July 2015 - June 2016
Annual Report

and

July 2017 - June 2018
Appropriation Request

to the

Tennessee Higher
Education Commission

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INTRODUCTION

Dr. Terry Hazen, ISSE Director

As I complete my first full year as director, I am pleased with our progress in 2015-16. ISSE has continued to expand its research and outreach, and the pages of this report provide an update of the activities carried out by ISSE staff, students, and ISSE-affiliated faculty. Here is a summary of ISSE activity this year:

- ISSE has supported more than a dozen externally funded research projects, and continued to co-support two research initiatives with the UT Office of Research and Engagement.
- In addition to its seven on-going internally funded, faculty-led seed projects, ISSE awarded six new seed projects at the end of FY16.
- ISSE-related faculty, staff, and students received several awards during the year, as shown on page 49 of this report. Along with numerous presentations made to a wide range of audiences, several articles were published, most in peer-reviewed journals (see pages 50-54).
- ISSE research projects have engaged more than 50 UT faculty members, five post-docs, 38 graduate students, and 28 undergraduate students.
- ISSE's Tennessee Water Resources Research Center (TNWRRC), under the leadership of Director Thanos Papanicolaou and Assistant Director Timothy Gangaware, continued supporting nine on-going water resource projects funded through the USGS 104(b) program and awarded six new projects under this program, two of which were Graduate Research Assistant Supplemental Research Awards.
- TNWRRC's training programs in erosion prevention and sediment control were attended by approximately 2700 people around the state, and its hydrologic determination training program had approximately 120 attendees.
- TNWRRC supported the Knox County Adopt-A-Watershed Program, which involved 1687 students from 14 middle and high schools in East Tennessee. This program is managed by TNWRRC and sponsored by Knox County Stormwater and the Water Quality Forum. In addition, the Tennessee Smart Yards program (jointly supported by TNWRRC and UT Extension) held numerous workshops around the state and worked to adapt their materials to web-based delivery.
- In addition to other projects, the East Tennessee Clean Fuels Coalition was active in certifying "green fleets," promoting a CNG rally, and assisting other clean cities coalitions
- ISSE's Worker Health and Safety Training Program facilitated training of 1,700 DOE workers at sites around the country.
- ISSE closed out its Center for International Networking Initiatives/Gloriad upon completion of an on-going project in FY 16. Their remaining project was transferred to UT's Department of Electrical Engineering and Computer Science for completion.

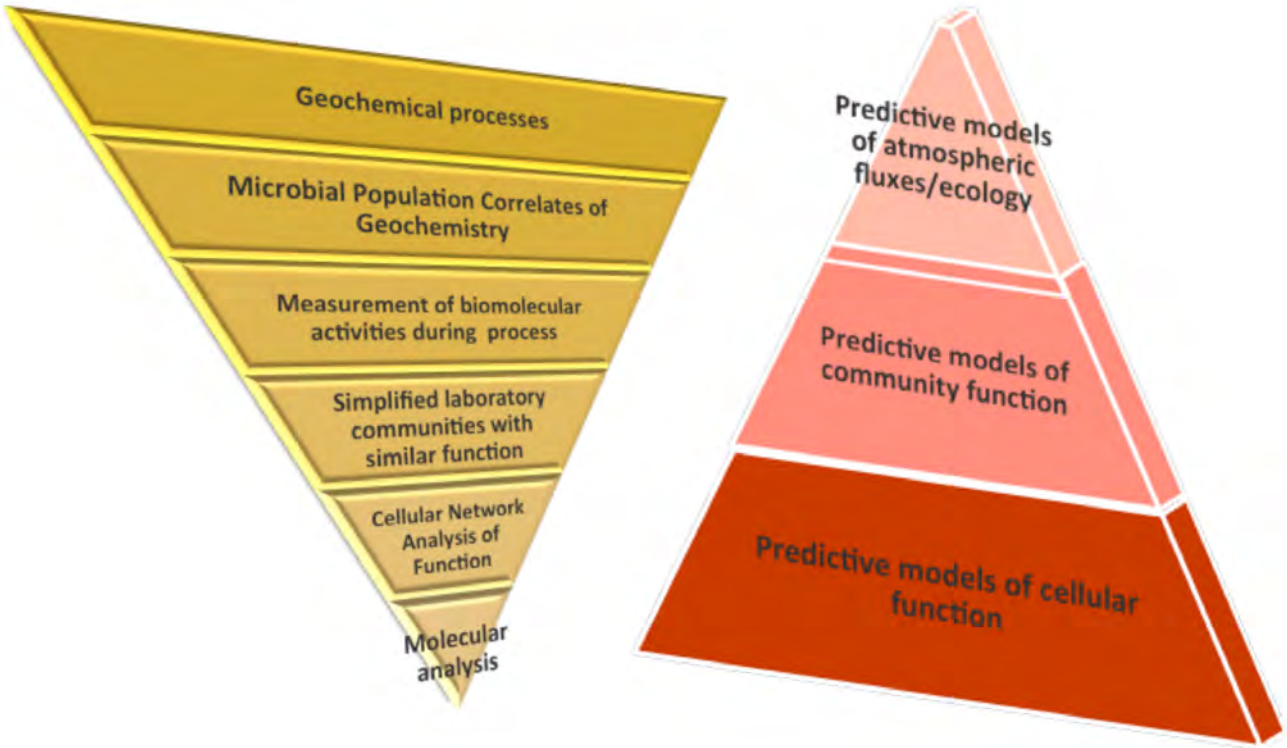
Introduction (cont)

In 2016, ISSE developed a Basic Ordering Agreement (BOA) to enable ISSE researchers to easily contract with communities and municipalities to offer technical assistance and expertise in areas such as recycling, solid waste management, bioenergy, solar energy use, alternative fuel use, water quality and supply issues, sustainable growth plans, tourism and business development,and other topics that fall under the broad umbrella of sustainability.

Assistance was provided to ISSE Researchers Timothy Ezzell and Catherine Wilt to promote economic development in rural West Virginia by creating a "Dark Skies" park to accommodate tourists drawn to the increasingly rare dark night sky. A 2016-17 ISSE seed grant will further their efforts.

A new initiative ISSE began to develop in FY2016 is the Methane Center, whose vision is to integrate across science, engineering, and business models to create a broad conceptual understanding of CH4 as a driver of ecosystem processes and services, and to use this understanding to create a lifecycle assessment framework for environmentally sustainable generation, management, and utilization of CH4. The mission of the Methane Center is to provide a continuum of fundamental and technological research advances and training in CH4 environmental science leading to a cohort of young engineers and scientists dedicated to effective communication of meaningful scientific findings to inform and stimulate the public, and provide structured rationale for economic and environmental policy decisions and regulations.

In the next fiscal year, ISSE will continue ti expand its research and outreach. A new ISSE Advisory Committee will meet in FY17 to assist in these expansion efforts and to develop a strategic plan for ISSE.



Model for new ISSE Methane Center

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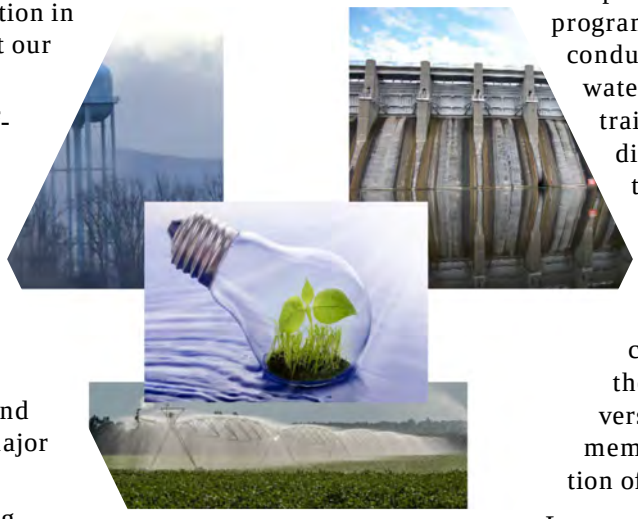
Tennessee Water Resources Research Center (TNWRRC)

(Team: Thanos Papanicolaou, Timothy Gangaware, Ruth Anne Hanahan, and Roy Arthur)

A note from the TNWRRC Director, Thanos Papanicolaou—Tennessee is surely blessed with an abundant supply of high quality water. However, in the years following the drought of 2007, many private, domestic, and commercial water stocks have become severely stressed.

The future has its challenges, too. Both higher temperatures and less frequent rainfall are predicted for the state. These changes will lead to deficits in soil moisture, as well as our surface and ground water stores. The repeated drying-and-wetting of the soils will also weaken their structure, making them susceptible to the higher intensity rains. Extreme erosion events will follow, washing away the soil and nutrients. The resulting degradation in water quality will further limit our water availability.

In addition to these climate effects on water availability, we have an increased demand from a rising population and our growing cities. Providing an adequate supply of good quality water for the agricultural, industrial, commercial, and urban sectors, while protecting our surface and groundwater resources, is a major concern for Tennessee.



The state legislature is working to establish a more integrated and coordinated policy for the management of our water resources. Yet, much work is needed. We still lack basic information regarding the various processes driving the hydrologic cycle.

To address issues of effective water resources management in Tennessee, a truly interdisciplinary and well-coordinated effort is needed. The Tennessee Water Resources Research Center (TNWRRC) has the right mixture of leadership, outreach, and interdisciplinary research that can unite the different groups and work towards a statewide adaptive governance plan to manage the state's water resources to the benefit of all.

It is a primary goal of the TNWRRC to assist the state in developing and implementing programs for sustaining high quality water. It serves as a link between the academic community, federal and state governments, water-related organizations, the private sector, and local communities.

During 2015, TN WRRC has taken several steps forward to establish a unifying body of water resources researchers, managers, and educators in Tennessee. These steps include forming an Advisory Board, enhancing the 104B seed grant program, and initiating larger state/national research efforts, as well as sustaining our already strong outreach efforts.

Our new Advisory Board has leaders from the US Geological Survey, Oak Ridge National Laboratory, and the Tennessee Valley Authority, as well as state agencies like the Departments of Agriculture and Environment & Conservation, and the private sector. One of the main charges of the board is to provide input on the important state water issues for the annual 104B seed grants.

The 104B Annual Base Funding grant program is the main push of the TNWRRC research program. These base grants are for conducting applied research on water resource issues, helping train new scientists, and coordinating outreach activities to water managers and the public. They are often used as seed funding for larger projects. The call for proposals for next year's funding cycle will be circulated to all the state's colleges and universities. Any full-time faculty member from a Tennessee institution of higher education is eligible.

