. Didymo mats change food resource availability for some macroinvertebrates but not for trout and does not significantly change macroinvertebrate community structure. Didymo is not used as a significant food resource in proportion to its abundance in fish or macroinvertebrates. Overall, it appears that both macroinvertebrates and trout have adapted to Didymo mats, and other parameters such as temperature may have greater effects on benthic communities than Didymo. Additional research may illuminate the mechanisms for community resiliency in eastern Tennessee tailwaters and beyond.

[1] Barge Design Solutions, Inc., Nashville, TN
[2] Department of Biology, Tennessee Tech University, Cookeville, TN

MANAGING ALGAL CHALLENGES IN SOUTHEASTERN SOURCE WATER RESERVOIRS

Terry Goldsby[1] and Matt Huddleston[2]

Water bodies challenged by excessive growth of algae, cyanobacteria, and diatoms may not be new, but information as to the how, where, and why is emerging every day. Lakes (e.g., drinking water reservoirs) and rivers are subject to natural and anthropogenic activities, including storm events and subsequent runoff, watershed and shoreline land use, water level management, and point and non-point source pollution. Managing source waters for the provision of reliably high-quality drinking water under these conditions is challenging. Some or all of these factors can combine to influence algal growth that can result in taste and odor and even toxin production. Examples of such compounds are geosmin and 2-methyl isoborneol, or MIB, which are tertiary alcohols naturally produced by certain species of algae, cyanobacteria, and diatoms commonly found in surface waters. They can inhabit the water column, the benthos, and be transient throughout the day and season. When conditions are "right", the onset of an adverse taste and odor event can be rapid, requiring drinking water utilities to be both reactive and preventative in their source water management plans. Managing taste and odor events often involves chemical applications to source waters to suppress the growth of taste and odor producing algae. This presentation will explore source water management approaches and lessons learned for taste and odor prevention and treatment, relying on several case studies. Topics include the importance of algae identification, algaecide application prescriptions and techniques, algaecide options, margins of safety for non-target species, and environmental conditions conducive for successful treatments.

[1] Jones Lake Management, Guntersville, Alabama

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SESSION 3-B

Thursday, April 4th at 8:30 am - 10:00 am
TECHNOLOGY
(Moderator: Brandy Hayes, RES)

Emerging IoT Technologies for Establishing Water Resiliency
R. Chuang, D. Huang

Proactive Management of Flooding with Innovative Technology for Every Budget
C. Kozora

A Tool for Accurate Stream Network Delineation from High-Resolution Digital Elevation
Md. Bhuyian, K. Gordon, D. Blackwood

EMERGING IOT TECHNOLOGIES FOR ESTABLISHING WATER RESILIENCY

Roy Chuang[1], Dannis Huang[2], Joseph Fan[3]

Emerging technology supported water monitoring tools provide solid support for establishing sustainable water resources management. Artificial Intelligence (AI)-enabled PCs with machine learning mechanism become powerful tool for data analysis for water and sediment levels, drone-based surveillance information, and meteorological data.

A multi-layer smart staff gauge electrical conductivity (EC) profiler using web-based Internet of Things (IoT) technologies for real-time data collection and transmission was introduced in 2023 for monitoring water and sediment levels, erosions, water health trending and flash flood early warning and more.

Low power consumption data transmission technologies such as Wi-Fi 802.11 ah and/or 4G narrow band (NB-IoT) and bluetooth data transmission protocol are introduced for sending data to mobile devices and web-based server. A rechargeable battery with solar panel is used for un-interrupted power supply to assure continuous data collection/transmission.

Connecting to cloud such as AWS GovCloud, the build-in end-to-end security solution provides high level hardware security and is now one of the fastest ways to connect to cloud service.

Connecting to local data center, Nexcom eSAF provides cybersecurity protection solution. eSAF Platform Manager and edge gateway device secure log data, evaluate vulnerability risks, establish the correlation of cybersecurity incidents, and behavior analysis reporting.

The function of self-calibration for elevation or height deviation is added to the Smart Staff EC Profiler for more accurate data collection. An earth vibration sensor can be added to the system for landslide or subsidence monitoring.

A flexible display tool, AIC Video Wall, is introduced for simultaneous display of geospatial data on split screens ranging from 2x2 to 4x4. The multi-screen display tool provides powerful assistance in decision making for water resources management via visual inspection of simultaneous display of real-time and/or historical data of water/sediment level, erosion, water pollution trending.

[1] ESG Consultant (roychuang@nexcom.com.tw)

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[3] Director, Product Management (josephfan@nexcom.com.tw)

PROACTIVE MANAGEMENT OF FLOODING WITH INNOVATIVE TECHNOLOGY FOR EVERY BUDGET

Chuck Kozora

As water managers and engineers, it's important to understand our watersheds, urban landscapes, their response to extreme events like heavy precipitation, and efficient ways to protect and inform the public with the resources we have available. Of the numerous tools at our disposal, there are many benefits to a flood warning system, including knowing in time where flooding issues could occur, enabling proactive action, and protecting lives while maintaining a high level of water quality. Many communities know they need to modernize their water data management, but shy away for cost, implementation pains, or the learning curve as they move away from a legacy client-server application.

A TOOL FOR ACCURATE STREAM NETWORK DELINEATION FROM HIGH-RESOLUTION DIGITAL ELEVATION

Md. N.M. Bhuyian[1], Kris Gordon[2], and David Blackwood[3]

The 3D Elevation Program (3DEP) by the U.S. Geological Survey (USGS) National Geospatial Program provides high-resolution (1m) digital elevation model (DEM) for almost the entire Tennessee. This data has wide-ranging applications such as streamflow quantification, inundation mapping, flood management, eco-hydraulic assessment, river morphology analysis, sediment transport modeling, and stream-wetland mitigation. However, high-resolution does not necessarily equate to high accuracy in terrain processing for hydrologic studies. For instance, a 1m resolution USGS DEM may depict stormwater infrastructures, culverts, and small bridges as instream obstructions. It primarily results from the postprocessing of DEM which typically eliminates large bridges and stream crossings along major roads only. Current postprocessing practice is better suited for a moderate (10m) to low-resolution (30m or more) DEM where such structures are subpixel size. In contrast, they can span over multiple pixels in a 1m DEM. Thus, it can be incorrectly characterized as a "digital dam" by conventional hydrologic terrain processing algorithms. To address this issue, a hydroconditioning algorithm is presented in this study to automatically identify and handle the digital dams in a 1m resolution 3DEP DEM. A preliminary experiment on the Piney Creek HUC12 watershed identified more than 100 digital dams of varying sizes. Stream network derived utilizing this algorithm shows a better representation of stream alignments than NHD Plus HR flowlines. Furthermore, the treated DEM reduces the unnecessary damming effect in a 2D rain-on-grid hydrodynamic simulation leading to a more accurate representation of flowrate and inundation adjacent to the digital dams.

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POSTERS

Exploring spatiotemporal trends and hotspots in heavy precipitation in Tennessee counties
E. Afriyie, I. Luffman

Surface water and sediment contamination of Per- and polyfluorinated alkaline substances (PFAS) in streams and reservoir coves on a Tennessee military base
P. Blum, J. Murdock

Identifying Irrigation Events Based on Remote Sensing Data
M. Farhadi Machekposhti

Identifying Tradeoffs in Ecosystem Services Due to Restoration Practices In Restored Agricultural Wetlands
Z. Porter, J. Murdock

Potential of Electrochemical Degradation in Waters with High Hardness/Salinity
C. Wang, C. Swanson, Q. He

Effects of irrigation regime in three soil types on the soybean yield in humid subtropical climate
S. Xie

Geostatistical Trend Analysis for the Distribution of Per- and Polyfluoroalkyl Substances (PFAS) in Alabama Surface Waters
O. Abimbola, I. Luffman

Assessment of Microplastics Treatability by Field-Installed Bioretention Systems
M. Chanda, L. Wright, M. Woody, JR. Bathi

Deep Learning Based Flood Early Warning System with Firefly Algorithm for The Blackburn Fork Watershed, Tennessee
G. Fordjour, A. Kalyanapu

Retrofitting a Parking Lot and Surrounding Area for Improved Stormwater Management: Cookeville, TN Case Study
C. Hitchcock, B. Cunningham, F. Nur, G. Fordjour, K. Hair, A. Kalyanapu, T. Datta

Urban Expansion and Land Use and Land Cover (LULC) Change in Tri-Cities, Tennessee
R.B. Ishan, I. Luffman

Determining Watershed Pollution Environmental Justice Scenarios Using Data from Ambient Water and Fish Tissue
B. Lane, P. Li

Increasing HAB Monitoring in Urban Environments and Addressing Diversity in the Geosciences through Illuminating Projects
D. Moore, R. Archer, K. Hill, T. Byl

Identifying optimal ranges of light for harmful algal growth in riverine algae
D. Tryba

Updating the Cummins Falls flood warning system using field infiltration measurements
A. Brant

Paleoenvironmental Reconstruction of the South Fork Holston River Using Unionidae as Environmental Indicators
A. Keenan, I. Luffman, C. Widga

Design and Implementation of a Mobile Sampling Device for Quantifying Microplastic Concentrations in Stormwater Runoff
K. Kimes, D. Brown, L. Norman, A. Agnew, J. Bathi

The creation of state-wide standards assessing water quality and watershed health face difficulties regarding fairness across ecoregions
C. Martin

Seasonal Variation in Water Quality at Rocky Mount State Historic Site
K. Pollard

Determining the Extent to which Zinc Enhances the Toxicity of Microplastics
V. Palanati

EXPLORING SPATIOTEMPORAL TRENDS AND HOTSPOTS IN HEAVY PRECIPITATION IN TENNESSEE COUNTIES

Emmanuel Afriyie[1]* and Ingrid Luffman[1]

INTRODUCTION

Heavy precipitation patterns are changing in response to climate change. Studies have linked excessive rainfall and extreme climate events to floods and flash floods that have directly caused property damage and loss of lives (Alipour, 2020; Arnell & Gosling, 2016). On July 16, 2023, a rainstorm in eastern Pennsylvania produced 7 inches of rain in 45 minutes, causing a flash flood that killed five people (Barker & Donegan, 2023). In Tennessee (TN), a record 20.73-inch 24-hour rain event recorded on August 21, 2022 caused a flash flood that resulted in 22 fatalities and over $100 million in property damages (NOAA, 2021; Gabriel, 2022). This event set a new TN state 24-hour rainfall record (SCEC, 2021). These recent series of large hydrologic events points to the importance of understanding the spatial and temporal dynamics of heavy precipitation events. Spatiotemporal analysis, a uniquely appropriate geographic tool, was used to analyze the trends and emerging hotspots and cold spots in heavy precipitation in Tennessee counties. This study is an important step toward better understanding spatiotemporal trends in heavy precipitation events and will be useful in hazard mitigation planning in Tennessee at both state and county levels.

