Tennessee Water Resources Research Center
University of Tennessee

Annual Technical Report
2018

Part B – General Information

Products/Publications

1. 2017TN129B – Evaluation of Fecal Indicators and Pathogens at Recreational Beaches in Central Tennessee. Conference Proceedings -Todd A.C., J. Jatko, D. Chan, M. Stallard and F. Bailey, 2018, Presence of Fecal Bacteria and Associated Pathogens at Recreational Freshwater Beaches in Tennessee, USA, "in" Proceedings 39th Annual meeting of the Society of Environmental Toxicology and Chemistry. Sacramento, CA. November 4-8, 2018.

2. 2017TN129B – Evaluation of Fecal Indicators and Pathogens at Recreational Beaches in Central Tennessee. Stallard, Megan, 2019. Factors that Influence the Presence of Fecal Indicator Bacteria from Three Potential Exposure Pathways, "PhD Dissertation" Department of Biology and Molecular Biosciences, Middle Tennessee State University, Murfreesboro, TN. pp. 158.

3. 2017TN132B – Examining Sediment Rating Curves Hysteresis with State-of-the-Art Sensors. Conference Proceedings – Wyssmann, M.A., A.N. Papanicolaou, T. Kyriakopoulos,2018. Particle resting times: Modeling the role of turbulence. *In* Proceedings of the American Geophysical Union Fall Meeting. Washington, D.C., December 10-14, 2018.

4. 2017TN133B - Field study of Spatiotemporal Variability in Bedload Transport in Mountainous Boulder Arrayed Streams for Development of a Mechanistic Model. Articles in Refereed Scientific Journals – Papanicolaou, A.N., A.G. Tsakiris, M.A. Wyssmann, and C.M. Kramer. 2018. Boulder Array Effects on Bedload Pulse and Depositional Patches. Journal of Geophysical Research: Earth Surface, 123. DOI:10.1029/2018JF004753.

5. 2017TN133B - Field study of Spatiotemporal Variability in Bedload Transport in Mountainous Boulder Arrayed Streams for Development of a Mechanistic Model. Conference Proceedings- Wyssmann, M.A., and Papanicolaou, A.N. 2018. Lagrangian Modeling of Bedload Movement via the Impulse Entrainment Method. *In* Proceedings River Flow 2018, EDP Sciences, 0541,doi:10.1051/e3sconf/20184005041.

6. 2018TN136B – Three-Dimensional Modeling of River Flows Under Extreme Weather Scenarios. Other Publications- Roy, S.,J.R. Bathi.2019, Decision Supporting Hydrodynamic Modeling of Tennessee River, 28th Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. April 10-12, 2019 (Poster).

7. 2018TN136B – Three-Dimensional Modeling of River Flows Under Extreme Weather Scenarios. Conference Proceedings- Bathi, J.R., S. Tareq, S. Palchoudary, 2019, Detection and Treatability of Nanomaterial in Surface Waters, *In* Proceedings of the 28th

Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. pp. 8A41-45.

8. 2018TN135B – Low-cost Real-time Streamflow Network for Falling Water River Watershed. Conference Proceedings – Kalyanapu, A.J., A. Davis. 2019, Developing an Early Warning System for Floods for Window Cliffs State Natural Area, Putnam County, Tennessee, *In* Proceedings of the 28th Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. pp. 5C 13-17.

TNWRRC FY 2018 Information Transfer Program

The major emphasis of the information transfer program during the FY 2018 grant period focused on technical publication support, conference planning/development, and improvement in the information transfer network. The primary purpose of the program was to support the objectives of the technical research performed under the FY 2018 Water Resources Research Institute Program.

During the FY 2018 grant period, a major focus of the information transfer activities was on the participation of the Center staff in the planning and implementation of several statewide conferences and training workshops.