Last year's 104B seed grants focused on how land management and nutrients affect Tennessee's water resources and water/soil management decisions. Excess runoff and soil erosion, resulting from our land management choices, affect soil health and landscape productivity, as well as water quality and quantity across the state. This year's call will include issues related sediment and non-point source pollution control and water availability, among others.

The 104B program will also include student stipends with funding of up to $5,000. This stipend program was designed to allow the students to complete additional research objectives or products beyond the scope of their current water-related funded project. With these funds, the students are encouraged to use the money for publication costs, so that they can submit their research to top-tier, peer-reviewed journals.

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USGS Projects

The TNWRRC is one of 54 state-level Water Resource Research Institutes of the US Geological Survey (USGS) and administers several state-level grants through the 104(b) program. Active projects during this reporting period are discussed below.

Engineered Strategy to Remediate Trace Organic Contaminants using Recirculating Packed-Bed Media Biofilters at Decentralized Wastewater Treatment Systems: Determination of Trace Organic Sorption to Treatment Media

(Team: John R. Buchanan and Jennifer DeBruyn, Biosystems Engineering and Soil Science)

Recirculating packed-bed media biofilters (RPBMB) are a low-cost and low-maintenance wastewater treatment process that is well suited for individual onsite and very small community applications. Approximately 25% of the domestic wastewater generated in the U.S. is processed by individual onsite or very small wastewater treatment systems. Packed-bed media biofilters are a slow-rate, fixed-film (or attached-growth) unit process used for secondary and tertiary treatment. This process passes effluent through a porous, inert media (the packed-bed) where waste constituents diffuse out of the bulk water and into the biofilms that form on the media. Aeration is provided as the wet media is exposed to atmospheric oxygen. A recirculating packed-bed media biofilter (RPBMP) recirculates the effluent through the media several times for enhanced organic carbon removal and nitrification (oxidation of ammonia to nitrate). After trickling through the media, approximately 80% of the effluent is sent to the recirculation tank (for additional passes through the media) and the remainder goes to the final discharge (typically via a drip irrigation system). Because the influent from primary treatment is anaerobic, the recirculation tank is usually anaerobic and this reducing-environment allows for denitrification. Under reducing conditions, nitrate can be converted to nitrogen gas, thus reducing the nitrogen concentration in the effluent. Previous trace organic wastewater contaminant (TOWC) research has focused on the disappearance of these compounds as wastewater passes through various treatment technologies and subsequent environmental monitoring in surface water. This project sought to determine the specific TOWC removal processes within this decentralized wastewater unit process. This knowledge will allow scientists and engineers to optimize these processes for TOWC remediation and to minimize or eliminate their release to natural environments mitigating potential ecological disturbance.

Nature, Scope and Objectives of Project—By design, the organic loading rate to RPBMBs is low (typically 2 to 5 kg BOD5 100 m-2 d-1). This loading rate minimizes the accumulation of biosolids within the media and starves the microorganisms for organic carbon rather than oxygen (endogenous respiration). It is possible that this operating mode may encourage the aerobic biodegradation of otherwise recalcitrant TOWC. Further, there is some evidence that changing from oxidizing to reducing conditions can enhance TOWC degradation. Lastly, the media provides tremendous trace organic contaminant adsorption/absorption potential. The specific objective of this project is to determine whether sorption to the media is the primary removal mechanism. Four laboratory-scale RPBMB were constructed and were dosed with septic tank effluent that was augmented with 0.1 mg/L of either triclosan, ibuprofen, or naproxen for eight weeks. We monitored the treated effluent for the disappearance of the listed trace organics as part of a separate project. It is assumed that the major removal mechanisms are biodegradation and sorption. By measuring the sorption component, it is hoped to get a better understanding of the biodegradation aspect.

Methods, Procedures and Facilities —Four laboratory-scale recirculating media biofilters were assembled. These systems included a supply tank, a 56-cm tall column filled with media (3-5 mm fine gravel), and a recirculation tank. Primary-treated wastewater from a community-scale decentralized treatment system was used as the wastewater source. The supply tanks emulated the discharge from primary treatment (liquid/solid separation) and fed into the recirculation tank on a diurnal basis – representing higher wastewater flows that occur during mornings and evenings. Effluent in the recirculation tank was micro-dosed to the media column five times per hour. The discharge of the column flowed back into the recirculation tank. The recirculation rate was five volumes passed through the media column with respect to the daily volume of treated effluent, representing a 5 to 1 recirculation rate. A cycle consisted of five doses. During four doses, the column effluent returned back to the recirculation tank. Just before the fifth dose, a three-way valve on the bottom of the media filter switched and directed the effluent to the finished product container. All system components were manufactured from stainless steel, glass, or coated with polytetrafluoroethylene (PTFE) in order to minimize the partitioning of the trace organic compounds to the system surfaces.

Each of the four systems received primary treated wastewater for a minimum of 20 days to establish a biofilm within the media. COD analysis was used to

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confirm that the biofilm was established and metabolically active. After the initial maturation period, three of the four systems began receiving a 0.1 ppm spike of either triclosan (TRI), ibuprofen (IBU), or naproxen (NAP). The fourth system served as a non-spiked control. The septic tank effluent sourced for this project contained measurable concentrations of each of the selected compounds. Thus each of the experimental units received concentrations of TOWC found in the septic tank effluent, with the TRI, IBU, and NAP units receiving an additional 0.1 ppm spike of their respected compounds.

The recirculating media biofilters received this dosage for 60 days. During each experiment, the concentration of the selected contaminants was measured in the spiked effluent and finished product.

Biofilm samples were collected to determine sorption of the target compounds. At the end of the eight week study period, the units were disassembled and media samples were taken from the top, middle, and bottom of each column. For the sorption study, a 25 mL aliquot of each media sample was placed in a glass centrifuge tube, along with 2.5 mL each of methanol and distilled water. Each tube was hand shaken, and then placed on an orbital shaker at 500 rpm for 1 day to dislodge the biofilm from the media. The media was removed from the tubes and the remaining mixture was centrifuged at 2400xg for 10 min. The supernatant was collected and evaporated under nitrogen gas until approximately 1 mL remained. The 1 mL was added to 300 mL of acidified distilled water and was loaded onto solid phase extraction cartridges.

Results and Findings —Media samples from each of the experimental units were collected from different depths (top, middle, and bottom layer) for analysis of the biofilm present. Initially, simple loss on ignition (LOI) tests were performed to determine the amount of total organics present between each of the layers. Two-way ANOVA analysis confirmed that there were statistical differences between the organics present within the layers ($P>0.01$, alpha=0.05) and no significant differences between experimental units ($P=0.68$, alpha=0.05). LOI measurements showed that the highest percentage of total organics were consistently present in the top layers (3.4% to 3.8%) of the columns, with minimal shown in the middle and bottom (0.45% to 0.83%). Results like these are expected from RMFs, because biofilm typically forms within the first 6" of media. Therefore, it can be stated that most of the biological treatment within the system was occurring within the uppermost layers of the column.

With regard to the mass of adsorbed TOWC, there were significant differences between layers ($P=0.04$) but no significant differences between experimental units ($P=0.26$). Most of the absorbed TOWC were shown to be within the top layer of the columns, which correlated to the LOI data presented earlier. However, there was an adequate amount of PPCPs detected within the middle layer as well. Totaling the concentrations of adsorbed PPCPs within each layer for each experimental unit, the control system was shown to have the highest amount (0.52±0.01%, 0.73± 0.01%, and 4.31±0.02% of IBU, NAP, and TRI), with the NAP column showing minimal sorption of IBU only (0.15±0.00%). TRI was shown to participate in sorption more than IBU and NAP, which corresponds to previous research, and had the highest sorption percentages within the control and TRI column (4.31±0.03% and 5.13±0.03%). It was interesting to note that TRI only did so within those two columns; there was no sorption of TRI within the NAP columns, and minimal in the IBU column. IBU had half as much sorption occurring within the IBU column when compared to the control column (0.35±0.00%), with even less occurring within the NAP and TRI columns. NAP experienced low sorption in all columns except within the NAP column, where no sorption was detected.

High Resolution Monitoring of Urban Stormwater Quality: Phase 2

(Team: Jon Hathaway and Kimberly Carter, Civil and Environmental Engineering)

Nature, Scope and Objectives—In the 2010 Tennessee Water Quality Assessment Report, urban runoff was identified as one of the primary causes of impairment in streams and rivers in the state. Similar results were found for the Southeast Region in states such as Georgia, Alabama, and Virginia. As such, watershed restoration efforts (such as developing TMDLs) require consideration of stormwater runoff. Stormwater had been shown to transport nutrients, sediments, metals, and indicator bacteria to local surface waters. Despite this fundamental understanding, further research is needed to understand the fate and transport of pollutants in stormwater. Modeling is an integral part of watershed restoration efforts, as is an understanding of the pollutant of concern's fate and transport and what factors influence the pollutant's variability. Modeling provides valuable insight into the pollutant sources, sinks, and processes within a given watershed. This insight allows more targeted, efficient, and cost-effective pollution abatement efforts. High resolution data can aid in such efforts, offering a preliminary investigation of the variability of pollutants in stormwater and what factors influence this variability. In addition, pollutants

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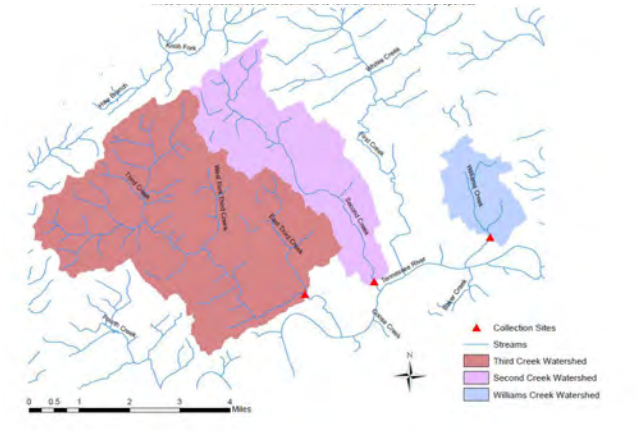
such as E. coli and organic chemicals have not been extensively characterized in stormwater runoff, resulting in a lack of understanding as to the potential threat these pollutants pose to public and ecological health. The overall goal of this research is to better understand urban stormwater and provide sustainable ways to reduce its contribution to surface water degradation.

Objective—The specific objective of this project is to collect high resolution water quality data from urban streams in Knoxville, TN, to allow an understanding of factors explaining the variability of pollutants observed in these systems.