APPROACH

For this study, a heavy precipitation event was defined as a 24-hour precipitation accumulation that exceeded the frequency duration thresholds for specified recurrence intervals. To construct the dataset, first rainfall frequency duration estimates for 24-hour rainfall events for 1-year, 2-year, and 5-year recurrence intervals (return periods) were extracted from the NOAA Rainfall Atlas 14 volume 2 version 3 (available at https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html?bkmrk=tn). Values were extracted at the centroid of each county. Second, daily (24-hour) rainfall accumulation was downloaded for the 95 TN counties for each year from 1991-2022 using the closest stations to the county centroid. Third, 24-hour rainfall totals in each county were compared to the 24-hour 1-year recurrence interval rainfall estimate for all days within the study period. An event was assigned a code of one (1) if the 24-hour rainfall total exceeded the frequency duration estimates for the 1-year recurrence intervals and zero (0) otherwise. The tally of exceedances was aggregated into the sum of exceedance per county per year using pivot tables in MS Excel. This workflow was repeated for 2-year and 5-year recurrence intervals, creating three heavy precipitation event datasets defined by the three recurrence intervals; these were used as inputs in ArcGIS Pro to build heavy precipitation event space-time cubes for the analysis. Trend analysis and emerging hot spots analysis were conducted in ArcGIS Pro to assess the spatiotemporal trends in heavy precipitation in TN counties.

RESULTS AND DISCUSSION

Trend analysis revealed that 1-year heavy precipitation is trending up in 19 counties distributed across the state with a downtrend in one county (Figure 1). Uptrends in 2-year heavy precipitation were identified in 17 counties, with downtrends in two counties (Figure 1), and uptrends in 5-year heavy precipitation were identified in seven counties (Figure 1). All these trends were at a 90% or higher confidence level. Several

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counties in middle Tennessee were identified as heavy precipitation sporadic and consecutive hotspots for all return periods (Figure 2). The results indicate that heavy precipitation hotspots are localized in central TN and that heavy precipitation events are generally trending up in TN counties.

The number of counties experiencing uptrends in heavy precipitation in TN far outnumbers the number of downtrends, suggesting that the recent heavy precipitation events are increasing around the state. For example, the catastrophic rainfall event in Humphreys County in 2021 that became the state's new record 24-hour rainfall was caused by a single heavy precipitation event classed as a 1000-year event (The Tennessean, 2021). The intensity of the rainfall (20.73 inches over 24 hours) influenced the magnitude of the resultant flash flood event that claimed 22 lives and caused $100 million in property damages.

CONCLUSION

This study evaluated the spatiotemporal trends and hotspots in heavy precipitation in Tennessee counties. We assessed a 32-year (1991-2022) record of 24-hour precipitation using intensity duration frequencies to define heavy precipitation for 1-year, 2-year, and 5-year return periods and provide a comprehensive assessment of the patterns in the clusters of the heavy precipitation events in Tennessee. The results indicate that middle Tennessee is experiencing increasing heavy precipitation that can be hazardous and requires the attention of meteorological hazard mitigation stakeholders. This study is an important step toward understanding spatiotemporal trends in heavy precipitation events better and will be useful in hazard mitigation planning in Tennessee at both state and county levels.

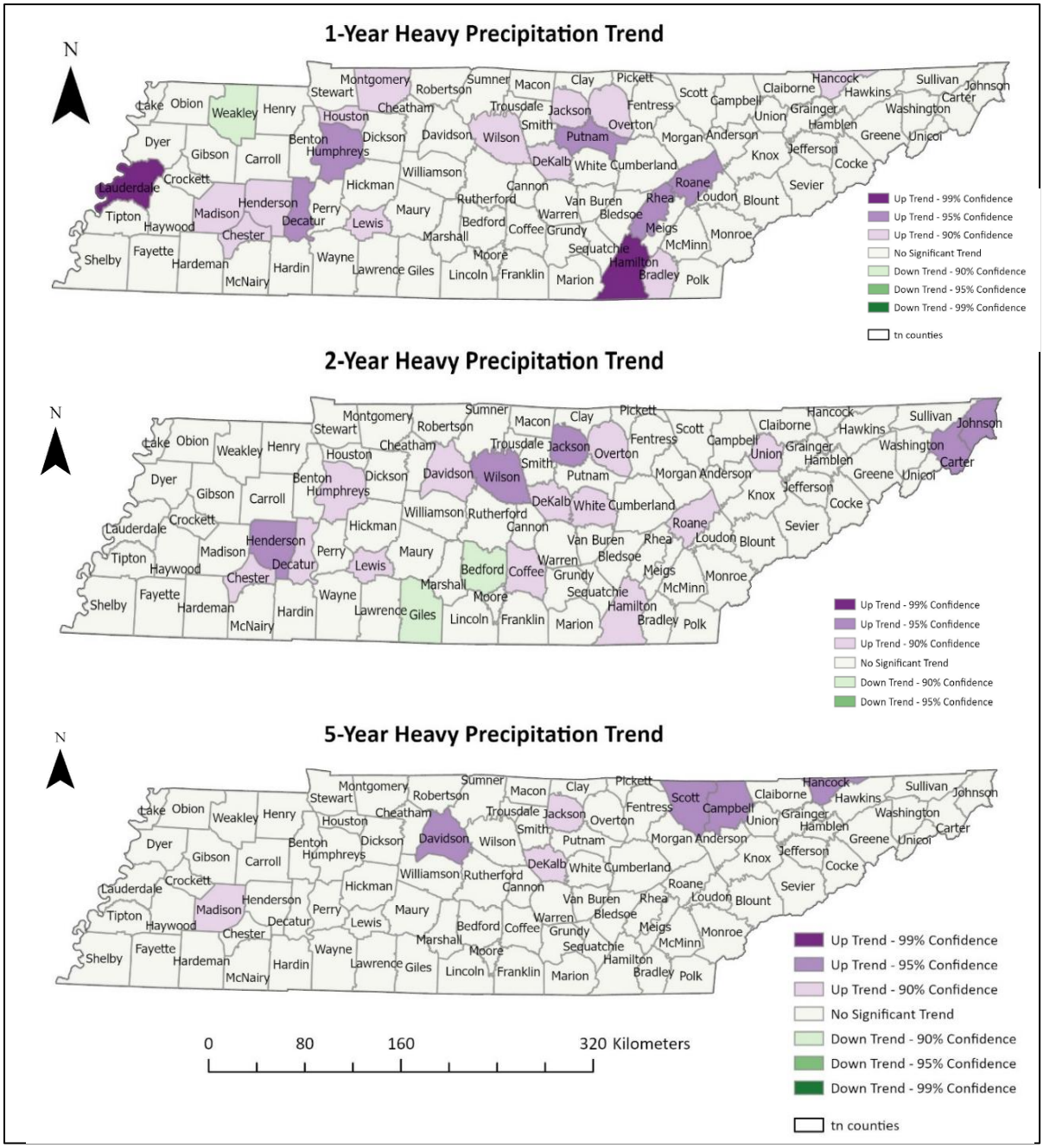

Figure 1: 1-, 2-, and 5-year return Heavy precipitation trends in Tennessee counties from 1991 to 2022.

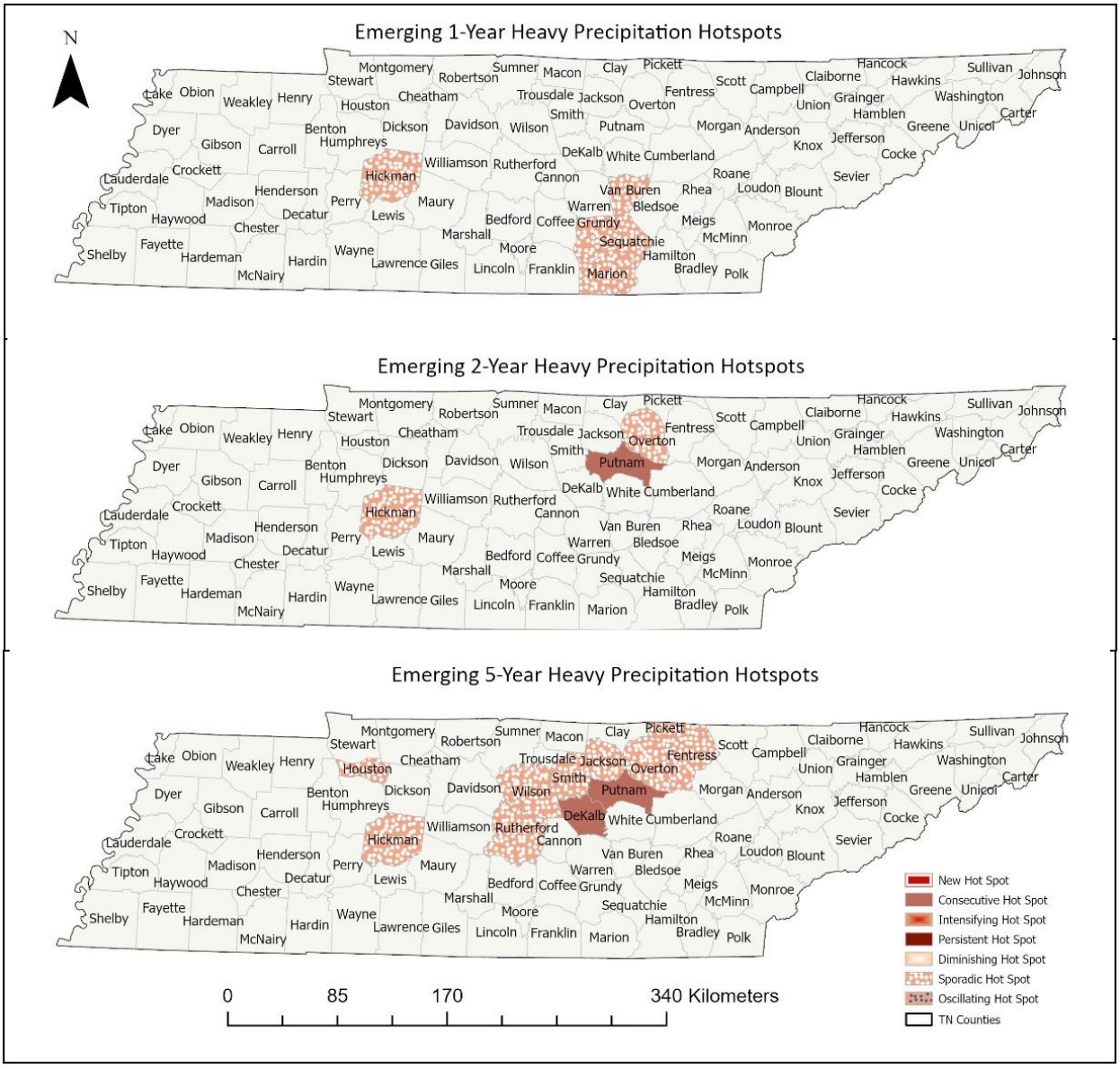

Figure 2: Emerging hotspots for heavy precipitation in 1-, 2-, and 5-year return periods in Tennessee counties from 1991 to 2022.