As an on-going sponsor, the TNWRRC was involved in the planning and implementation of the 27th Tennessee Water Resources Symposium, which was held on April , 2018 at Montgomery Bell State Park in Burns, Tennessee. The goals of the symposium are: (1) to provide a forum for practitioners, regulators, educators and researchers in water resources to exchange ideas and provide technology transfer activities, and (2) to encourage cooperation among the diverse range of water professionals in the state. As with previous symposia, the 27th Symposium was very successful with over 342 attendees and approximately 71 papers and 25 student posters being presented in the two-day period.

TNWRRC was a co-sponsor of the Tennessee Stormwater Association Annual Conference, "10 Years of Shimmering Success", held on October 15-17, 2018 at Montgomery Bell State Park. Over 268 attendees including MS4 communities, state and federal government agencies and engineering consulting companies from across the State participated in the three-day event. The opening keynote speaker was Ed Carter, Executive Director of Tennessee Wildlife Resources Agency. The conference included over 48 presentations, a special Stormwater Utilities workshop and several social networking sessions.

TNWRRC FY 2018 Student Support

Undergraduate: 10

Masters: 7

Ph.D.: 6

PostdDoc: 0

Total: 23

TNWRRC FY 2018: Notable Awards and Achievements

Dr. Jon Hathaway, Assistant Professor, Department of Civil and Environmental Engineering received the Outstanding Faculty Award from the UT Chapter of the *Phi Eta Sigma* National Honor Society.

TNWRRC Director, **Dr. John Schwartz** was nominated and is serving on a National Academies of Sciences, Engineering, and Medicine (NASEM) committee to comprehensively evaluate the Watershed Protection Plan for New York City's drinking water supply. Eighteen experts from around the US are serving on this 21- month long assignment.

Henry Goodrich Chair of Excellence Professor**, Dr. Thanos Papanicolaou** and past Director of TNWRRC received the 2018 Hans Albert Einstein Award from American Society of Civil Engineers (ASCE) for his research using a concept called "the aerial probability of entrainment," which helps predict how underwater materials will spread.

Whitney Lisenbee, a Civil & Environmental Engineering doctoral candidate in Water Resources Engineering was one of 100 doctoral students in the US and Canada selected to receive a $15,000 Scholar Award from the P.E.O Sisterhood in 2018.

Students in the **UT Department of Civil & Environmental Engineering** Spring 2018 Senor Design capstone course received Second Place in the Water/Environmental Division of the Water Environment Federation (WEF) Student Design Competition. The student's capstone project required implementing stream rehabilitation strategies to stabilize portions of the stream banks along the Alex Haley Farm property in East Tennessee.

TNWRRC FY 2018 Annual Report

Part A – Research Projects

Project Number: **2017TN129B**

Title: **Evaluation of fecal indicators and pathogens at recreational beaches in central Tennessee**

Project Type: Research

Focus Categories: WQL, SED, REC

Keywords: Fecal indicators, sand, freshwater beaches, pathogens, *E. coli*

Start Date: May 1, 2017

End Date: February 28, 2019

Principal Investigator(s):

Dr. Frank C. Bailey, Professor
Middle Tennessee State University
Department of Biology
frank.bailey@mtsu.edu

Congressional District: 4th Congressional District Tennessee

Primary Findings/Impacts (250 words)