Methods, Procedures and Facilities—During FY2014, a gaging station was installed in Second Creek near its confluence with Lake Loudoun. This station is powered by a permanent electric supply run from Estabrook Road on the campus of the University of Tennessee. The station consists of a refrigerated sampler connected to an ISCO Signature flow meter. Flow was initially characterized using an area velocity probe fixed to the channel bed to collect depth and velocity readings for the stream. A survey of the stream cross section was performed by graduate and undergraduate students to allow development of a stage discharge relationship for the station. After this relationship was established, an ultrasonic depth sensor was installed underneath a foot bridge to allow measurements while avoiding in-stream hazards.

During Phase 2 of the project (the second year of funding), monitoring sites utilized by the City of Knoxville for Third Creek and Williams Creek were leveraged to add an additional two sites to the project. This allows a better diversity of land use and watershed configuration within the project, resulting in more robust analyses. Automatic samplers with bubbler flow meters were installed at each stream at the same location as that of the longer term monitoring installations of the City of Knoxville. Historic data from the city was used to build stage discharge relationships for application to the monitoring regime herein.

Samples are flow paced, allowing evenly distributed sample collection throughout targeted storm events. Samples are retrieved after storm events, and transported to the water quality analysis lab in the SERF building at the University of Tennessee. Samples are analyzed by UT students for E. coli, TSS, nutrients, and metals. Additionally, a composite sample was created for a number of events at Second Creek and was sent to an outside laboratory for analysis of organic compounds.



Results and Findings—Since sampling began in September 2014, seventeen, eight, and eight storm events have been collected at Second, Third, and Williams Creeks, respectively. Well-defined pollutagraphs for the storm events were captured to better understand the variability in the inter and intra-event pollutant concentrations.

The data collected thus far confirm high concentrations of sediments, indicator bacteria, and some forms of nitrogen (nitrate) in the storm samples. For instance, E. coli concentrations reached as high as 19,700 MPN / 100 ml during the storm event on 11/2/2015 at Second Creek. This is over 150 times the average concentration desirable for primary contact in recreational waters. Initial analyses also suggest a variability in pollutant concentrations through the study, in particular for Second Creek, where inter-event TSS concentrations showed substantial fluctuations similar to fecal coliform, and even higher than those observed for E. coli. This is notable considering the high variability typically ascribed to bacteria data. However, the same trend was not observed in Third Creek, where TSS had much lower variability. This highlights that watershed specific attributes likely influence pollutant transport trends. Additional analyses will be performed to allow an investigation of the first flush tendencies of each pollutant, and how antecedent climate impacts pollutant concentrations.

Organics analysis failed to result in positive identification of organic pollutants in the storm flows sampled in the latter part of the 2014 as all concentrations were below the detection limits of the methods used. Further samples taken in the spring of 2015 also resulted in non-detected compounds. Stormwater samples taken for fluorinated organics and other organic contaminants samples also yielded no results.

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Samples taken from June to October 2015 storm events showed phenol in five of the stormwater samples collected. Additionally, diethyl phthalate and Endosulfan I were detected in one of the samples. Table 1 displays the date, the organic compounds, the concentration, and the detection limit of the analysis that was used for these samples. Because these compounds were barely above the detection limit, it is suspected that the majority of the chemicals tested in these samples were below the detection limit of the methods used.

Table 1. Compounds detected in the stormwater samples taken during the course of the proposed project.

Date	Sample Type	Compound	Concentration (□g/L)	Detection Limit (□g/L)
6/29/15	Water	Phenol	45	10
7/1/15	Water	Phenol	30	10
7/15/15	Water	Phenol	11	10
8/23/15	Water	Phenol	17	10
8/23/15	Water	Diethyl phthalate	3.27	3
10/1/15	Water	Endosulfan I	0.063	0.05
10/6/15	Water	Phenol	12.4	10

Phenol is used for the production of herbicides, pharmaceuticals and plastics and is produced during the decomposition of plant material. The highest concentration of phenol was detected in June and decreased in July. The concentration then increased slightly in the August samples but then decreased in October. The increase (then fluctuation) of phenol could be due to the use of herbicides upstream of where the samples were taken or because of the vegetation surrounding the sampling area. Endosulfan I is a pesticide that is found in the environment at low levels and is a derivative of other components in the pesticides. Pesticides are commonly used during the sampling period in which this compound was detected. Diethyl phthalate is used in the production of certain plastics and trace amounts can be found in burned plastics.

In addition to insights into water quality made possible through this monitoring, the flow data collected from Second Creek are being paired with data from other streams in Knoxville by a doctoral student to investigate the patterns and connection of impervious areas in the city. Connected impervious areas have been found to most substantially impact the quality of receiving streams, thus, this is also a critical area of research need. Through this, more targeted approaches to watershed restoration may be possible.

Synergistic Activities—Additional funds were secured from the University of Tennessee Green Fee program to add to the infrastructure at Second Creek and develop the Second Creek Observatory. This will allow Second Creek to function as a living laboratory for research and teaching while building public awareness as to the impact of stormwater runoff on surface waters.

Measuring Evapotranspiration and Soil Moisture to Close the Hydrologic Budget under Different Land Uses in Tennessee

(Team: Thanos Papanicolaou and Christopher Wilson, Civil and Environmental Engineering; Collaborator: Jon Hathaway, Civil and Environmental Engineering)

Discussion of the water problems addressed— Evapotranspiration (ET) is a major component of the land surface water cycle, as it directly affects the amount of water available for runoff and recharge, and hence human consumption. Despite the relative importance of ET to the hydrologic cycle, especially in the U.S. Southeast, which has some of the highest mean annual ET in the country, it is one of the least systematically measured parameters.

Evapotranspiration in the United States varies significantly both spatially and temporally. The science community currently lacks ET data of adequate spatial density and temporal frequency to account for the level of heterogeneity seen within both natural and human-altered landscapes, thus preventing the identification and discrimination of the competing processes that control the observed patterns in the water quantity and quality of our local ecosystems. Furthermore, the stationarity of hydrologic data from the past 100 years is now in question because of major changes in land-use and climate. Hence, current models used for both research and management are based on insufficient data from all phases of the water cycle.

The most important factors that drive ET are net solar radiation, climate conditions (e.g., humidity, wind speed, temperature), soil moisture, and vegetative cover. However, most measurements use meteorological properties and reference crop corrections to determine potential ET, but neglect the role of soil moisture at the soil boundary surface (i.e., top 30 cm) on actual ET. As a result, our current ET monitoring and modeling capabilities lacks understanding about the role of soil moisture and pedology at different spatial and temporal resolutions sufficient to quantify ET, especially in regions exhibiting high heterogeneity in landscape characteristics

Water availability is a developing research theme as it is projected to become very important as the climate warms and our cities grow. Recently, the Tennessee Water Resources Technical Advisory Committee (WRRCTAC) has joined the effort of other states throughout the country and requested the development and maintenance of a statewide hydrologic database

to assess the impact of drought on public water supply systems in Tennessee. This study can contribute significantly to this hydrologic database and it will significantly enhance our understanding of how changing land management, irrigation, and urbanization affect water quantity in mixed agricultural-urban watersheds of the Southeast under different climates to assist watershed planners in applying management strategies for mitigating drought impacts, as well as aid societal efforts to obtain sustainable water resources through integrated surface-subsurface water management.

Research objectives—In this study, we are helping address a critical gap in our current ET monitoring and modeling capabilities, namely the lack of understanding about the effect of soil moisture on ET in regions exhibiting high landscape heterogeneity. Past research has used only meteorological properties and reference crop corrections to determine potential ET, but neglected the role of soil moisture at the soil surface on actual ET. A mobile array of state-of-the-art sensors was developed that is capable of measuring not only the rate of ET under multiple land-uses throughout the region, but also the resulting change in soil moisture. The mobile array of state-of-the-art sensors measures ET, Leaf Area Index (LAI), and soil moisture changes. It provides essential but missing data for a GIS Data Management System for water resources research in Tennessee, as well as ground-truthing data for satellite-based estimates of ET and soil moisture to develop regional scale water budgets for long-term water resources planning, management, and risk analysis.

The nature of our study encompassed three main objectives centered on the development and use of the mobile ET/ LAI/ soil moisture monitoring array. The objectives included the development and testing of the mobile array; select data collection of ET, LAI, and changes in soil moisture; and a comparison of these data with remote sensing images from MODIS as a form of ground-truthing. These three objectives will be the initial stepping stones to closing the hydrologic budgets for the different ecosystems in Tennessee.

Methodology—This project is a seed instrumentation grant, with its whole purpose being to design/acquire the appropriate equipment to conduct current and future research that is beyond the short term lifespan of the seed grant. In this case, the equipment consisted of monitoring stations for evapotranspiration (ET) corrected for soil moisture, a key parameter affecting ET magnitude in the state and region.

To monitor the resulting changes in soil moisture and its implications to ET, we use Water Content Reflectometers, which measure the volumetric water content of soils and porous media using time domain measurement methods sensitive to dielectric permittivity. Monitoring soil moisture is central as it constrains plant transpiration; however, the sparse availability of ground observations continues to be a limiting factor in understanding the connections between LULC, ET, and soil moisture. Finally, we also purchased a LP-80 Ceptometer from Decagon Devices to measure Leaf Area Index. The role of vegetation in affecting ET has been previously established and LAI has been shown to be a critical variable when determining actual ET as it provides the total area of the transpiring surface.

Essentially, ET will increase as LAI increases. The ceptometer is a portable sensor that will measure Photosynthetically Active Radiation (PAR) in real time. The PAR data can be coupled with the climate data to estimate total biomass production without destroying the crop and other canopy processes, such as precipitation interception and evapotranspiration. Additionally, ET can be determined using remotely sensed vegetation indices (e.g., Normalized Difference Vegetation Index, NDVI) and micrometeorological data, although ground-truth results are needed. Our array will provide the meteorological/temperature data and LAI data for the ground-truthing of the satellite-derived images.

Principal findings—Initially, after we reviewed the literature pertinent to droughts in the Southeast, we completed the satellite analysis in advance to identify ranges of variability and bounds of uncertainty. ET was estimated using remotely sensed vegetation indices (e.g., Normalized Difference Vegetation Index, NDVI) and micrometeorological data. We looked at the ability of MODIS data to give us some spatial variability information for ET.