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SURFACE WATER AND SEDIMENT CONTAMINATION OF PER- AND POLYFLUORINATED ALKALINE SUBSTANCES (PFAS) IN STREAMS AND RESERVOIR COVES ON A TENNESSEE MILITARY BASE

Peter W Blum, IV and Justin N. Murdock

Per- and polyfluorinated alkyl substances (PFAS) are a diverse group of human-generated molecules that consist of a non-polar fluorinated carbon chain and a polar head. Due to their beneficial properties, they are used in many personal, industrial, and military applications. However, PFAS compounds are associated with endocrine disruption and other negative health outcomes, raising concerns about their widespread use and ubiquity in household products. United States military installations have experienced PFAS contamination through various activities, including the use of aqueous film-forming foams for fire control and regular firefighting training exercises. Groundwater testing around Arnold Air Force Base in Tullahoma, TN, has revealed PFAS contamination exceeding EPA recommendations for maximum PFAS contamination in drinking water. However, less is known about the current contamination affecting streams that drain from the base into the surrounding reservoirs or if and how PFAS moves through aquatic and riparian food webs. In this study, we found evidence findings from a survey of 14 stream and reservoir cove sites surrounding the base. These findings will be used to design a subsequent research project assessing the movement and concentration of PFAS in stream and riparian fauna.

IDENTIFYING IRRIGATION EVENTS BASED ON REMOTE SENSING DATA

Mabood Farhadi Machekposhti

Currently, Tennessee lacks information on agricultural water withdrawal, while quantifiable water use from streams and aquifers is essential for state and regional water management. For example, the interstate aquifer conflict (Mississippi v. Tennessee, 2021) highlights the importance of knowing agricultural water withdrawal in order to protect Tennessee water rights. This study aims to detect field-scale irrigation events within irrigated farms in West Tennessee based on remote sensing methods. Time series of soil water content data with 100 m resolution from six irrigated sites and six nearby rainfed sites has been obtained from Planet Lab. These six irrigated and non-irrigated sites have in-field monitoring to verify the remotely sensed data. The changes in soil moisture within each consecutive available date (1-3 days) will be evaluated for each pair of irrigated and rainfed fields. If soil moisture for both fields increases ($\geq 2cm^3.cm^{-3}$) compared to the previous date, a rainfall event likely occurred between the two consecutive dates. If a significant increase in soil moisture happened ($\geq 2cm^3.cm^{-3}$) only within the irrigated field, an irrigation event likely occurred. If soil moisture from the two nearby farms does not change or slightly decreases ($\leq 2cm^3.cm^{-3}$), there is likely no rainfall and no irrigation event between the two consecutive days. The findings of this study will help water managers develop a dataset for groundwater withdrawal in West Tennessee without tying water use to individual farmers.

IDENTIFYING TRADEOFFS IN ECOSYSTEM SERVICES DUE TO RESTORATION PRACTICES IN RESTORED AGRICULTURAL WETLAND

Zoë Porter[1] and Justin Murdock[1]

Intensification of agriculture within the lower Mississippi River Basin (LMRB) has dramatically altered wetland environments and expanded inorganic fertilizer use, resulting in excess nutrients being transported across the landscape and downstream to the Gulf of Mexico. A major goal of the USDA Wetlands Reserve Program (WRP) and Wetland Reserve Enhancement Partnership (WREP) is the restoration of wetland ecosystem services; however, the environmental conditions that optimize nutrient retention and minimize greenhouse gas fluxes are poorly understood. This study is identifying tradeoffs in these ecosystem services in restored agricultural wetlands due to different hydrologic and vegetation restoration practices. We are studying WRP/WREP easements in western Tennessee to identify the environmental conditions that control these biogeochemical transfer pathways and determine the environmental conditions and restoration practices that optimize nutrient and greenhouse gas flux rates. Here we present initial data investigating nutrient and greenhouse gas flux rates in restored easements and discuss potential tradeoffs in services. This work will inform how future restorations could be optimized to ensure the long-term functional success of federal restoration programs in the face of a changing climate.

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POTENTIAL OF ELECTROCHEMICAL DEGRADATION IN WATERS WITH HIGH HARDNESS/SALINITY

Chenyang Wang[1]*, Clifford S. Swanson[1], and Qiang He[1]

Advanced oxidation processes (AOP) offer a robust technical option for the degradation of recalcitrant pollutants. An emerging AOP is electrochemical oxidation, where redox-active species generated from electrochemical reactions are exploited for efficient pollutant degradation. The application of electrochemical AOP, however, is limited in waters with elevated hardness/salinity due to scale formation on the electrodes, resulting in rapid deterioration of treatment efficiency. To address this challenge, a novel strategy of alternating polarity was developed and tested to mitigate scale formation with enhanced electrochemical degradation effectiveness.

An electrochemical reactor system was developed with simulated produced water typically found in oil/gas industry. Methylene blue was used as a model pollutant in this bench-scale, continuous system with the monitoring of water quality parameters, such as pH, major cations and anions, and potential oxidants. Operational parameters tested included electrical load applied (i.e., voltage and current), electrode materials (i.e., boron-doped diamond vs graphite), and polarity configuration (i.e., constant polarity vs alternating polarity). Under all conditions tested, the electrochemical removal of methylene blue was greater than 95% in 30 min, evidence of high efficiency of degradation. Water quality analysis further suggests that free chlorine, likely produced from electrochemical conversion of chloride, was the dominant oxidant at levels reaching 2,000 ppm. Under constant polarity, the reaction pH reached over 8.0, leading to scale formation at a rate of 18.01 mg/hr on the cathode. With alternating polarity, the reaction pH was lower, stabilized around 7.5, resulting a much slower scale formation rate of 4.99 mg/hr with sustained degradation efficiency. Findings from this study demonstrated the effectiveness of alternating polarity in reducing scale formation with sustained degradation efficiency. Ongoing efforts are focused on the optimization of the electrochemical process for the degradation of more recalcitrant pollutants.

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EFFECTS OF IRRIGATION REGIME IN THREE SOIL TYPES ON THE SOYBEAN YIELD IN HUMID SUBTROPICAL CLIMATE

Shuhua Xie

The humid subtropical climate of the Mid-South region results in high rainfall; however, only 18% of the annual precipitation falls with the critical growth period of soybean. This difference poses a challenge for farmers: how to manage irrigation efficiently to conserve water while achieving higher yields in such climatic conditions and varied soil types. To address this, soybean irrigation experiments were conducted over two years (2018 and 2019) in Jackson, TN, in a field including three soil types: deep silt, silt over sandy, and sandy soil. The primary objectives were to determine the optimal irrigation regimes for these soil types and to evaluate the effectiveness of soil matric potential sensors and the water balance method in managing irrigation. Irrigation treatments, supplementing rainfall at rates of 1.6 and 1.1 inches per week, were initiated from the first bloom (R1), first pod (R3), and first seed (R5) stages. These treatments were compared against a rainfed control across the three soil types. The findings revealed no significant impact of irrigation treatments on deep silt soil. However, significant differences were observed in sandy and silt over sandy soils. In sandy soil, a significant linear relationship was found between irrigation water and soybean yield. Both soil matric potential sensors and water balance methods proved effective for scheduling irrigation.

GEOSTATISTICAL TREND ANALYSIS FOR THE DISTRIBUTION OF PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) IN ALABAMA SURFACE WATERS

Olatayo Abimbola[1]* and Ingrid Luffman[1]

INTRODUCTION

Water quality in lakes, rivers, and streams in the United States has been affected by discharges from wastewater treatment plants, industrial operational waste, and various non-point sources, causing concerns about the contamination of surface water bodies. Among the emerging contaminants of concern (CECs), per- and poly-fluoroalkyl substances (PFAS), commonly known as forever chemicals, have been identified as one of the most critical groups (Sunderland et al., 2019). PFAS were originally created in 1938 and have been widely used by the chemical manufacturing industry since the 1950s (Voulgaropoulos, 2022) for consumer products such as cookware and food packaging, stain- and water-repellent products and fabrics, and the formulation of aqueous film-forming foam (AFFF) fire extinguishers (Viticoski et al., 2022). Recent studies have found widespread occurrence of PFAS in approximately 75% of tap water across the United States (Muir and Miaz, 2021; Voulgaropoulos, 2022). Human exposure to PFAS primarily occurs through food and drinking water (Steenland et al., 2013), with notable impacts observed on surface water used for tap water production in the USA due to discharge and diffusion from PFAS production sites (Banzhaf et al., 2017).

Alabama ranks 4th in the US for the highest level of toxic PFAS contaminants in its water supply (MEC&F, 2016), found widely in the eight north Alabama water systems (ADPH, 2016). Viticoski et al., 2022, in their statewide assessment, identified a particular coldspot for PFAS in Alabama northern rivers (Tennessee River), with increased levels of PFAS effluents being observed downstream of the river. Several studies have linked the contamination of surface water in North Alabama to a 3M plant located on the Tennessee River (ADPH, 2016; MEC&F, 2016). Recent studies have also shown that PFAS' origin in Alabama's water can be linked to the chemical industry, waste water treatment plants (WWTPs), and military sites (Andrew & Montgomery, 2016; Viticoski et al., 2022). Despite existing research on pollution emission sources of PFAS in Alabama surface waters, source apportionment for spatial distribution of PFAS in its water bodies is still unclear.

Statistical techniques to identify specific emission sources like principal component analysis, cluster analysis, and multivariate linear regression can result in significant errors (ADPH, 2016; Cheng et al., 2023). One promising statistical model for source apportionment and spatial distribution trend analysis for emerging contaminants (ECs) is spatial autocorrelation, applied by Cheng et al., 2023, in the Tai Lake basin in China. However, using spatial autocorrelation for multiple ECs can be challenging in a complex natural environment with high concentrations of certain pollutants. Ideally, spatial autocorrelation would be applied to a single contaminant with multiple sources in surface water systems to more accurately predict the source and concentration in space.

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To that end, in this study, we reanalyzed a published PFAAs dataset of Alabama surface water to address two major questions:
a.) What are the spatial distribution trends of PFAS in Alabama surface water?
b.) What are the major potential sources of PFAS in Alabama?