Two Tennessee freshwater beaches (Cedar Creek [CC] and Barton Springs [BS] Recreational areas) were sampled 8 times during summer 2018. Ten sand and 3 water samples/site/event were collected and analyzed for *Escherichia coli* and methicillin resistant *Staphylococcus aureus* (MRSA). MRSA was found in 98% of sand and 94% of water samples. *Escherichia coli* was found in 100% of both sand and water samples. Interactions were found between sites and date for sand concentrations of both *E. coli* (ANOVA, $F_{7,144} = 4.93$, $p < 0.001$) and MRSA ($F_{8,149} = 4.96$, $p < 0.001$). MRSA was highest at both sites during August with levels $>10^4$ CFU/100g sand, while *E. coli* was highest in August at CC and June/July at BS with levels $\sim10^4$ MPN/100g sand. The average for both MRSA and *E. coli* was > 100 CFU(MPN)/100g sand for all dates. For water, both *E. coli* ($F_{7,32} = 12.5$, $p < 0.001$) and MRSA ($F_{7,28} = 9.45$, $p < 0.001$) showed interactions between sites and date. MRSA was highest at CC in September and in May at BS, both having >100 CFU(MPN)/100mL. The highest *E. coli* concentration was at CC in July and June at BS, both having ~100 CFU(MPN)/100mL. In contrast to sand samples, water concentrations of MRSA and *E. coli* were typically <30 CFU(MPN)/100mL at both sites. The presence of fecal bacteria and pathogens at these beaches demonstrates potential risk to beachgoers, especially those who dig in the sand at the shoreline and do not wash their hands before eating.

Project Number: **2017TN130B**

Title: **Sediment Source Tracking in Urban Watersheds: An Application in the Second Creek Observatory**

Project Type: Research

Focus Categories: WQL, NPP, SW

Keywords: sediment, source tracking, urban, stormwater, stream

Start Date: March 1, 2017

End Date: February 28, 2019

Principal Investigator(s):

PI: Jon Hathaway, Assistant Professor
Co-PI: Thanos Papanicolaou, Professor and Henry Goodrich Endowed Chair of Excellence in Civil & Environmental Engineering
Co-PI: Chris Wilson, Research Assistant Professor
Department of Civil & Environmental Engineering
University of Tennessee – Knoxville
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Congressional District: Second Congressional District of Tennessee

Primary Findings/Impacts

This project aims to better understand sediment transport in urban streams, contributing to national needs for reducing sediment pollution and ameliorating the impacts of urbanization on local streams. Our objective was to use the Second Creek Observatory (SCO) in Knoxville, TN, funded by previous USGS 104b studies, as a case study of urban stream processes. Specifically, we aimed to identify sediment sources and decipher transport dynamics during stormwater runoff events. Initial sediment sampling at the site indicated that material from impermeable surfaces were too coarse for using isotopic fingerprinting methods. Alternative methods using artificial radio frequency tags were discussed, but developing suitable artificial particles that match the material from impermeable surfaces would take too long complete. However, the use of existing flow and sediment concentration data from the SCO to develop hysteresis loops proved promising. Data from ten storm events over a one-year period were analyzed yielding six clockwise loops and 4 anti-clockwise loops. The clockwise loops suggest source material exhaustion from the limited availability of the material in the impermeable surfaces nearest the stream channel. The anti-clockwise loops suggest possible stream bank erosion from the sedimentstarved waters delivered during subsequent events following a flush of the readily available material. Additional analysis of the patterns shifts and similarities across seasons are continuing towards a peerreviewed journal paper. These insights can help explain variations in sediment transport in urban streams, with the ultimate hope of better modeling sediment transport in urban systems.

Project Number: **2017TN131B**

Title: **Characteristics of Fine Sediment Embeddedness: Towards Understanding Drainage Network Transport Lags** Project Type: Research.

Focus Categories: SW (surface water), SED (sediment), WQ (water quality)

Keywords: Sediment transport processes, fine sediment, sediment TMDL, embeddedness

Start Date: March 1, 2017

End Date: February 28, 2019

Principal Investigator (s):

John S. Schwartz , Professor
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Congressional District: 2nd Congressional District; Tennessee

Primary Findings/Impacts:

Understanding the biophysical dynamics of fine sediment infusion into the streambed gravel is critical to enhancing management and restoration strategies for impaired streams and generally is termed as embeddedness. However, there is no standard technique to field measure and assess its impact on benthic habitat quality. The study design had two objectives for a student: 1) conduct a literature review of the different definitions and measurement methods for embeddedness, and 2) conduct some field experiments exploring potential means to improve how embeddedness can be quantified. In general, embeddedness is defined as to the extent which streambed gravel and/or cobble are surrounded or covered by fine sediment and visually categorized by estimates of the percentage surface area covered by fines or the quantity. Differences in definitions have led to the inconsistency of how it is measured. The literature review identified issues in that: 1) measurements are visual and do not quantify the potential available pore

space; 2) sample location is not procedurally specified, other than a riffle/run, therefore deposition processes are not recognized in the context of the measurements; and no recognition of the role of biofilms on entrainment and retention of fines in the substrate. Grab samples from 12 streams were completed in three categories, urban impaired, urban restored, and ecoregion reference. Percent fines (<2mm) and %organic matter were significantly greater in urban versus ecoregion references streams. Various ratios of particle size percentages were investigated but due to variance none were found to be an ideal quantitative measure of embeddedness.

Project Number: **2017TN132B**

Title: **Examining Sediment Rating Curve Hysteresis with State-of-the-Art Sensors**

Project Type: Research

Focus Categories: SW (Surface Water); SED (Sediments)

Keywords: GEOMOR (Geomorphological Processes); SED (Sediments); SW (Surface Water)

Start Date: March 1, 2017

End Date: February 28, 2019

Principal Investigator(s):

PI: Thanos Papanicolaou, Professor and Goodrich Chair
Co-PI: Achilles Tsakiris, Hydraulics and Sedimentation Laboratory Manager
Co-PI: Jon Hathaway, Associate Professor
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University of Tennessee - Knoxville
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Congressional District: 2nd Congressional District; Tennessee

Primary Findings/Impacts:

Sediment rating curves are a central component for successful sediment management. A key difficulty in developing these curves is the time lag, or hysteresis, that exists between water and sediment fluxes, which can introduce significant variability in sediment flux estimations. Our ultimate goal is to incorporate artificial particles "tagged" with miniature Radio Frequency IDentification (RFID) sensors to determine how long it takes a particle to move through a stream reach considering both its travel and resting times. We will combine the sediment flux information with flow discharge to resolve the relations between water and sediment for the rising and falling limbs of a hydrograph. Before reaching this goal, the existing RFID technology needed improvement. An anti-collision feature was applied to our existing *PAPTSAK RFID detection software* to interrogate automatically multiple transponders in the vicinity of the antenna. This improvement was necessary to overcome the communication breakdown between that occurs when multiple transponders are close together. The transponders were also equipped with inclinometers to improve detection capability by correcting for the weaker signals when the orientation of a transponder relative to the antenna changes. The likelihood of detecting transponders significantly

drops when the particles are no longer perpendicular to the antenna. The tracking of these particles was successfully conducted in a flume at the Hydraulics & Sedimentation Lab and are ready for field trials. The particles have other applications such as scour estimation around bridges or measuring flows through culverts.

Project Number: **2017TN133B**

Title: **Field study of spatiotemporal variability in bedload transport in mountainous boulder arrayed streams for development of a mechanistic model**

Project Type: Research

Focus Categories: SW (Surface Water); SED (Sediments)

Keywords: GEOMOR (Geomorphological Processes); SED (Sediments); SW (Surface Water)

Start Date: March 1, 2017

End Date: February 28, 2019

Principal Investigator: **Thanos Papanicolaou**, Professor and Goodrich Chair
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Student Investigator: **Micah Wyssmann**, Graduate Research Associate
Department of Civil and Environmental Engineering
University of Tennessee - Knoxville
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Congressional District: 2nd Congressional District; Tennessee

Primary Findings/Impacts:

This student award to Micah Wyssmann, a Ph.D. candidate working with Prof. Thanos Papanicolaou in the Department of Civil & Environmental Engineering Department at the University of Tennessee, was to support his research in the development of a mechanistic bedload transport model that can predict fluxes in mountain river reaches with ubiquitous boulders, while capturing important timescales of pulsation in bedload transport rates. Specifically, the support allowed Micah to attend *River Flow 2018,* the annual meeting of the International Association of Hydro-Environment Engineering and Research which was in Lyon, France. His presentation, entitled "Lagrangian modeling of bedload movement via the impulse entrainment method" was held in the *Bedload and Bed Evolution Modeling* session. The presentation and conference paper discussed a conceptual framework to provide a better understanding of the intermittent behavior of bedload transport. The framework is based on the impulse entrainment method and predicted impulse statistics of particle resting time, t_R, and the magnitude of hydrodynamic momentum transfer (or impulse) during entrainment, I_{ent} by simulating turbulent time series realizations with a generic, regimebased streamwise velocity spectrum. Model predictions showed that an increase in stress was correlated with a sharp decrease in the average t_R and an increase in I_{ent}. Funding also went to support a paper that Micah co-authored with Prof. Papanicolaou and others on tracking bedload movement and deposition within a boulder array. The manuscript was published in the *Journal of Geophysical Research: Earth Surface*.

Project Number: **2018TN134B**

Title: **Rethinking bank stabilization in Tennessee to develop a classification protocol for agricultural and urbanized systems.**

Project Type: Research

Focus Categories: COV, GEOMOR, SED.

Keywords: Bank erosion, classification system, literature review.

Start Date: March 1, 2018.

End Date: December 31, 2019.

Principal Investigator(s):

PI: Thanos Papanicolaou, Professor and Goodrich Chair
Co-PI: John S. Schwartz, Professor
Co-PI: Christopher Wilson, Research Associate
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Congressional District: 2nd Congressional District; Tennessee

Progress to Date:

Bank stabilization in Tennessee is a concern for many landowners, city managers and governmental agencies. There is a critical need in the state to develop a decision making tool for selecting the most appropriate bank stabilization method depending on site characteristics. In this study, we are taking the first steps for developing such a tool by conducting detailed measurement of flow and stream bank interactions in Beaver Creek, T3nnessee and its tributaries. Over 130 erosion pins have been installed. All streams where we have erosion pins have active USGS gauging stations for flow data. These pins are being monitored on a regular basis. Additionally, detailed surveys and flow measurements are being conducted at one of the monitored stream reaches. The flow measurements include large scale particle velocimetry and traditional wading rod measurements. The detailed measurements are designed to provide an adequate representation of the distribution of the near_bank shear stress when secondary currents are present during higher flows, as well as estimation of the critical erosional strength and other sediment erodibility parameters for measuring bank erosion. The combination of the bank erosion rates and flow measurements are useful for river modeling as most models assume uniform flow conditions and consider a near_bank shear stress distribution derived from laboratory experiment. The presence of the secondary currents increases the magnitude of the depth_averaged sidewall shear stress at least by a factor of 2.0. This project was extended until December 2019 to allow for more data to be compiled and analyzed.

Project Number: **2018TN135B**

Title: **Low-cost real-time streamflow network for Falling Water River Watershed**

Project Type: Research

Focus Categories: HYDRO, FL, SW, M&P

Keywords: Water-level sensor, Sensor network, Real-time network, Cloud-based services

Start Date: June 18, 2018

End Date: December 31, 2019

Principal Investigator(s):

Dr. Alfred J. Kalyanapu, Associate Professor
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Tennessee Tech University, Cookeville, Tennessee
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Congressional District: 6th Congressional District Tennessee

Progress Report: (3 Tasks)

Task 1 – Assemble a low-cost real-time enabled water level sensor

Progress to Date: The project team used the prototype presented in the proposal and built a low-cost real-time water level sensor.The components of the sensor include a Particle Electron 3G Micro-controller (Particle, 2019), 1800 mAh Li-Po battery, Maxbotix MB 7920 Ultrasonic Sensor, 3.5V solar panel, half proto-board, few wires for connections and an IP-67 waterproof enclosure. The project team is developing a bill of materials with cost details which will be presented in the final project report.