It was through examining the MODIS data, and a modified Penman-Monteith equation that we found the variability was greater than 15-20%. Once that was done, we felt confident that our initial design supplemented with soil moisture and heat fluxes measurements would work. We then began with the development of a monitoring protocol and selective testing of the ET array, LAI, and moisture sensors. After the LAI meter was obtained, we began testing it with the soil moisture probes that we had available. Through our discussions, this isolated testing process, and exploring the available literature, we discovered a fourth sensor for monitoring soil heat flux, which was deemed important for Tennessee due to the expected increase in temperature and the need for a correction of potential ET due to losses. This soil heat flux sensor was not part of the original design but came as an outcome of the evolution in the project. This heat flux sensor was needed to proceed with the

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potential ET correctly. Because our goal was to measure actual ET under different land covers, including cover crops, coupled with the fact that the Southeast has ubiquitous soil heat exchanges, it became apparent that we needed the additional corrections with LAI and soil moisture, as well as soil heat flux. Therefore to determine the actual ET, the reference values from Eq.1 must be corrected using the crop coefficient for the specific crop/vegetation (Kc). These coefficients have been determined experimentally and are documented in the literature. However, as soil moisture decreases, it is less available for uptake by the plant. It will also be more difficult to uptake the water as it is more strongly bound by capillary and absorptive forces to the soil matrix. Hence, the ET will drop after the soil moisture content passes below a threshold value where the soil water can no longer be transported quickly enough to the roots to respond to the transpiration demand and the crop begins to experience a water stress. This value, p, is typically half-way between field capacity and the wilting point and detailed in the literature. Using this threshold value, the total available soil water in the root zone (Wt) from the DRI measurements, the measured change in soil moisture, $\Delta\theta$, we can determine the water stress coefficient (Ks) to correct our ETo, which reflects the effects of soil moisture on

$$ET.\ K_s=(W_t-\Delta\theta)/((1-p)\ W_t) \qquad (1)$$

The actual ET values over the monitoring can then be determined by correcting the ET0 with both the crop coefficient (Kc) and the (Ks). The acquisition of the soil heat flux ensured that we got (1) a system suited for Tennessee and droughts; and (2) that we were able to provide detailed measurements to support the seed grant needs and support larger efforts.

Outreach—In terms of standard products/outputs, we provided presentations to the 2015 Tennessee AWRA and the 2016 American Ecological Engineering Society. The first presentation at the AWRA meeting showcased a physically based, modeling framework to predict saturated hydraulic conductivity in intensively managed watersheds. The framework integrated dynamic pedo-transfer functions, watershed models, and remotely sensed data with geospatial tools. This framework works well at capturing the influence of different land-uses and climate variability on adjusting infiltration rates. The remaining three presentations for the 2016 TN AWRA and AEES conferences focus specifically on the modeling of the Hiwassee and Obion watersheds. The presentations will highlight data selection, the extensive calibration/verification procedures, and some preliminary results. In conclusion, the seed grant has led to another grant from the Tennessee Water Resources Research Center (USGS 104b), which started March 1st (Measuring Water Table Fluctuations under Different Irrigation Regimes in Western Tennessee Agroecosystems). This new project builds on the ET measurements from the above stations, coupling them with changes in soil moisture levels. We have also used this grant to compile a proposal for the USGS-NIWR 104G program called "The Coupling of Bottom-Up and Top-Down Evapotranspiration Approaches with Remote Sensing-Based Scaling to Close the Water Budget in Adjoining Urban and Agricultural Areas."

Resulting Funding—This seed grant has led to another USGS-NIWR 104B grant from the Tennessee Water Resources Research Center—Measuring Water Table Fluctuations under Different Irrigation Regimes in Western Tennessee Agroecosystems. This new project builds on the ET measurements from the above stations, coupling them with changes in soil moisture levels. We have also used this grant to compile a proposal for the USGS-NIWR 104G program called "The Coupling of Bottom-Up and Top-Down Evapotranspiration Approaches with Remote Sensing-Based Scaling to Close the Water Budget in Adjoining Urban and Agricultural Areas."

Assessment of Watershed Land Use Stressors on the Biological Integrity of the Nolichucky River in Tennessee

(PI: J. Brian Alford, Forestry, Wildlife & Fisheries)

The Nolichucky River watershed (figure 1) of east Tennessee is home to five fish and seven mussel species listed as endangered or threatened by the U.S. Fish and Wildlife Service. Thus, it is considered a "hot spot" for North American biodiversity. Land use change from undisturbed forest to agriculture and impervious surfaces are known to affect sensitive species due to increased non-point source pollution. The majority of the watershed includes Greene County, which is a top producer of cattle and fescue in TN. There is growing concern over how conversion of these fields to row crops and impervious surface will affect fish and aquatic invertebrates in the watershed.

The objectives of this study are to (i) quantify changes in forested, impervious, and agricultural land use from

Figure 1. Nolichucky River watershed location in TN.

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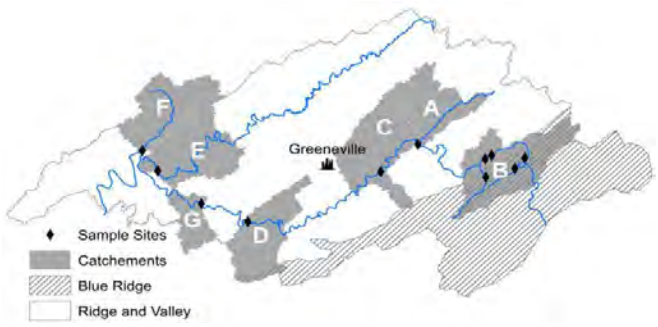
2000 to 2014 for selected HUC-12 sub-watersheds within the Nolichucky watershed, (ii) assess relationships between land use intensity and fish diversity, and (iii) use quantitative data to classify most impacted sites and guide land use management.

Study Design—Ten wadeable sites were surveyed for fishes during summer 2014 in the TN portionof the Nolichucky watershed (figure 2). Sites were located up- and downstream of observed ag-impacted areas (i.e., farms within 30 m riparian zone). Tennessee Valley Authority's (TVA) protocol for conducting Index of Biotic Integrity (IBI) assessments was used to assess fish assemblage health at riffle-run and pool habitats. A backpack electrofisher and seine were used to sample fish in run, riffle, and shoreline habitats. Seine hauls were used in pools. Fish species and number were recorded for each sample, as well as prevalence of diseases, external anomalies, lesions, and tumors (DELT) and evidence of hybridization. Twelve IBI metrics (Table 1) were calculated from fish species relative abundances (% of total number fish) and rihness (no. of species in a taxa).



A – Big Lime Stone Creek
B – Clark Creek – Nolichucky River
C – Sinking Creek – Nolichucky
E – Lower Lick Creek
F – Bent Creek
G – Oven Creek – Nolichucky River

Figure 2. Tennessee side of the Nolichucky watershed showing level-3 ecoregions and 12-digit HUC catchments.

A supervised classification was done on Landsat 8 and Landsat 7 satellite images to quantify % areal land cover change in the watershed from 2000 to 2014. For each sample site, 12-digit hydrological unit code (HUC) catchments and EPA level-3 ecoregions were downloaded (figure 2) and evaluated for percent change of land cover fr0m 2000 to 2014. Generalized additive models (GAM) were conducted in CANOCO v. 4.5 software to test for associations between mean HUC IBI scores and land use metrics.

Results—Overall, 199 electrofishing samples were taken and 43 species were identified at the 10 sites. Bent creek IBIs were not calculated due to cold weather. Impervious land cover increased the most from 2000 to 2014 with forested land increasing to a lesser extent than impervious surfaces, whereas agricultural land use decreased. IBI metrics were high for insectivores at all sample sites, low % of tolerant species, and a high CPUE for Sinking Creek. % DELT and % Hybrids occurred only in catchments with the greatest agricultural land use (Big Limestone and Lower Lick). More developed and farmed land cover occurred in the Ridge and Valley level-3 ecoregion than in Blue Ridge ecoregion. Fish IBI scores showed no statistically significant association with 2014 land use coverages (Generalized Additive Models [GAM]; $F < 1.0$; $P > 0.05$). Impervious and Forested land use change difference in km2 2000-2014) was positively associated with % DELT and % Hybrid, while these IBI metrics were negatively associated with change in agricultural land use (GAM; $P < 0.05$).

Discussion Current Results and Future Work—Supervised classifications show that there has been an increase in impervious surfaces in the total Nolichucky watershed as well HUC 12 catchments sampled for fish assemblages, but these are not showing any association with the variation in IBI scores. Therefore, the next step is to try and use remote sensing on a finer spatial scale (e.g., riparian buffers or plot-specific land use units) to discern associations between row-crop land use intensity and pasture intensity in the Nolichucky watershed, where tomato row crops occur, greater pesticide management is required to control insects, fungi, and weeds than on other types of crops (e.g., soy, corn) and pasture. If acute toxicity events, for example, fish kills caused by insecticides from storm-related agricultural runoff, are degrading fish community integrity, then it will likely be detected at smaller spatial extents than reported here. Future work will include a GIS-based assessment of riparian agricultural and urban disturbance as well as forested buffer width at 30-m and 240-m perpendicular distances from the stream channel at each site. The amount of disturbance and magnitude of forested buffer will then be modeled against fish assemblage and IBI metrics to determine if land use within the riparian zones has an effect on biotic integrity in the Nolichucky watershed.

Abbreviation	IBI Metric	Abbreviation	IBI Metric
%_DELT	% of fish with DELT	CPUE	Catch Rate
%_HYB	% of fish as Hybrids	N_INTOL	Number of pollution intolerant sp.
%_PISC	% of fish as Piscivores	N_SUCK	Number of Sucker sp.
%_OMNI	% of fish as Omnivores	N_SUNF	Number of Sunfish sp.
%_INSCT	% of fish as Insectivores	N_DART	Number of Darter sp.
%_TOL	% of fish Pollution tolerant	N_RICH	Total species Richness

Table 1. Definition of the 12 TVA fish IBI metric abbreviations

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Evaluating Environmental and Biological Impacts of Acid Runoff from Pyrite-Bearing Rock Formations

(Team: William Sutton and DeEtra Young, Department of Agricultural and Environmental Sciences, Tennessee State University)

The objective of this study was to, 1) use stream salamanders as biological indicators to evaluate the impacts of ARD (acid rock drainage) on stream integrity, and 2) attenuate ARD by manipulating the indigenous microbial community through different treatment injections, ultimately generating anaerobic sulfur-reducing conditions. The collective scope of the project was to evaluate the biological impacts of ARD and evaluate potential strategies to mitigate the impacts of ARD disturbance on stream ecosystems.