METHODS

A published dataset of seventy-five (75) PFAS samples from ten (10) major river basins (Alabama (AC-1,6), Black Warrior (BT), Cahaba (AC), Chattahoochee (CH), Conecuh (CO), Coosa (CT), Tallapoosa (CT), Tennessee (TN), Tombigbee (BT and TM), Mobile River and Tributaries (TM)) and four (4) minor rivers (Escatawpa (ES), Perdido (FP), Choctawhatchee (CW), and Yellow rivers (FP)) in Alabama was downloaded from https://doi.org/10.1016/j.scitotenv.2022.155524, representing previous work on the statewide study for PFAS fate in Alabama's surface water (Viticoski et al., 2022). The dataset was exported to ArcGIS Pro (ESRI - Environmental Systems Research Institute) for spatial analyses. Major rivers were extracted using defining query from the layer properties in ArcGIS Pro, and the sampling point dataset was loaded to display the inlets and outlets of the catchment area along the major rivers (Figure 1). Subsequently, data spatial autocorrelation was employed to identify potential sources of PFAS and spatial distribution trends in Alabama surface water. Locations of sampling sites and sum of PFAS (∑PFAS) were the input variables. Since the sample data were presented as points, and the discharge of contaminants from sources to surface water was predominantly influenced by distance, we used a default Euclidean Distance spatial weight matrix to generate Global Moran’s I and Anselin Local Moran’s I cluster and outlier map. Assessing the Global spatial autocorrelation index results will allow for acceptance or rejection of the null hypothesis of PFAS distribution randomness within the study region and Local Moran's I will uncover the distribution characteristics, distinguishing between positive and negative PFAS autocorrelations and revealing spatial clustering trends (Brown et al., 2023).

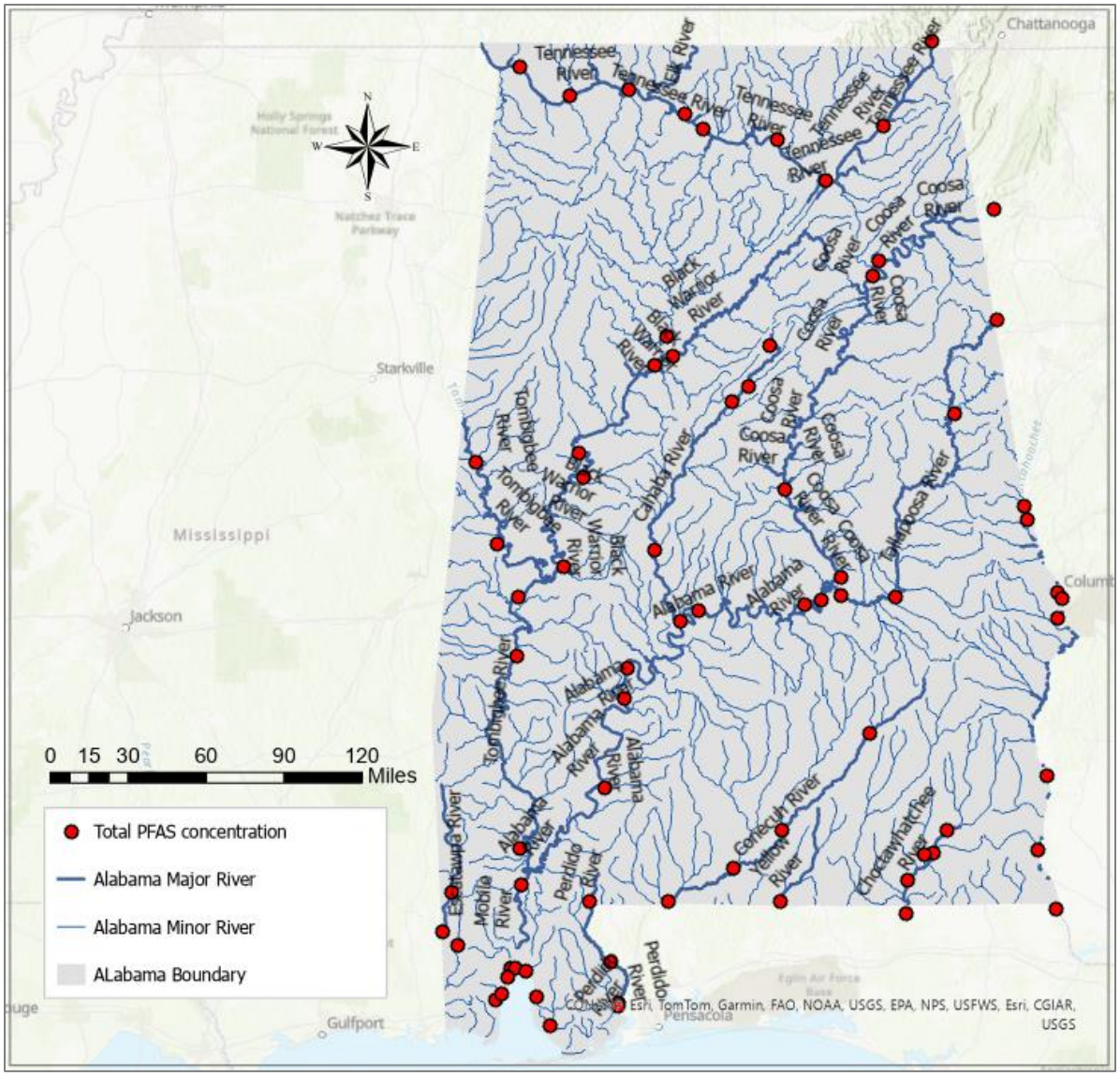

Figure 1. Simplified hydrologic map of Alabama showing locations of sampled PFAS across the surface waters, taken from inlets and outlets, confluences, and headwaters of the ten (10) major and four (4) minor rivers represented in blue.

RESULTS AND DISCUSSION

The Global Moran's index for ∑PFAS is 0.41, indicating that the PFAS concentrations are clustered in space (high values near high values, low values near low values). Twenty-two (22) PFAS concentrations (HH (6), HL (2), LH (4), LL (10)) exhibited distinct and significant ($p<0.000$) spatial agglomeration characteristics. These results suggest the existence of point emission sources of PFAS in the area.

The Local Moran's I result identify specific spatial agglomerations of high and low concentrations (Anselin, 1995). Therefore, Local Moran's I (Figure 2) was employed to pinpoint spatial agglomerations of PFAS analytes. Six (6) sample points formed High-High clusters and ten (10) formed low-Low clusters, Low-High clusters (four points) and High-Low clusters (two sample points) indicate outliers, and the remaining 53 samples did not show any significant spatial clustering. High-concentration clusters were all located in the southeast of Alabama, primarily along the Alabama River and its tributary, the Coosa River, indicating the concentration zone of anomalies and suggesting a strong likelihood of emission sources in the vicinity of

this region (Cheng et al., 2023). These two rivers are the most important river systems in Alabama, traversing the majority of counties in the state and contamination in Alabama's surface water along the Coosa River can potentially be linked to industrial landfills, military bases, airports, and municipal WWTP (Figure 3) (Viticoski et al., 2022).

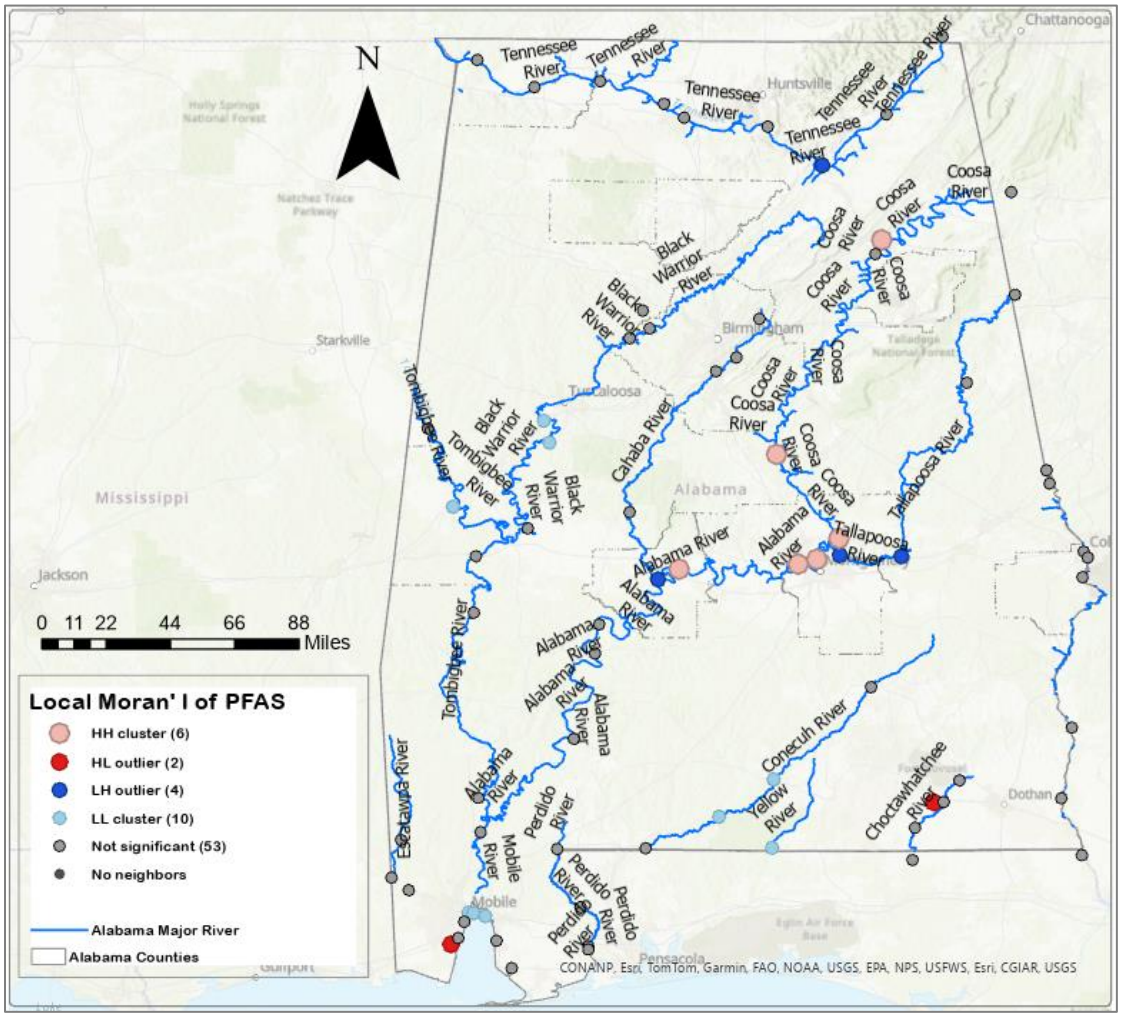

Figure 2. Anselin local Moran 'I spatial cluster and outlier significant map for seventy-five PFAS in Alabama surface water.