Each sensor node is configured to collect the water level every 15 minutes and they publish the data on a Cloud-Hosted Realtime Data Services (CHORDS) Server at TTU. CHORDS is a real-time data service infrastructure developed by NCAR and their collaborators that provides easy-to-use system to acquire, navigate and distribute real-time data streams via cloud services and the internet. It is supported by the National Science Foundation EarthCube initiative, which is a community-led cyberinfrastructure initiative for the geosciences Daniels et al., (2016). At TTU, CHORDS server is established using our IT infrastructure. The URL is: https://chordsapp.tntech.edu. The data published on our CHORDS server is then visualized using Grafana, an open platform for data analytics and monitoring (Grafana, 2019). Our Grafana server is available at: https://chordsrtf.tntech.edu.

Task 2 – Field-testing of the sensors Progress

to Date:

During this task, the project team tested the outdoor performance of the sensors within the TTU Campus. The team would monitor the logger's readings including the distance measured by the ultrasonic sensor and the Li-Po battery voltage. Figure 3 shows the setup that was used for the field testing. Over a course of two weeks, these tests were conducted, and once it was established that the sensors are working well, these were installed along the Falling Water River Watershed.

Task 3 – Installation of sensors and sensor network Progress

to Date:

During this task, the project team identified various locations along the Falling Water River and its tributaries for installing the sensors. The criteria used for selecting these sites were: i) the location has good cellular coverage, ii) the location has relative open areas with good solar coverage throughout most of the day, and iii) presence of bridges, so that we can use the structure to attach the sensor box. Based on these criteria, out of 19 possible locations, three locations were selected in the first phase, and the sensors were installed. The selected locations are: i) along Pigeon Roost Creek at the Cookeville Wastewater Treatment Plant, ii) along Falling Water River near Adams Acres Bridge, and iii) along Cane Creek near Ditty Road.

The data from these sites are currently published on TTU CHORDS server (https://chordsapp.tntech.edu) and can be visualized using TTU Grafana server. All the three hydrographs are made available at: https://www.techwarms.org/fwr-real-time-data.

Project Number: **2018TN136B**

Title: **Three-Dimensional Modeling of River Flows Under Extreme Weather Scenarios**

Project Type: Research

Focus Categories: SW, MOD and FL

Research Category: Climate Change and Hydrological Processes

Keywords: Extreme Flows; River Hydraulics; 3D Modeling; Fate and Transport of Pollutants; Infrastructure

Start Date: June18,2018

End Date: December 31,2019

Principal Investigator(s):

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Congressional District: 3rd District Tennessee

Project Progress:

The primary objective of our ongoing research is to demonstrate the use of 3D hydrodynamic and water quality simulation model for river management under extreme flow conditions. U.S. EPA approved Environmental Fluid Dynamics Code (EFDC) 3D is being developed for the Tennessee River in the urban stretch of Chattanooga. Despite its wide applicability, its complex grid generation process makes the use of the EFDC model difficult for end-users. It uses a FORTRAN based GEFDC program, which requires a substantial amount of knowledge and craftsmanship to generate a compatible grid. In order to make the grid generation process automated and compatible, a MATLAB based structured grid generator is being developed as part of our current research. The new program creates the required grid and necessary input files from geospatial information system (GIS) data sets. A test model was set up and executed to confirm grid generation and verify compatibility of our new grid generator. A simplified test model was created with 22 cells and other necessary input files to execute the hydrodynamics module of the EFDC program. Compatibility test of our new grid generator was found to be satisfactory, hence currently we are settingup the EFDC model using the new grid generator program for the proposed model domain of the Tennessee River. Overall, as a demonstration, the project goal is to help prepare the Tennessee River watershed management for possible extreme weather scenarios that may cause devastating impact to the critical infrastructure, environment, and public health, if not prepared in advance.