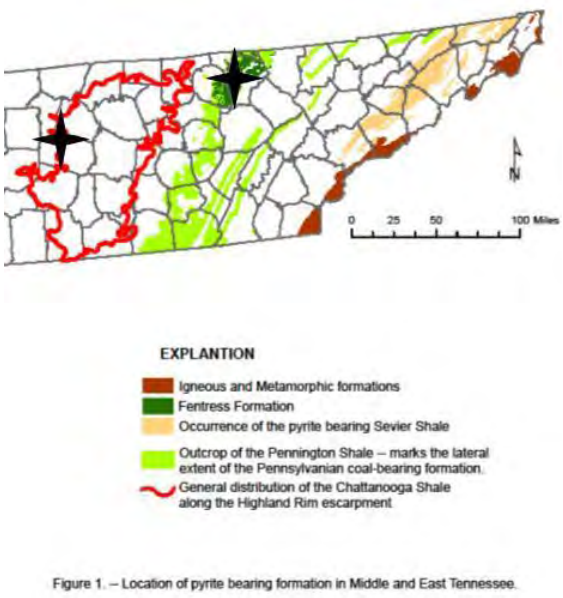

Figure 1. – Location of pyrite bearing formation in Middle and East Tennessee.

Materials and Methods—Study sites were located in the Chattanooga and Fentress shale formations in middle Tennessee (Figure 1). Sites were selected to coincide with an on-going ARD project implemented by the USGS. While the USGS project has numerous ARD monitoring sites across Tennessee, we targeted 2 ARD sites in middle TN with direct drainage from the ARD disturbance into neighboring low-order streams. The first site included a road cut through the Ordovician geologic formation containing the Chattanooga Shale, located in south Williamson County, on US 840 and drains to the headwaters of Carter's Creek – which flows into the Mill Creek watershed. It is an example of a Central Basin – Highland Rim escarpment ARD site. The second site was located in Fentress County, TN, and feeds to a headwater stream in the Wolf Creek watershed.

Discussion—Bioattenuation of ARD Discharge: This study used geochemical and biological indicators to evaluate treatments with the goal of attenuating microbial-derived ARD. The treatment strategies included disrupting the microbial population through chemical shock or shifting the microbial population from iron-sulfide oxidizing bacteria to sulfur-reducing bacteria with supplements. In addition to evaluating effectiveness of the treatment, consideration was given to the longevity of the treatment. The optimum attenuation and longevity treatment was a sequential injection of NaOH, followed by sodium lactate and soy infant formula. This sequential treatment promoted the highest rise in pH, alkalinity, sulfide, slime-producing and sulfur-reducing bacteria in the discharge waters as compared to the other treatments and reference controls.

The initial injection of NaOH probably neutralized the pH within a niche long enough to allow heterotrophic, aerobic and anaerobic bacteria to colonize and feed on the lactate and soy formula. The dissolved soy formula is rich in nutrients, such as protein, carbohydrates, fats, and B vitamins. These nutrients stimulate heterotrophic aerobic bacteria, such as the slime-producing bacteria, responsible for rapidly consuming oxygen and establishing an anaerobic environment. Once the oxygen is consumed, the facultative anaerobic and obligate anaerobic bacteria begin to dominate the microbial community. Lactate was included in the supplement treatment since it is the preferred food of sulfur-reducing bacteria and has been used to stimulate their growth in groundwater systems. The B-vitamins present in the soy formula are essential to anaerobic respiration enzymes and would normally take a long time to synthesize. Another benefit associated with the soy formula was that the milky liquid flowed effortlessly into the pore spaces while adhering to the shale surfaces. Even as the soy formula began to spoil and curdle, it continued to adhere to the surfaces, providing excellent conditions for biofilm development and generating anoxic conditions on the surfaces of the shale. Despite pumping 45 pore volumes of water with relatively high dissolved oxygen (6 to 10 mg/L) through the microcosms, the treatment continued to provide alleviation of ARD symptoms for the duration of the experiment (231 days). The success of the treatment was probably due in part to the biofilm development on the shale materials. Beyenal and Babauta, (2012) describe how environmental bacteria such as Geobacter sulfurreducens develop biofilms on solid surfaces and establish extremely anaerobic, reducing (electron rich) conditions at the biofilm-solid interface. Such a biofilm would provide a physicochemical barrier to the oxygen and the chemolithotrophic bacteria involved in the oxi-

dation of iron-sulfide minerals and production of acid rock drainage.

In addition to the beneficial results from the sequential injection of NaOH, soy formula and lactate, there were some other interesting results. Use of phosphate in experiment 2 provided favorable pH control, reduced iron and sulfate, and enhanced bacteria populations for both the lactate, and the lactate + soy formula. However, the treatments in experiment 2 also released water with high levels of phosphate, median values ranged 51-95 mg/L. Phosphate levels of this magnitude would not be acceptable due to eutrophication potential of receiving streams. Perhaps treatments using phosphate buffer would work in an engineered bioreactor where flow is more tightly controlled. Additional research is needed to determine if use of phosphate buffer would be feasible in a bioreactor. As noted earlier, the results of sequential treatment using NaOH, soy formula and lactate provided a promising treatment. There was one negative side effect of the treatment, a foul odor in the discharge waters associated with the initial curdling of the formula. The odor was most noticeable after 4 days and lingered for another 5 days. This odor might be an issue in a populated area, but not in rural areas removed from the general public. In conclusion, the results of this study indicate there is good potential that ARD can be passively attenuated by using a sequential treatment of NaOH, followed by a mixture of lactate and soy formula.

Salamander Sampling: Our project evaluated the biological impacts of ARD on stream salamander communities. Overall, we found little evidence to suggest that ARD is negatively impacting stream biota at the two sites that we examined in this study. Specifically, we found negligible differences in larval and adult salamander counts and richness between ARD-impacted vs. non-ARD-impacted stream segments. However, we did find that percent composition of E. cirrigera was greater in ARD-impacted stream segments when compared to non-ARD-impacted sites. Previous research suggests that E. cirrigera is somewhat tolerant of streamside disturbance and can assume a dominant position in moderately disturbed stream sites. We observed this relationship of salamander diversity at the 840 site in Williamson County. Specifically, the upstream non-ARD site had a more diverse salamander assemblage composed of three species, including D. conanti, E. cirrigera, and E. lucifuga. The adjacent, ARD-disturbed stream section only contained one species, E. cirrigera, which we attribute to the disturbed nature of the downstream stream section. We did not observe the same relationship at the Fentress County site, but did find that the abundance of G. porphyriticus was comparatively less in the downstream ARD-disturbed stream section. The downstream ARD-disturbed stream section at the Fentress County site had a short streambed section that terminated underground abruptly approximately 30 m downstream from ARD runoff from the adjacent road construction. The ARD disturbance at the Fentress County site was not as extensive as the 840 site in Williamson County and likely explains the comparably high salamander abundance and richness of the downstream site compared to the upstream stream site at the Fentress County ARD site.

We explored the utility of steam salamanders as indicators of biological condition. Streamside salamanders in the family Plethodontidae are lungless and rely primarily on cutaneous respiration to acquire oxygen. Previous research efforts have shown that degraded steam environments tend to have reduced abundance, richness, and total counts of stream salamanders. Collectively, these species require well-oxygenated stream habitats with an abundance of cover objects and intact riparian buffers. Although salamanders are useful as indicators of biological integrity, these organisms can present difficulties as monitoring tools because they can be difficult to detect because they are primarily fossorial and activity patterns can vary greatly depending on weather patterns. Repeated sampling is often necessary account for environmental covariates that impact detection and to obtain accurate estimates of occupancy and abundance.

Road cut in Williamson County, Tennessee with signs of acid rock

Our results provide a preliminary examination of the impacts of ARD on stream salamander communities. Previous research in the Great Smoky Mountains National Park illustrated that ARD runoff from an Anakeesta shale formation resulted in decreased abundance and species richness of stream salamanders. Our study only evaluated the impacts of ARD on salamanders at two sites in TN, which greatly limits the inference of ARD impacts on stream biota statewide. However, our preliminary data suggests that impacts of ARD on stream salamanders appears to be site-specific and related to the relative length of the stream impacted by the adjacent ARD disturbance. Future studies should include a much larger sample of sites

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across Tennessee and a variety of ecoregions and include streams that have a variety of impacts from ARD discharge.

Underground Reactive Barrier to Attenuate Contaminants from Agricultural Drainage

(Team: Jaehoon Lee, John R. Buchanan, Jennifer DeBruyn, Shawn Hawkins, and Andrea Ludwig, Biosystems Engineering and Soil Sciences)

Statement of Critical Regional or State Water Problem(s)—Typical concentrated animal feeding operations such as dairy facilities produce large quantities of manure which is stored in lagoons or holding ponds before being applied to nearby crop or pasture fields. Off-site movement of the manure as well as other fertilizers through storm water runoff or percolation to groundwater has been well recognized as a major source of contamination of water bodies. This is especially true in east Tennessee with high rainfall and substantial topographic relief. The author of this proposal has been actively involved in assessing the new UT Little River Animal and Environmental Unit for potential stream and groundwater contamination. Our preliminary data show that the underlying soil and rock of the unit is highly permeable and will allow a rapid movement of chemicals and pathogens to groundwater and surrounding streams and rivers. In Tennessee, there is a 303(d) list of impaired water bodies due to excess pathogens and nutrients. There is a great need for cost-effective and proven best management practices to mediate the excess nutrients. Our research findings will create science-based recommendations for the use of underground reactive barriers in challenging environmental conditions found in many areas of the Tennessee. This project will also be a demonstration at the UT Research and Education Center, and data will continue to be collected in the future.

Research Objectives—There are two specific aims and hypotheses in this proposed project.

Specific Aims: (1) Evaluation of biochar and charcoal as a medium for reactive barrier to capture P and other organic chemicals (e.g., veterinary antibiotics and pesticides), and (2) Evaluate the effects of water level and temperature on the rate of treatment.

Hypothesis: (1) Underground reactive barriers using combined sawdust and biochar/charcoal will increase the level of nitrate (NO3-) removal as well as P and other organic chemicals, and (2) Control of water level and residence time in the barrier in conjunction with seasonal variations of drainage will improve the removal rate.

Methods, Procedures and Facilities—Barrier construction: We will install underground reactive barriers in the new UT Little River Animal and Environmental Unit located at 3217 Ellejoy Road, Walland, TN, about a 30-minute drive from the UT Campus. The research and education center is bounded by streams on three sides and lies in the floodplain of a state-declared exceptional waterway. A charcoal-woodchip barrier will be installed right next to the already planned 100% woodchip traditional barrier. The new barrier will use a mixture of sawdust (80%) and biochar or charcoal (20% in volume). The barriers will be approximately 1.5 m deep, 7 m wide, and 15 m long, and will be designed to catch surface runoff as well as shallow ground water. The locations of the barriers are already determined by a consultation with Dr. Bobby Simpson (Director of the East TN Research & Education Center) and support staff, considering five years of previous runoff and groundwater monitoring data.