High clusters of WWTPs, industrial sites, and military bases upstream of the Coosa and Alabama Rivers could be responsible for the spatial agglomeration of PFAS in the area. On the other hand, the Coosa and Tallapoosa Rivers are heavily linked to effluents from Georgia rivers, indicating the possibility of PFAS effluents from Georgia contributing to the increasing contaminants in the Alabama River. For example, carpet manufacturers in Dalton, GA, have their effluents treated by a municipal wastewater treatment plant with possible input through the tributaries from Georgia connected to the Coosa River (Viticoski et al., 2022).

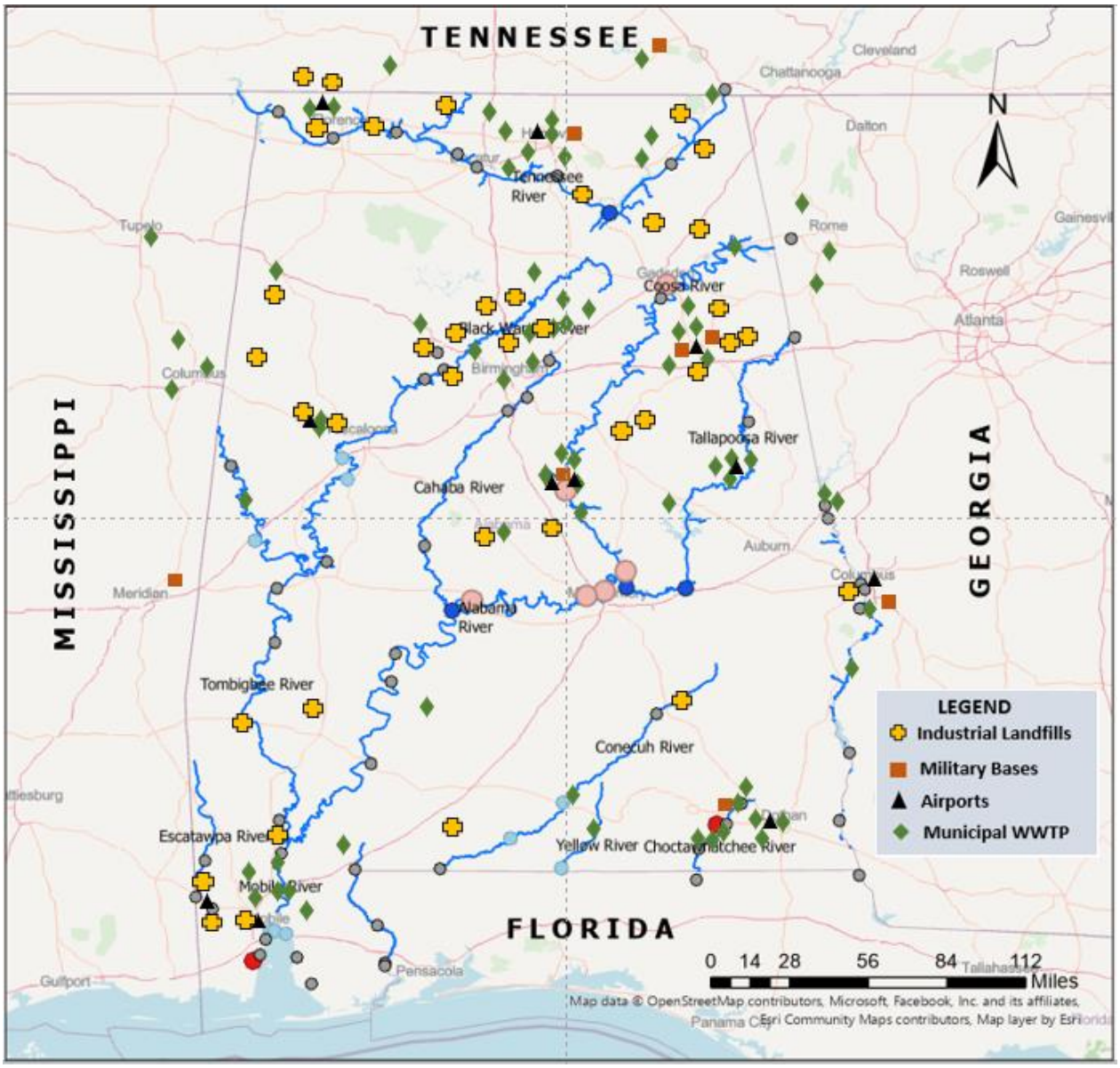

Figure 3. Potential source apportionment of PFAS contamination from WWTP effluents, industrial landfills, military bases, and Airports to Alabama river system (Viticoski et al., 2022). in the 67 counties of Alabama.

CONCLUSION

Spatial agglomeration techniques were used to identify spatial clusters for ∑PFAS analytes with their respective potential sources. A pattern of High-High (HH) spatial cluster of six (6) PFAS contaminant hotspots were identified along Alabama River and its tributary, Coosa River. Conversely, notable coldspots characterized by Low-Low (LL) concentration of PFAS clusters were observed along the Tombigbee River and Black Warrior Rivers (both tributaries to the Mobile River), as well as along the Conecuh and Yellow Rivers. The application of spatial agglomeration techniques is useful as a complement to the previous statewide assessment of PFAS in Alabama river systems, to identify hotspots and indicate the location of potential sources. Consequently, it is recommended that PFAS monitoring and assessment be carried out at locations with High-High clusters of PFAS with respect to industrial, military bases, airports, and WWTPs influence.

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ASSESSMENT OF MICROPLASTICS TREATABILITY BY FIELD-INSTALLED BIORETENTION SYSTEMS

Mithu Chanda[1], Laura Wright[1], Meggie Woody[1], and Dr. Jejal-Reddy Bathi, Ph.D., PE[1]

The escalating environmental threat posed by plastic pollution has prompted intensive research across various ecosystems, including aquatic and terrestrial environments. Soil-dependent stormwater bioretention systems (BRS), designed to mitigate the impact of urban runoff, can act as crucial receptors and pathways for pollutants. BRS offers a unique environment where the occurrence and vertical distribution of microplastics (MP) necessitate investigation. This paper adopts a multi-faceted approach to elucidate microplastics' prevalence and vertical distribution within bioretention systems, which are crucial components of sustainable stormwater management infrastructure. Field sampling was conducted across two active and controlled urban bioretention settings of downtown Chattanooga to capture the variability in MP distributions within systems. The sampling strategy included collecting soil samples at different depths (2", 12", and 24") within bioretention cells, enabling a comprehensive analysis of the vertical distribution and retention of MP. The sample processing and identification of MP were achieved through oxidative digestion, density separation, and advanced fluorescence microscope techniques. Our analysis revealed the prevalence of microplastics, primarily in the form of fragments and fibers, within bioretention systems, indicating their potential to infiltrate and persist within these engineered ecosystems. MP concentrations exhibited spatial and depth-dependent variations, highlighting the need for a nuanced understanding of the factors influencing their distribution within bioretention media. The findings also underscore the importance of considering bioretention systems as potential MP reservoirs and conduits, necessitating targeted mitigation strategies.

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DEEP LEARNING BASED FLOOD EARLY WARNING SYSTEM WITH FIREFLY ALGORITHM FOR THE BLACKBURN FORK WATERSHED, TENNESSEE

George K. Fordjour[1] and Alfred J. Kalyanapu[1]*

Flood disasters are frequently occurring natural disasters worldwide at various spatial scales, significantly affecting lives and infrastructure. To mitigate the devastating impacts of floods, effective Flood Early Warning Systems (FEWS) are crucial. This study focuses on enhancing FEWS by developing a Deep Learning (DL)-based model, optimized with the Firefly Algorithm (FA) for precise water level predictions in the Blackburn Fork River watershed, located in Putnam and Jackson Counties in middle Tennessee region. While traditional FEWS depend on physical modeling, the integration of Machine Learning (ML) and DL promises more dynamic and accurate forecasting methods. This study specifically aims to optimize Long Short-Term Memory (LSTM), Gated Recurrent Units (GRU), and one-dimensional (1D) convolutional neural networks (CNN) models with the FA. Preliminary findings show promising results, particularly with the LSTM model optimized with FA, which demonstrates good performance with a Mean Absolute Error (MAE) of 0.032ft and Mean Squared Error (MSE) of 0.005ft2. The anticipated outcome of this study is to substantially improve flood prediction accuracy, facilitating timely warnings and safe evacuation strategies for vulnerable locations such as Cummins Falls State Park. By contributing to the community's safety and readiness, this research aims to serve as a foundational work for future advancements in FEWS through the application of sophisticated computational techniques.

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RETROFITTING A PARKING LOT AND SURROUNDING AREA FOR IMPROVED STORMWATER MANAGEMENT: COOKEVILLE, TN CASE STUDY

Bruce Cunningham[1], Caroline Hitchcock[1], Faria Nur[1], George Fordjour[1], Kalei Hair[1], Dr. Alfred Kalyanapu[1], and Dr. Tania Datta[1]

In the United States, stormwater runoff contributes to approximately 15% of impaired river miles and serves as the leading cause of pollution in fresh and brackish receiving waterbodies. The volume of runoff can also result in severe flooding, which poses risks to human lives and causes extensive damage to infrastructure, property, and downstream ecosystem. An example of an impaired waterbody due to urban stormwater runoff is Cookeville, TN's Pigeon Roost Creek. The creek's impairment stems from urbanization, channelization, municipal discharges, and sanitary sewer overflows, leading to excess nutrients, and habitat changes. The city also experiences flooding due to excess stormwater runoff. To reduce these impacts, the Willow Tree Shopping Center parking lot and adjacent greenspace along Willow Avenue in Cookeville, TN were selected to evaluate if retrofitting stormwater control measures (SCMs) in an existing impervious area can alleviate the downstream consequences to Pigeon Roost Creek. This project aims to model the reduction of stormwater quantity generated within the study area by at least 50% and the reduction of pollutant runoff by designing and modeling SCMs utilizing the Environmental Protection Agency's Storm Water Management Model (SWMM). The Willow Tree Shopping Center was retrofitted by implementing five bioretention basins in the parking lot and one in the greenspace. These SCMs reduced the runoff volume by 55% during 10-year 24-hour storm events, as well as removed approximately 55% of Total Suspended Solids (TSS), Total Phosphorus (TP), Total Nitrogen (TN), and Bacteria. Additionally, an educational outreach program was developed to better engage and educate the Cookeville community in stormwater management, bioretention basins, and native vegetation.