Barrier Control: Two water level control structures similar to the Agri Drain will be installed to control water levels in the barriers and tile-drained field. One structure will be installed right before (inlet) the barrier and the other will be installed at the end of the barrier. The two structures will allow us to control water level of the tile-installed filed as well as the barrier itself. The structures bypass excess drainage and runoff to nearby drainage field, if there is more water than the barrier can handle. The structures will also be used for routine water sampling. Temperature sensors will be installed in two locations at two depths (30 and 90 cm) to monitor barrier temperature. It is well documented that saturation provides the best environment for denitrifiers and thus works best for N reduction. However, there is limited information in the literature about charcoal amendment in the barrier, especially related to treatment of P, other organic chemicals, and pathogens and its relationship with water level. The barrier will be maintained for the highest possible water level to provide the best reduction of N. However, when there is not enough water, we will record the water level and/or saturation rate, and closely monitor the rate of reduction for N, P and other organic chemicals.

Water quality monitoring: At least two samplings each month will be done for analysis of N, P, selected chemicals (e.g., tylosin, chlortetracycline, sulfamethazine, and a few pesticides as well), and fecal bacteria/pathogen. The investigators have two full-time research associates (one engineer and the other for soil and water analysis), and nearly 1500 square feet of modern lab space combined. We have an analytical chemistry lab equipped with all the equipment and apparatus necessary for the water sample analysis (e.g., HPLC,

GC, ICP, AA, GC/MS). The BESS also has qualified faculty, scientists, and technicians with extensive experience in both laboratory and field research, as well as students interested in this research topic. Several types of vehicles (vans, trucks, trailers, and tractors), and a well-equipped fabrication shop with two full-time staff members are also available.

Principal Findings to date—Pilot Scale Test: We did small scale experiments to test the efficacy of biochar and charcoal as a reactive barrier medium. Various ratios (5, 10 and 20% v/v) of biochar and charcoal with sawdust were evaluated for their removal of N, P and other agricultural chemicals. The results showed that 10% of charcoal by volume provided the most economic rate of treatment. We also found out that addition of silage leachate to the reactive barrier significantly increased denitrification. The silage leachate contains high carbon content and degrades nearby water, however, if added to the barrier, the carbon can be immediately used for the denitrification process.

Field installation of barrier: Two locations in the Center has been identified and prepared for installation. All the materials, liners, woodchips, sand, charcoal, construction equipment, sampling access tubes, etc., are secured and installation will begin this summer.

Recalibrating the SAGT SPARROW to Accommodate Changes in Agricultural Inputs

(Team: Dayton M. Lambert, Christopher N. Boyer, and Christopher D. Clark, Agricultural Economics)

Introduction—By 2022, the US Renewable Fuels Standard (RFS) mandates that 36 billion gallons of ethanol be blended into gasoline, with 21 billion gallons of that coming in the form of advanced biofuels, including at least 16 billion gallons of cellulosic ethanol (USDOE, 2015). In examining increased cellulosic ethanol production, the Biomass Research and Development Board assumed conservatively 4 billion gallons of cellulosic ethanol would originate from woody material in support of meeting the RFS by 2022. Other research suggests that 10.5 billion of the 21 billion gallon annual production targets for advanced biofuels mandated by the RFS could originate in the Southeastern United States. Nearly all of the biofuel currently produced in the US comes from first generation feedstock, primarily corn grain. Meeting the RFS requirements will require increased biofuel production from second-generation feedstock, such as switchgrass, miscanthus, canola, camelina, or woody biomass. The increased market demand for energy crops is expected to result in extensive conversion of previously uncultivated land, fallow agricultural land, pastureland, or Conservation Reserve Program (CRP) land, potentially resulting in a substantial increase in land in agricultural production. Increased biofuel production from second generation feedstock offers the possibility of reducing the amount of tilled land and mitigating climate change by reducing the emission of greenhouse gases (GHG) associated with transportation fuels. However, converting enough land to feedstock production to meet the RFS could significantly affect nutrient emissions from agriculture and regional water quality balances. Changes in fertilizer use, tillage practices, and vegetal cover may generate unintended consequences that affect the ecosystem services provided by the region's streams and rivers. Agriculture is a major contributor to the region's economy and communities and predicting the nature of these consequences is difficult because of the extended growing season and diverse types of agricultural practices currently employed in the region. Seasonal and spatial variability in rainfall, temperature, soil types, and access to water all support an intensive and diverse agricultural production region. This research modifies the South Atlantic-Gulf-Tennessee basin (SAGT) system SPARROW (Spatially Referenced Regression on Watershed Attributes) model (SAGT-SPAROW), developed by Hoos et al. (2008) and calibrated and applied by Hoos and McMahon (2009), to examine potential impacts of land use change resulting from a mature cellulosic biofuel industry on water quality in the SAGT basin. The primary data-generating and modeling challenges addressed in this research are 1) generating agronomic and economic data sets to reflect the distribution of feedstock production potential, attendant production costs, and crop nutrient demand, and 2) integrating the agronomic and economic data sets with hydrological data sets provided by the US Geological Survey (USGS) at commensurable geospatial scales. Both procedures make extensive use of internal GIS capabilities and data management algorithms. A data harmonizing procedure is developed to benchmark data collected by NASS with fertilizer use data available in the SAGT-USGS data sets. After compiling downscaled and integrated data sets, we augment variables in the USGS-SAGT data set reflecting agriculture's contribution of N and P to aggregate N and P emissions. The revised set of variables is used to compare ex ante a baseline scenario (an agricultural landscape's impact on N and P emissions absent the RFS) to various target biofuel production levels for the SAGT region based on the RFS mandate. Canola (for biodiesel) and short rotation woody crops (SRWC) (for pyrolysis) are the feedstock considered in the analysis.

Results—Nitrogen Emissions and Canola/bio-diesel Production: Producing 2.31 BGY (or 22% of 10.5 BGY) of advanced biofuel in the Southeastern US, would

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result in the conversion of 1.97 million hectares of cropland in the SAGT region to canola production. The primary source for the land needed to produce canola is land currently devoted to cotton, soybean and wheat production, accounting for around 94% of the converted land. Soybeans receive very little or no nitrogen and nitrogen application rates for cotton and wheat are less than for canola. Phosphorous application rates for soybeans and wheat are less than for canola, while the rate for cotton is about the same as that for canola. At this level of feedstock production, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 14.25% (from 28,039.73 to 32,037.5 kg yr-1) compared to the baseline and an increase in the agricultural source share of 12.79% (from 3.83% to 4.32%) from the baseline. However, this increase is not enough to change the mean concentration in the SAGT region, which remains 1.09 mgL-1. This level of feedstock production results in an increase in the mean level of P application in the region's watersheds of 2.19% (from 16,562.6 to 16,926.61), an increase in the agricultural source share of 1.24% (from 15.28% to 15.47%), and an increase in the mean P concentration from 1.50 to 1.51 mgL-1 from the baseline.

Producing 3.255 BGY (or 31% of 10.5 BGY) of advanced biofuel in the Southeastern US would require converting 2.37 million hectares of cropland in the SAGT region to canola production . Land devoted to cotton, corn and soybean production remain the primary source of the land converted to canola production, accounting for around 94% of the converted hectares. At this level of production, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 16.89% (from 28,039.73 to 32,775.69), and an increase in the agricultural source share of 10.18% (form 3.83% to 4.22%) from the baseline. This increase is still not enough to alter the mean N concentration in the region. At this level of production, there is an increase in the mean level of P application in the region's watersheds of 1.95% (from 16562.6 to 16886.97), the agricultural source share increases by 1.7% (from 15.28% to 15.54%), and the mean P concentration increases from 1.50 to 1.51 mgL-1 relative to the baseline.

Producing 5.25 BGY (or 50% of 10.5 BGY) of advanced biofuel in the Southeastern US would require the conversion of 3.71 million hectares of land in the SAGT region to canola production. Land devoted to either cotton, corn or soybean production comprises 94% of the land converted to canola production. At this production level, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 26.71% (from 28039.73 to 35530.8) compared to baseline and an increase in the agricultural source share of 8.87% (form 3.83% to 4.17%) from the baseline. This increase is still not enough to alter the mean N concentration in the SAGT region. At this level of production, the agricultural source share of P applications increases by 3.59% (from 15.28% to 15.83%), and the mean P concentration increases from 1.50 to 1.51 mgL-1 relative to the baseline. At this level of production, there is an increase in the mean level of P application in the region's watersheds of 3.67% (from 16562.6 to 17170.56) compared to baseline.

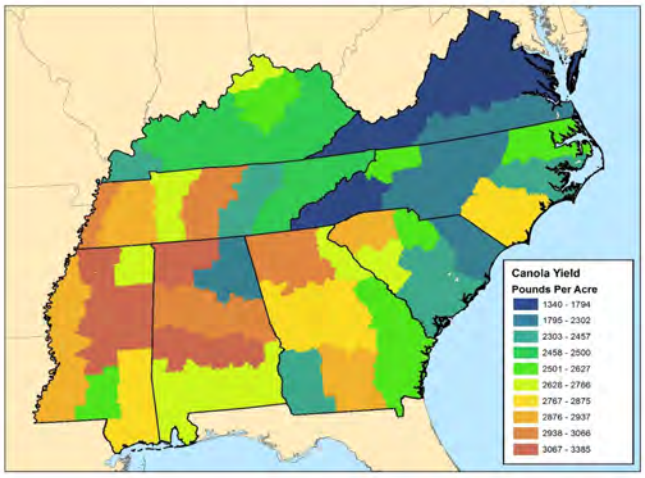
Conclusions and Further Research—The goals of this project were to 1) modify the USGS/SAGT database to include data that reflected land use change driven by the 2007 RFS mandate for the development of second-generation feedstock sources for biofuels, and 2) estimate the impacts land use change would have on nutrient loading into the SAGT basin with SPARROW. Two feedstocks were considered – short rotation woody crops and canola. Each feedstock required the development of production costs, which were subsequently used to determine changes in applied nutrient levels, in particular, N and P. Findings suggest that, while agricultural land uses would clearly be impacted by the introduction of alternative feedstock sources such as canola or SRWC, the impact on water quality (in terms of nutrient loading into the SAGT system) in broad geographic terms would not differ from current nutrient levels.

Our research developed a procedure whereby crop production data generated by NASS could be used to proxy changes in applied fertilizer, given the displacement of conventional crops by dedicated energy crops. The research addressed two key challenges. The first was the dearth of information for canola and short rotation woody crop budgets. This information is critical for determining the opportunity costs of producing conventional crops (given economic impetus to develop feedstock), and therefore changes in land use. The second challenge was harmonizing the NASS cropland data layers (recorded in 2009) with the USGS/SAGT database (recorded in 2002). Addressing the second challenge required an imputation procedure that accommodated differences in spatial resolution and temporal scale.