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URBAN EXPANSION AND LAND USE AND LAND COVER (LULC) CHANGE IN TRI-CITIES, TENNESSEE

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INTRODUCTION

The southeastern United States has experienced a significant LULC change since 1940, drastically reducing cropland over the following 60 years (Ellenburg et al., 2016). From 1982 to 2012, Tennessee's developed land doubled from 1,656.4 to 3,115.8 thousand acres (Hall & Azad Hossain, 2020). This growth is mirrored in the Tri-Cities (Bristol, Johnson City, and Kingsport), in northeastern Tennessee (https://www.tridec.org/population/, n.d.). This region has undergone significant urbanization since the early 1900s as the growth of metropolitan areas began. Since 2000, the Tri-Cities footprint has enlarged by 15% through annexation, coinciding with notable Land Use and Land Cover (LULC) change. The aim of this study was, therefore to:

1) Asses the urban expansion; and
2) Analyze the LULC change in the Tri-Cities between 2001-2021.

METHODS

This study investigated urban expansion within the Tri-Cities region by utilizing city boundary data obtained from the Tri-City Development Council and land cover data sourced from the National Land Cover Database (NLCD) for 2001 and 2021. The NLCD data, classified into sixteen distinct Land Use and Land Cover (LULC) categories, underwent change detection analysis in ArcGIS Pro to delineate the conversion dynamics of these categories over the two-decade period. To facilitate a comprehensive analysis, the initial sixteen LULC classes were aggregated into nine broader land use types consistent with the NLCD classification scheme (Table 1). Qualitative and quantitative assessments of land use change were then performed for 2001 and 2021. This analysis involved subtracting pixel values between the two satellite images to highlight spatial patterns and the extent of change.

Table 1. Types of different land use classes.

Land Use Types	Land Use Classes
Open Water	Open Water
Developed	Developed, Open Space
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, High Intensity
Barren Land	Barren Land
Forest	Deciduous Forest
	Evergreen Forest
	Mixed Forest
Shrubland	Shrub/Scrub
Herbaceous	Herbaceous
Cultivated	Hay Pasture
	Cultivated Crops
Wetlands	Woody Wetlands
	Emergent Herbaceous Wetlands

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RESULTS AND DISCUSSION

The evolving urban landscape of the Tri-Cities region (Figure 1) highlights the dynamic expansion of city boundaries for Johnson City, Kingsport, and Bristol. Notable increases were observed post-2000, depicted in darker shades of purple to underscore the region's urbanization trajectory. While all three municipalities experienced substantial boundary growth from 2001 to 2010, a nuanced narrative emerged thereafter, notably for Bristol, which displayed a more conservative expansion pattern compared to the other two cities. Kingsport experienced the most urban expansion by 18% while Bristol's boundary increment remained comparatively modest, only 7% (Figure 2). Overall, the total area of the three cities increased by 13% between 2001 to 2021.

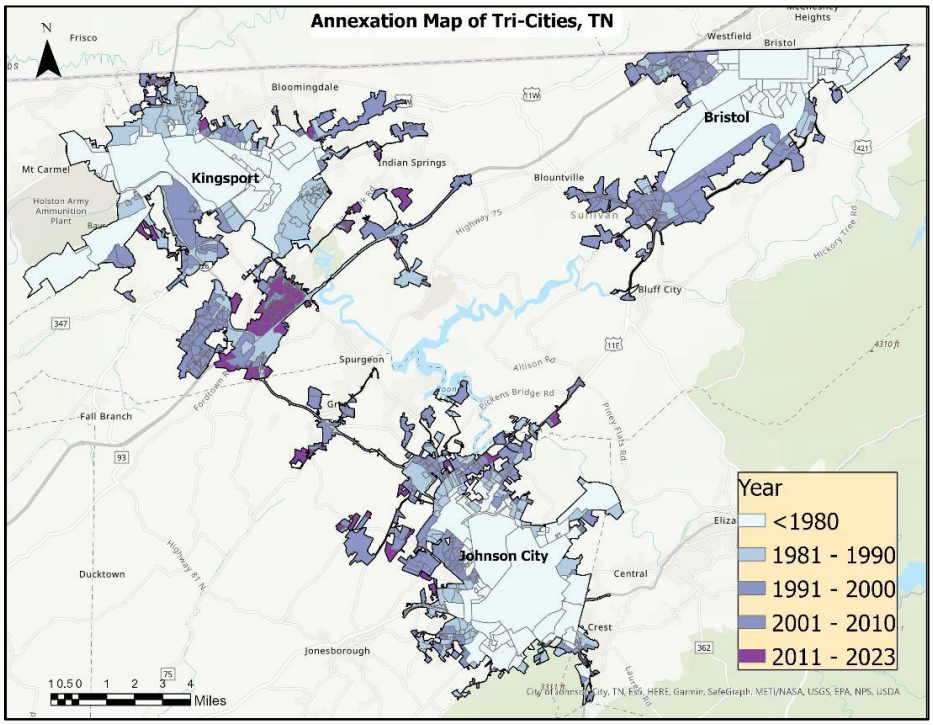

Figure 1. Annexation Map of Tri-Cities, Tennessee

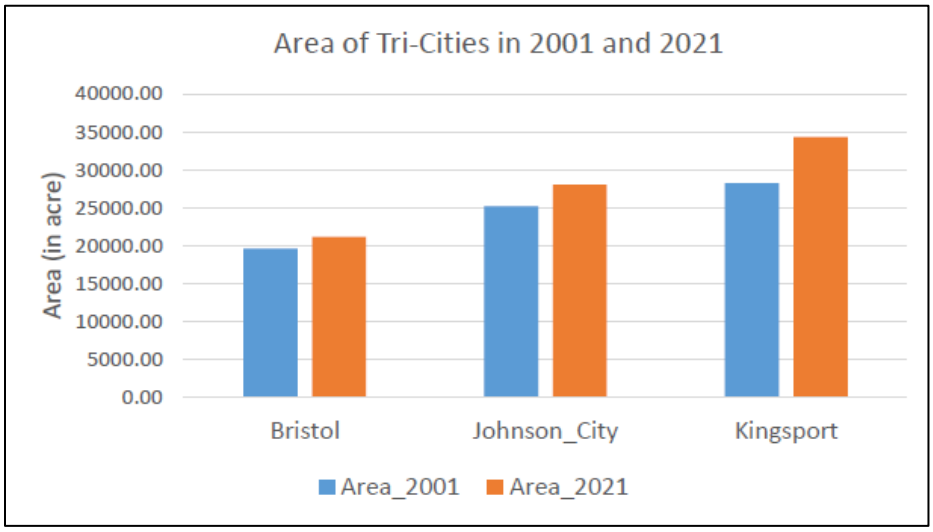

Figure 2. City boundary expansion in Tri-Cities, Tennessee

Figure 3 displays land use classes for 2001 and 2021. Table 2 enriches this analysis by offering a granular breakdown of land area changes across various land use classes, shedding light on areas of expansion and contraction. Notably, the significant expansion of developed medium-intensity land stands out, signaling a pronounced urbanization trend, followed closely by the augmentation of developed low-intensity areas and developed high-intensity zones. Conversely, the marginal increase in cultivated crops land underscores shifting agricultural dynamics amidst rapid urbanization pressures. Among classes experiencing contraction, hay/pasture land emerges as the most affected, indicative of land use trade-offs accompanying urban expansion. Deciduous forest land, too, witnessed a notable reduction, underlining the complex interplay between urbanization and environmental conservation efforts. Figure 4 provides a visual synthesis of these changes, revealing contrasting trends in land use dynamics from 2001 to 2021. The Tri-Cities changing urban-rural interface is comprehensively depicted by the notable losses in open water, forests, and cultivated areas juxtaposed with gains in developed land, barren land, shrubland, herbaceous land, and wetlands.

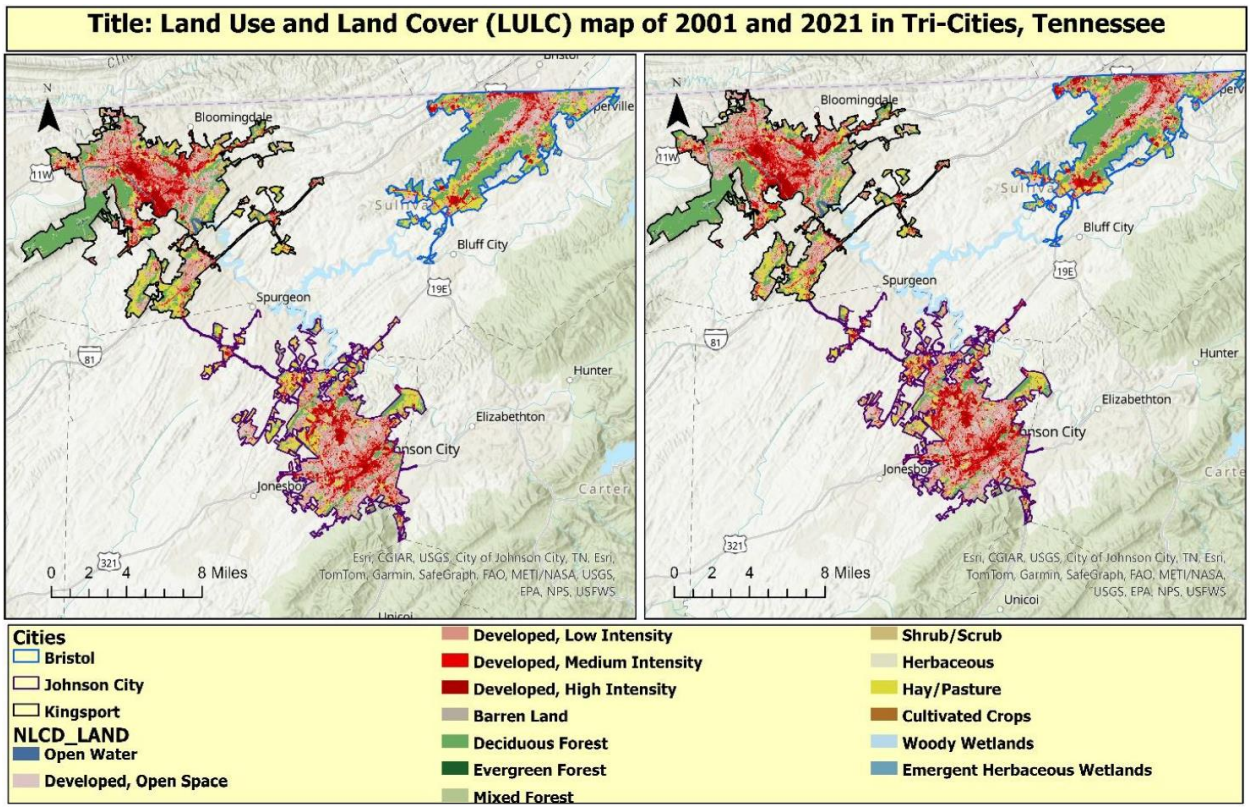

Figure 3. Land Use and Land Cover (LULC) map for 2001 (left) and 2021 (right) in Tri-Cities, Tennessee