There are caveats to this research. First, we did not model intensification of traditional crop production, assuming there would be no expansion of traditional crop production coincident to the conversion of agricultural land to feedstock production. Indirect land use changes resulting from intensified crop production could affect water quality in the SAGT basin and

elsewhere. Second, nitrogen fixation by soybeans was not modeled, therefore underestimating changes in N loadings associated with conversion of soybean area to feedstock production. Third, livestock N sources were modeled, but no effort was made to determine the effects of hay and pasture land to feedstock production on livestock production. Fourth, we assumed pastureland and land cultivated in hay receive the same quantity of fertilizer N and P, and that 100% of their respective acres were treated. This assumption may be untenable. The 2009 USDA Census of Agriculture did not distinguish land in hay and pastureland, which therefore precluded calculating the quantity of N and P applied to each land use separately. The relative contributions of hay and pastureland to emissions therefore represent an upper-bound estimate since less N or P is usually applied on pastureland. Lastly, the counterfactual scenario depends on the assumption that fertilizer N and P expenditures were similar between 2002 and 2009. That high-resolution cropland data layers were unavailable until 2009 precluded generating a comparable data surface for 2002.

With these limitations in mind, our research extends the empirical methodology of integrating economic-driven land use change models with a mass-balance hydrologic model. The integration of these systems provides a gateway through which the interaction between economic variables affecting land use change and water quality can be analyzed. The combined system facilitates the examination of ceteris paribus effects of policy on water quality indicators at a macro-regional scale. Other water quality models, such as the Soil and Water Assessment Tool (SWAT), could possibly be modified to accommodate the simulation procedures outlined by this research.



Canola yields generated by EPIC, aggregated to the Crop Reporting District level

Characterizing Stream Sediment Source Potentials in Small Urbanizing Watersheds

(PI: John Schwartz, Civil and Environmental Engineering)

Urbanization causes widespread changes to watershed hydrology and channel geomorphic processes, where increased impervious surfaces cause hydromodification mostly observed as greater peak stormflows and longer durations. Hydromodification leads to channel bed and bank erosion increasing fine sediment loads to stream. These increases in fine sediment loads result in degradation of aquatic habitat and impairment of biotic integrity. Impacted streams are identified on federal/state 303(d) list requiring a total daily maximum loads (TMDLs) for suspended sediment to be produced, in addition to an implementation plan to achieve loading targets. In urban watersheds, the potential generation of fine sediment loads from geomorphic incision cannot be separated from uplands stormwater management practices. Although stormwater control measures improve water quality from local sites, a key question remains as to what levels of treated stormwater discharges are acceptable to maintain in-stream geomorphic stability, termed channel protection flows. However, the linkages between urbanization, stormwater management policy, and stream channel response are still poorly understood over the range of watershed settings. Therefore, a critical need exists for state and local agencies charged with the water quality protection of streams to have geomorphic field assessment tools that can prioritize streams reaches most vulnerable to in-channel bank/bed erosion. This research proposes to clarify interrelationships between hydromodification from urbanization, fluvial geomorphological processes, and stormwater management and policy. It is proposed that classification of urban stream reaches by trajectory of response to hydromodification allows an approximation of impacts of land-use modifications, development of effective regulation to avoid or minimize externalities, and prioritization of mitigation efforts between stormwater control measures and stream rehabilitation. The classification scheme will be based on improved geomorphic field assessment protocol for urban streams. Ultimately, this research is expected to support stream system rehabilitation in Ecoregion 67 through adaptation of mitigation practices relative to channel erosive resistance properties and adapted for use in channel protection efforts throughout the nation.

Progress to Date—Analysis of field collected data as well as desktop is currently being conducted by Robert Woockman. Work started in late May and continues. This work is currently on a timeline to be completed by late July if things continue to progress on schedule.

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Pending Publications: It is intended that this work will be submitted for publication to River Research and Applications or Geomorphology. Expectations are initial submission should be as early as fall 2016.

New USGS projects (March 1, 2016-February 28, 2017)awarded this reporting:

- Using UV/Peroxyacetic Acid to Remove Pharmaceuticals from Reclaimed Wastewater (PI: John Buchanan, Biosystems Engineering and Soil Sciences)
- Investigating Changes of River Course of the Tennessee River and the Impact from Regional Climate Change (PI: Joshua Fu, Civil and Environmental Engineering)
- Measuring Water Table Flucations under Different Irrigation Regimes in Western Tennessee Agroecosystems (CoPIs: Christopher Wilson and Jon Hathaway, Civil and Environmental Engineering)
- Environmental Impacts of Coal Ash Spill on Nutrient Cycling and Surface Water Quality in Eastern Tennessee (PI: Anna Szynkiewicz, Earth and Planetary Science)

Two additional awards were made as Graduate Research Assistant Supplemental Research Awards:

- Urban Stream Restoration Planning: Towards Cost-Effective Mitigation of the Effects of Hydromodification (Co-PIs: Robert Woockman and John Schwartz, Civil and Environmental Engineering)
- Development of a Robust Model for Cross-scale Prediction of Flow and Sediment Transport (Co-PIs: Benjamin Abban and Thanos Papanicolaou, Civil and Environmental Engineering)

Training Activities

TNWRRC coordinates two statewide training and certification programs for the Tennessee Department of Environment and Conservation (TDEC). The Tennessee Erosion Prevention and Sediment Control Training and Certification program (TNEPSC) is comprised of three basic courses:

- The Level I Fundamentals of Erosion Prevention and Sediment Control for Construction Sites is a one-day, foundation-building course for individuals involved in all aspects of land disturbing activities. It was offered 16 times in nine communities with 1301 people attending.
- The Level II Design Principles for Erosion Prevention & Sediment Control for Construction Sites is an intensive two-day course for engineers and other design professionals focused on engineering technology needed to plan and design practices and controls for preventing erosion and managing sediment and other stormwater pollutants on construction sites. It was offered six times in five communities with 236 professionals attending.
- The Level I Recertification is a half-day course for those who have successfully completed the Level I course and need to renew their Level I certification. Recertification is required every three years. It was offered 12 times in 11 communities with 1194 people attending.

The Tennessee Hydrologic Determination Training Program (TN-HDT) is the second training program coordinated by TNWRRC for TDEC. The TN-HDT program consists of a three-day course designed to provided participants with a basic understanding of the underlying scientific principles, the legal ramifications, and the practical investigative techniques surrounding the determination of wet weather conveyances versus streams and other surface water features. The course was offered twice with a total of 46 people attending. The state regulations that established the TN-HDT certification program require those that successfully complete the TN-HDT course attend a one-day Refresher course every three years to maintain their certification. The one-day Refresher course was offered four times in 2016, twice in both Knoxville and Nashville, with 78 persons attending.

Low Impact Development Stormwater Manual and Training Courses—The TNWRRC, including faculty and graduate students from the Department of Civil and Environmental Engineering (CEE) and the Department of Biosystems Engineering and Soil Science (BESS), are working with staff from TDEC Division of Water Resources to develop the first edition of the Tennessee Permanent Stormwater Management and Design Guidance Manual. TDEC has established stormwater runoff reduction as the primary treatment objective for new development and redevelopment projects across Tennessee. This new manual will provide detailed design guidelines for permanent stormwater control measures that meet this treatment objective. The primary purpose of this manual is to serve as a technical design reference for designated and non-designated (unregulated) MS4 (municipal separate storm sewer system) communities in Tennessee. It is intended to provide the information necessary to properly meet the minimum permanent stormwater management requirements as specified in MS4 permits. The UT team has also developed the Runoff Reduction Assessment Tool (RRAT) to be used in conjunction with the Manual. The RRAT will assist

professional engineers and other design professionals to ensure that the stormwater management plans they have prepared meet the permanent stormwater performance standards for new or redevelopment sites. The first edition of the Manual was released in December 2014. The Manual and the RRAT model may be down loaded from the new Tennessee Stormwater Training Program website, http://tnstormwatertraining.org/index.asp.

Knox County Adopt-A-Watershed Program

The 2015/16 Knox County Adopt-A-Watershed (AAW) Program involved 1687 students from 14 middle and high schools in hands-on learning activities to prepare them to conduct a service that would improve the well-being of their schools' watersheds. Approximately two-thirds of these students participated in five hours or more of class and field lessons in preparation of service engagement, with 90 percent completing a service project. AAW is managed by the TNWRRC and is sponsored by Knox County Stormwater and the Water Quality Forum. Service learning projects are curriculum based and the selected services are coordinated with community partners to ensure they meet a need within the school's watershed.

Service learning projects completed this year were wide-ranging in scope from on-the-ground remediation projects to data collection for ongoing University of Tennessee research projects. Students across Beaver Creek, Conner Creek, Baker Creek, First Creek, Stock Creek, and Ten Mile Creek Watersheds collectively removed about 2.6 tons of invasive, exotic plant material and installed 698 native plants. Planting projects were conducted to stabilize eroding hillsides; establish streamside riparian buffers; serve as pollinator sources; and for beautification. At South Doyle Middle, an AAW Club teamed up with the University of Tennessee Hydrolunteers Club to plant 275 native tree seedlings. These were planted as part of a grant to offset the carbon footprint of the American Ecological Engineering Society Conference held at UT in early June, 2016. Holston Middle students planted trees along an adjacent greenway while students from Hardin Valley Academy planted 150 seedlings as a part of the annual statewide "50,000 Trees across Tennessee" initiative.

AAW classes and clubs also identified nonpoint source pollutant problems on campuses and conducted initiatives to address them. These included on-the-ground projects like Career Magnet Academy students who cleaned out sediment-covered stormdrains and West High students who organized and implemented a campus-wide litter campaign. Projects also included educating the student body as well as school staff on actions they could take to protect their school's watershed. For example, at Grace Christian, the Environmental Science classes conducted a multi-media Stormwater Awareness Day that involved doing "chalk art" on campus stormdrains to raise awareness that they drain to Beaver Creek. At Holston Middle, a 7th grade Honors Science class wrote and produced an educational video on waste reduction and recycling.

2015/16 AAW students also continued their participation in UT Civil and Environmental Engineering Department projects. Working with UT doctoral student, Andrew Tirpak, West High students collected data from an outdoor research lab set up by Andrew and AAW students the prior year. This data is being used by Andrew in his US. Forest Service-sponsored research that is analyzing the impacts of stormwater on urban trees. At South Doyle Middle, AAW students assisted UT doctoral student, Jessica Thompson, in planting a regenerative stormwater conveyance that she has installed on campus to evaluate the effectiveness of this innovative stormwater management approach. Working with the 15/16 students, Jessica also set up a data collection system for the students in the coming year to collect research data for her at this site. Central High students also supported a project led by UT Associate Professor, Garry Mendendez, in the Plant Sciences Department. The AAW students built a "floating island" prototype that was recommended by Garry as a part of his master plan for the revitalization of Fountain City Lake. The island's intent is to provide wildlife habitat and to serve as a means for nutrient uptake through the plants. The students researched its design, built it, and then tested its floatability. The resulting product was highly functional, with its design archived for future use.