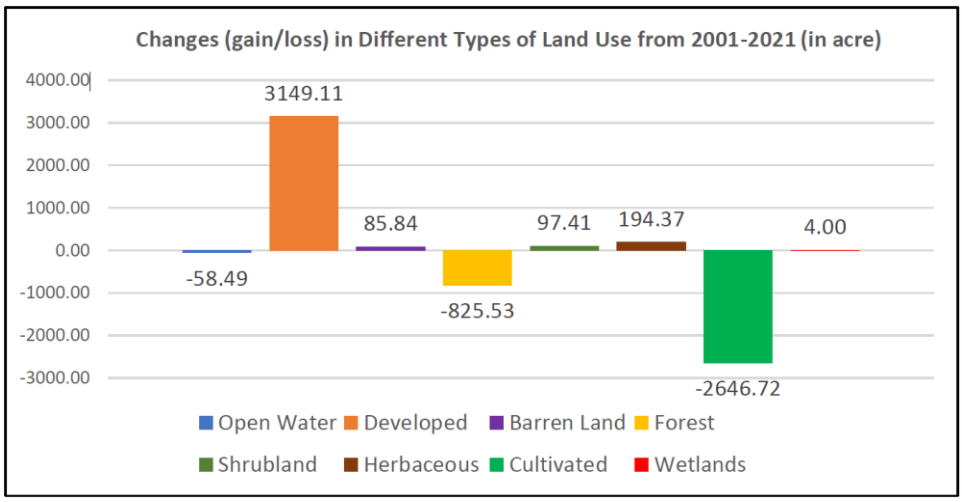

Figure 4. Graph of changes (gain/loss) in different land use types from 2001 to 2021 in Tri Cities, Tennessee

While most of the land area (nearly 94%) remained unchanged in terms of its LULC (Figure 5; Table 2), the LULC change map (figure 5) highlights a significant transformation, primarily involving the conversion of cultivated land to developed land (3.7% of land area) during this two-decade period. This change is concentrated in northwestern Johnson City, southeastern Kingsport, and southwestern Bristol, showing infilling development between the three cities. Additionally, 650.06 acres of forest land (1%) was converted into developed areas between 2001 and 2021.

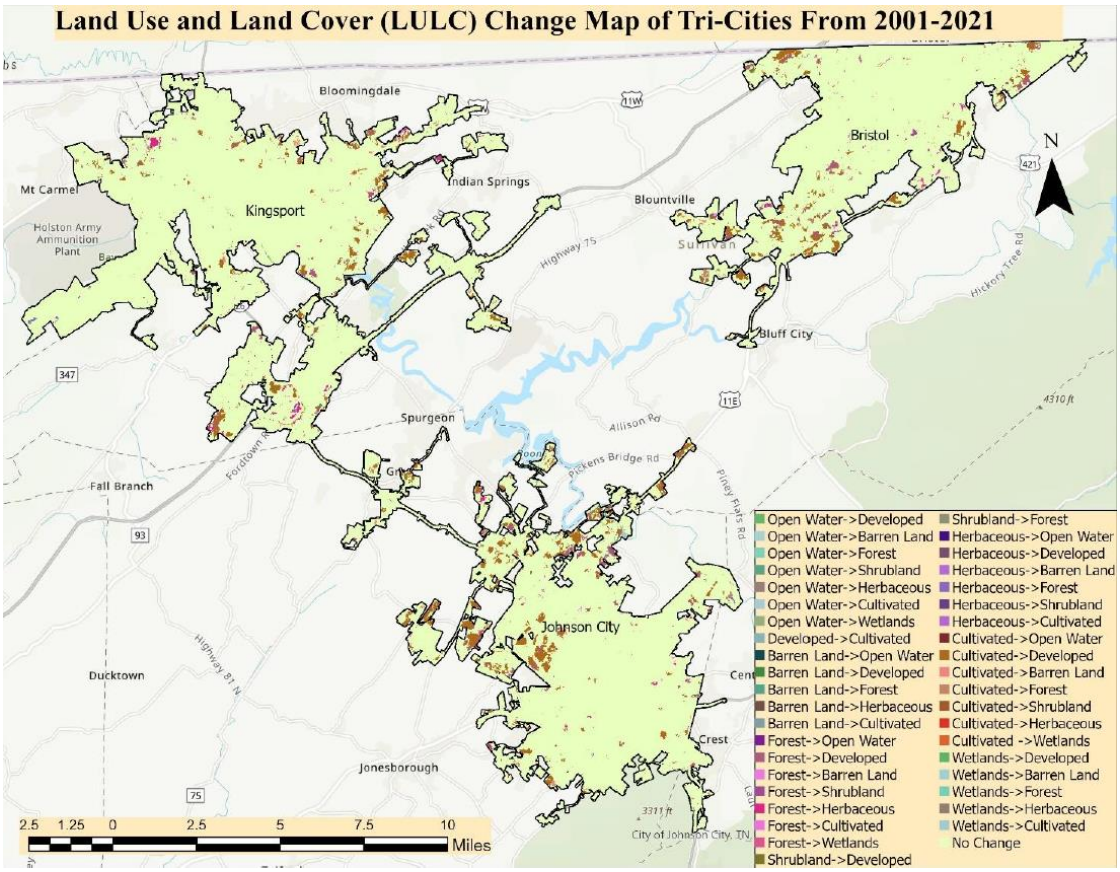

Figure 5. LULC change map from 2001-2021 in Tri-Cities, Tennessee.

Class name	Area (acre)	Percent of land area
No Change	61538.21	93.94%
Cultivated->Developed	2418.99	3.69%
Forest->Developed	650.06	0.99%
Others	902.91	1.38%

DISCUSSION AND CONCLUSION

This study evaluated the Tri-Cities region's city limit boundaries and LULC change from 2001 to 2021, revealing noticeable increase in urban growth and expansion and LULC change. This history characterizes a significant increase in developed land at the expense of agricultural and forest regions. Such land use conversion increases the imperviousness of the land surface by reducing infiltration, which is one of the factors responsible for increased urban flooding (Eliminated, 2022). Moreover, the upward trend in developed areas suggest increased use of materials like asphalt, bitumen, brick, concrete etc. which is one of the drivers for creating Urban Heat Islands (Mathew et al., 2016).

Future research should explore the broader ecological impacts, assess mitigation strategies, and inform sustainable urban development practices in the region. These findings emphasize the need for continued research to comprehensively understand the environmental consequences of LULC change in the Tri-Cities, Tennessee. Such investigations are imperative for informed decision-making in urban planning and environmental management. This study serves as a crucial foundation for ongoing efforts to balance urban growth with environmental preservation in the Tri-Cities area.

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DETERMINING WATERSHED POLLUTION ENVIRONMENTAL JUSTICE SCENARIOS USING DATA FROM AMBIENT WATER AND FISH TISSUE

Benjamin Lane, Dr. Peter Li

The quality of ambient water and fish tissues are important indicators when analyzing environmental quality in watershed-based units. Pesticides and other chemicals in water and fish tissues data from Tennessee Department of Environments and Conservation (TDEC) are used in this study. The purpose of this project is to determine what watersheds are at risk for certain common pollutants and toxins found in water and fish tissue. To accomplish this, ambient water quality and fish tissue data gathered by the District of Water Resources along with the locations of the stations they maintain have been downloaded and input into ArcGIS Pro. By joining the data for stations and related pollutants, we can determine what watersheds are most at risk for a particular pollutant. Presently, most of the pollutants do not register enough in any station to warrant concern. The few pollutants that do show up, such as DDT, are runoff from pesticides or other agricultural chemicals. These compounds most often show up in fish tissue as opposed to ambient water and often have adverse effects on the fish and anything that consumes them. Environmental Justice factors in watershed-based units are compared and mapped with pollutants and fish tissue data. The results show watershed-based environmental justice scenarios in Tennessee.

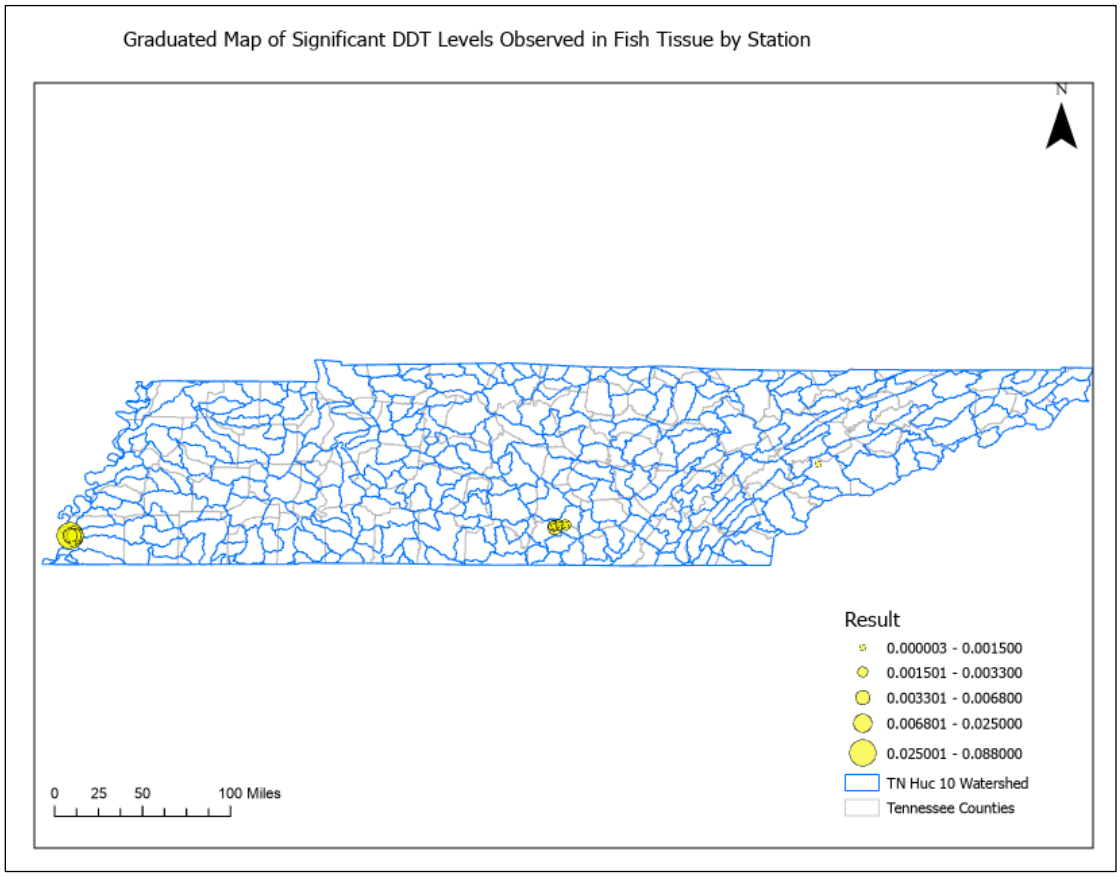

Figure 1 DDT Levels Measured in Fish Tissue Across Tennessee

INCREASING HAB MONITORING IN URBAN ENVIRONMENTS AND ADDRESSING DIVERSITY IN THE GEOSCIENCES THROUGH ILLUMINATING PROJECTS

Devin Moore[1], Reginald Archer[1], Kristi Hill[1], Tom Byl[1,2]

Waterbodies in urban areas are a significant resource to the community serving as a focal point for social interaction and recreational activities, such as fishing. Currently, there are no national, regional, and state programs that target HABs in urban waterbodies apart from a U.S. Environmental Protection Agency (EPA) program in Kansas. Tennessee State University (TSU), in partnership with the US Geological Survey (USGS) and Tennessee Department of Environment and Conservation, are conducting HABs research in urban ponds in Nashville, TN. Inspired by the various interactions of African American communities with urban waterbodies, the project seeks to increase water quality monitoring while increasing community engagement with USGS and the natural environment in an urbanized landscape. Preliminary monitoring found greater than 5 micrograms per liter concentrations of microcystin in wetlands draining an historically black neighborhood in north Nashville, which is greater than EPA's drinking advisory, and approaching the recreational water advisory. The project has successfully provided many excellent opportunities to connect with under-represented communities to discuss water quality issues, field work activities, and the geosciences.

Through this HAB research in urban communities in Nashville, TN, it has shown that projects in diverse or under-represented communities can be eco-revelatory in nature. By conducting research in diverse communities, it allows for natural interaction that informs those in the area about the potential danger in the water, but also the field of careers that deal with those types of issues.

The geosciences are one of the least diverse of all the science and technology disciplines. Over the past 40 years, despite efforts, demographics within the geosciences have not shifted significantly, and are still fairly homogenous. Many agencies and university programs are trying to address this problem through scholarships and recruitment, and while these programs are helpful, they have not proven to be the most effective. An avenue that would help recruitment efforts would be to conduct more earth and environmental studies in under-represented communities to increase awareness and knowledge of the geosciences, and the opportunities that the field presents.

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IDENTIFYING OPTIMAL RANGES OF LIGHT FOR HARMFUL ALGAL GROWTH IN RIVERINE ALGAE

Dalton Tryba

Harmful algal blooms (HABs) have increased in both occurrence and intensity in large rivers posing a risk to drinking water supplies, recreational use, and ecological stability. Our knowledge of how environmental conditions, such as light, affect algal growth in large rivers is insufficient for predicting blooms as flowing water can continuously change conditions at small spatial scales. This study examined the effects of light intensity on algal growth and the dominance by HAB forming cyanobacteria or other algae, such as green algae and diatoms. Water from the Cumberland River, Tennessee was incubated for ten days across a light gradient from 10 to 730 µmol m^{-2} s^{-1} to identify a lower light threshold for growth, as well as to identify light levels of optimal growth. A minimum threshold for growth appeared between 10 and 50 µmol m^{-2} s^{-1}, where little to no growth or nutrient consumption occurred at 10 µmol m^{-2} s^{-1} and observable growth occurred at 50 µmol m^{-2} s^{-1}. Maximum total algal biomass occurred at 550 µmol m^{-2} s^{-1}, with 350 and 730 µmol m^{-2} s^{-1} having slightly lower concentrations. Cyanobacteria, measured as phycocyanin concentrations, did not have a strong relationship with light intensity, but trended higher at higher light, indicating that the optimal light range for cyanobacteria was greater than the eukaryotic algae. This study suggests that riverine HAB forming cyanobacteria can have unique light requirements, indicating that vertical and horizontal light variation in flowing waters is important in understanding HAB development in large rivers.

UPDATING THE CUMMINS FALLS FLOOD WARNING SYSTEM USING FIELD INFILTRATION MEASUREMENTS

Alex Brant[1]

July 5th, 2017 Cummins Falls State Park flooded trapping more than 40 people and killed 3. After the incident, work was done with the Tennessee Department of Environment and Conservation (TDEC) and Tennessee Tech's Earth Science Department to install a flood warning system for Cummins Falls State Park. Though the system was calculated mostly with estimations. One of the estimates was Infiltration. Infiltration, the process of water being absorbed into the ground, is vital for understanding runoff which leads to flooding conditions. This research's objective is to take field infiltration measurement to implement into a flood modeling system to update the Cummins Falls flood warning system.

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PALEOENVIRONMENTAL RECONSTRUCTION OF THE SOUTH FORK HOLSTON RIVER USING UNIONIDAE AS ENVIRONMENTAL INDICATORS

Ash R. Keenan, Ingrid E. Luffman, Christopher C. Widga

As ecologically sensitive organisms, freshwater mussels serve as environmental indicators in the rivers and lakes they inhabit. The South Fork Holston River, once abundant with freshwater mussels, has been impounded and channelized, which can result in habitat loss of riffle and shoal areas and thereby negatively impact native species. The aim of this study is to analyze the fluvial geomorphology of a roughly 40 mile reach of the South Fork Holston River, encompassing the distance from Boone Dam and Reservoir to Eastman Chemical Company in Kingsport. Mussel assemblages from two archaeological sites, Eastman Rockshelter (40SL34) and 40SL330, (ca. 1600 B.C. – 100 A.D.) and two historic collecting events, South Fork Holston River (SFHR) km 25.1 and SFHR km 27.0 (October 1986, January 2003) were evaluated. Occurrence data and ecological preferences of all recorded taxa were used to determine a list of river conditions, including flow velocity and water depth, using the UNIO platform for modeling past aquatic environments. Analysis of the assemblages from all four sites revealed an increase in unfavorable conditions post-industrialization for many species, leading to a loss in mussel diversity. The most abundant species in archaeological sites, Ptychobranchus subtentus and Fusconaia subrotanda prefer to live in riffle areas with fast current. Currently, P. subtentus is listed as endangered while F. subrotanda is listed as a species of special concern. The most abundant species at both historic sites is Lampsilis fasciola, a species tolerant of conditions unfavorable for many native species. The substrate of the South Fork Holston River, a sandy-gravel, has remained the same, but evidence suggests that impoundment has resulted in the loss of fast-moving currents and riffle areas and extirpation of freshwater mussels the South Fork Holston River.

DESIGN AND IMPLEMENTATION OF A MOBILE SAMPLING DEVICE FOR QUANTIFYING MICROPLASTIC CONCENTRATIONS IN STORMWATER RUNOFF

Kara Kimes, David Brown, Landon Norman, Antonio Agnew, and Jejal Bathi

Assessing the concentration of microplastics (MPs) in stormwater runoff is crucial for comprehensively understanding the global impact of microplastic pollution. This initiative is driven by the objective of effectively capturing and quantifying MPs within local stormwater conveyances. To attain this objective, with funding support from the U.S. Environmental Protection Agency, we are researching to design a specialized device capable of separating solid particles from the continuous flow of stormwater. The incorporation of an enhanced sampling device will guarantee consistent performance, yielding a highly mobile testing platform. This platform can be deployed across various locations, facilitating repetitive usage and generating MPs concentration data. The accumulated dataset will be instrumental in determining the overarching environmental accumulation of microplastics.

The creation of state-wide standards assessing water quality and watershed health face difficulties regarding fairness across ecoregions

Crispin Tucker Martin

Tennessee is home to several ecoregions across its great width. The creation of state-wide standards assessing water quality and watershed health face difficulties regarding fairness across ecoregions. Exemplary, a reference stream in ecoregion 66 may have different geomorphological features and functionality than a reference stream in ecoregion 74. The Urban Water Report Card (UWRC) seeks to provide MS4's a standard to assess urban watershed health accurately and fairly across the state of Tennessee. The question is then raised: does the urban nature of streams provide a similarity in geomorphological condition across Tennessee's ecoregions? This presentation explores the morphological similarities in urban streams across Tennessee ecoregions, through rapid geomorphic assessment (RGAs). Nine individual metrics are scored in an RGA to assess the geomorphic stability of a stream reach. Analysis of RGA scores from metropolitan areas across the state of Tennessee provide evidence that certain parameters within the UWRC are not governed by specific ecoregion and can be assessed a cross common morphological criterion, such as urban vs. reference condition.

SEASONAL VARIATION IN WATER QUALITY AT ROCKY MOUNT STATE HISTORIC SITE

Katherine Pollard

This study investigates seasonal water quality at two springs, termed the artesian spring (AS) and residential spring (RS), at Rocky Mount State Historic Site in Piney Flats, TN. Water quality is an important issue, especially in East Tennessee where karst systems, characterized by rapidly changing groundwater quality, are so prevalent. This research addresses a discrepancy between findings from May of 2021, when very elevated E. coli levels were detected at AS and RS, and findings from subsequent winters (2022, 2023) showing negligible E. coli concentrations and compliance with state water quality standards. The primary goals of this research were to assess water quality compliance with TDEC recreational water quality standards, evaluate seasonal water quality changes, and examine the correlation between precipitation and water level of AS. In 2023, in-situ measurements of physiological (turbidity (FNU), dissolved oxygen percentage (DO%), specific conductivity (µs/cm), water temperature (°C), pH, water level of AS, electrical conductivity of AS, and on-site precipitation) and bacteriological (E. coli and fecal coliform concentrations) parameters revealed significant differences between springs based on water chemistry , and highest E. coli concentrations in AS were found during the fall. A weak negative correlation between precipitation and AS water level suggests that precipitation is not the dominant control on water level, suggesting groundwater as control on water level and a potential source of contamination. The study concludes that the water quality of these springs is unpredictable and often does not meet state water quality standards for recreational water use. These conclusions help to characterize the hydrology of a complex karst system and highlight the rapidly fluctuating nature of groundwater quality in karst areas. They also provide quantitative data that may be used to guide water use policies at Rocky Mount State Historic Site.

DETERMINING THE EXTENT TO WHICH ZINC ENHANCES THE TOXICITY OF MICROPLASTICS

Venkata Palanati

The emergence of microplastics in the environment has been studied extensively over the past few decades. Less studied, however, is the increasing prevalence of heavy metals in the same water systems as these microplastics, and their combined effect on organisms. Our research exploring the extent to which such metals amplify toxicity deals with particularly zinc and polystyrene as our respective metal and microplastic components. Both zinc and polystyrene will be used on human AGS stomach cancer cells to determine the level of toxicity to humans. Four different solutions (negative control, polystyrene only, zinc only, polystyrene and zinc) are plated with cells. Rates of growth and death of the cells are monitored and recorded via hemocytometer counts. The amount of polystyrene and zinc used are proportional to the environmentally relevant concentrations.