Central High students building a "Floating Island Habitat" Prototype

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(above) South Doyle Middle students team up with UT HydroVolunteers to install plants next to Baker Creek. (right) South Doyle Middle students assist with planting the UT Regenerative Stormwater Conveyance Project

Karn High Engineering students design and build raise bed and Environmental Science students install with native plants

Emily Human, 17, paints her storm water conservation message on the spirit rock at Grace Christian Academy during an "Adopt-a-Watershed service project on Dec. 8. "Don't be a dodo and spill your cocoa, only rain down the drain." Pictured from left are Emily Human, 17, Wade Sluss, 17, Seth Paczkowski, 17, Luke Smith, 17, and Christian Davis, 17.

GCA kids give a hoot

Students in Tasha Walker's Environmental Science class at Grace Christian Academy met outside the school's entrance last Tuesday morning for a service project creating sidewalk chalk art describing storm-water issues and how they impact Beaver Creek.

Jessica Stapleton from Knox County Stormwater Management and AmeriCorps Water Quality Team met with the students as part of the Knox County Adopt-a-Watershed Program.

"The project is a wrap-up of what the kids learned this semester about storm-water and water-treatment infrastructure having toured a water-treatment plant as well as Harrell Road Storm-water Park.

"They are depicting the different types of pollution that can get into the storm drains and make its way to Beaver Creek – like the trash from our own parking lot, for example.

"Litter gets washed down the storm drain and ends up in Beaver Creek where it endangers the whole ecosystem.

"It's a way to take everything we've learned and put it outside in front of the school so visitors can see it, get interested in storm-water conservation and be part of Knox County's Adopt-a-Watershed Program," said Stapleton.

Info: www.knoxcounty.org/stormwater/pub_AAW.php

Nancy Anderson

Shopper News article featuring Grace Christian Academy AAW who conducted Campus-Wide Stormwater Awareness Day

Tennessee Smart Yards

Tennessee Smart Yards (TNSY) program is jointly conducted by UT Extension and TNWRRC and has been going through a "make-over" in its programming to broaden its scope in both content and delivery strategy options as well as to expand its spatial coverage across the state. With the support of a grant from the Tennessee Department of Agriculture 319 Program that came to completion this summer, the TNSY Team created a train-the-trainer workshop for homeowner rain garden design and delivered it three times across each grand division of the state to both Extension agents and municipal stormwater staff. In conjunction with these workshops, demonstration rain gardens were installed at the UT Plateau Research and Education Center, UT Extension Clyde Austin 4-H Center, and the West Tennessee Research and Education Center. Spinning off from this effort, the team also collaborated on three additional workshops hosted by municipal stormwater programs (Mt. Juliett, Rutherford County, and Collierville).

Under the 319 grant, the original six-hour TNSY workshop was restructured into nine modules based on the program's nine guiding principles. The intent of this revision was to develop a modular system of materials that would allow for more flexibility in program delivery. In a modular format, the materials may now be more easily delivered in venues such as lunch-and-learns, evening club meetings, and half or full day sessions. They were also formatted so that they may be adapted to web-based delivery.

The creation of the modular framework was a response to feedback from pilot program trainers who expressed the need for broader delivery options. In addition, four new modules were developed around the following topics: 1) turf grass management, 2) pet-friendly yards, 3) integrated pest management, and 4) protecting the water's edge. All of the new modules include hands-on activities that allow the attendees to apply the knowledge they have learned so that they feel more prepared to use them in their home landscape.

As a part of the program makeover, TNSY was re-branded with a new color palette and logo. In addition, the content of the Handbook and the Yardstick (that allows participants to track progress) were updated along with the revised branding.

Prompted by the progress made under the TDA 319 grant, the UT Extension partners now have a Sustainable Landscape Workgroup whose focus is to help deliver TNSY programs. The Extension Workgroup also secured internal funding to expand the geographic coverage of the program across Tennessee. Three re-

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gional trainings, jointly conducted by Extension and TNWRRC, will be offered in Fall 2016 for UT Extension Agents and municipal stormwater staff. In addition, 15 counties with TNSY-trained Extension Agents will receive participant materials. The long-term funding plan for the program includes Extension fee-based training along with support from municipal stormwater programs.

"No Mow" signs designed by South Doyle Middle School students for their newly installed buffer along Baker Creek.

Photo collage from rain garden workshops held at the West Tennessee Research & Education Center (top), Plateau Research & Education Center (Center), and 4-H Camp in Greeneville (bottom).

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UT Watershed Symposium—TNWRRC supported the 2015 Watershed Symposium held on the UT campus September 15, 2015. About 250 students, faculty, professionals, and the public convened at UT for the 4th Annual Watershed Symposium. Presentations included the latest research in water-related fields and insights from state and federal experts around this year's theme of "Horizons of Environmental and Water Policy: Where We Are and Where We Are Going."

The themes that surfaced out of the keynote address, provided by Chris Thomas, Branch Chief for Sustainable Communities and Watersheds, and technical panel were that we needed to continue to work collaboratively among agencies and researchers to identify the best possible solutions to challenges posed by a changing climate, population growth demands on clean water, and urbanization. Some of the solutions discussed included green infrastructure to manage urban runoff, multi-agency approaches for nutrient reduction in the agricultural sector and education of the general public to instill a sense that we are all in this together and everyone has role to play. This symposium was part of the ongoing efforts of the Watershed Faculty Consortium to perpetuate a healthy dialogue between all stakeholders in water quality.

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East Tennessee Clean Fuels Coalition (ETCleanFuels)

(PI: Jonathan Overly, Executive Director)

Helping Fleets Write CMA Grants—In 2015 and 2016, ETCleanFuels helped numerous fleets write CMAQ—Congestion Mitigation and Air Quality—proposals to the Tennessee Department of Transportation (TDOT). TDOT released two rounds of funding opportunities for entities in Tennessee: a) the PM-2.5 and diesel-focused funding that was only applicable in six eastern Tennessee counties, and b) the "General Call" funding that was applicable in all of the highlighted (nonattainment or former nonattainment) counties shown in the map below.

Certified "Tennessee Green Fleets"—In 2014, ETCleanFuels began researching green fleet programs in the US and looking at what kind of program could be designed to serve Tennessee fleets, encourage the use of alternative fuels for the purpose of improving air quality, and be effectively managed by our relatively small office of two people. In late 2015 we developed the blueprint for what would become the certification program for Tennessee fleets.

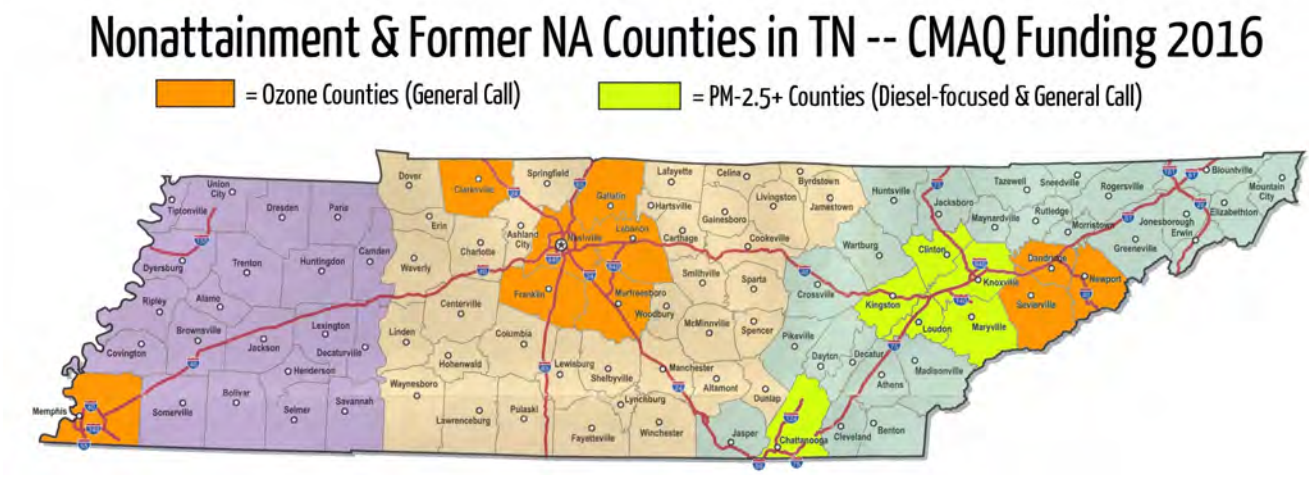
The program looks at a fleet's petroleum and alternative fuel use and the associated emissions profile, as well as poses a number of questions about how that fleet is managed. Points are provided for a) tons of greenhouse gas emissions reduced, b) the percent of petroleum use reduced, and c) the percent increase in the number of used alternative fuel vehicles that are in the fleet. Additionally, a smaller number of points are provided to fleets if they have, for example, a written down strategic plan for reducing petroleum use, are using telematics, externally communicate about their actions, or have an idle reduction plan. Fleets must achieve a minimum of at least 40 points to achieve certification and depending on their points, can end up as a one-star, two-star (minimum of 80 points) or three-star certified fleet (minimum of 120 points).

In our first year, eight fleets were certified into the program, three each in the one-star and three-star categories, and two fleets in the two-star tier. These fleets included large international companies to smaller local private fleets and Tennessee municipalities. Learn more about the certified fleets by visiting www.tncleanfuels.org.

CNG Rally Across the USA—Following on the heels of several Tennessee-based natural gas vehicle (NGV) expositions and road rallies that lasted from 2012 through 2015, ETCleanFuels assisted CNG visionary Pat Riley of Gibson County Utility District in western Tennessee in implementing the 2016 "Sea to Shining Sea CNG Road Rally." This rally started in Long Beach, California and made 13 media stops in 10 states along I-40 before reaching Washington, DC two weeks later. Five vehicles ran on natural gas for well over 90 percent of the entire route, helping prove that you can travel long distances in the United States running on natural gas. ETCleanFuels helped organize the Clean Cities coalitions in support of the event and provided other services like site and media assistance.

Crowd gathered at one of the stops along the Rally route, in Trenton, Tennessee

Assisting our Other Clean Cities Coalitions in Tennessee—Due to several different issues that were taking place in the Middle and West Tennessee Clean



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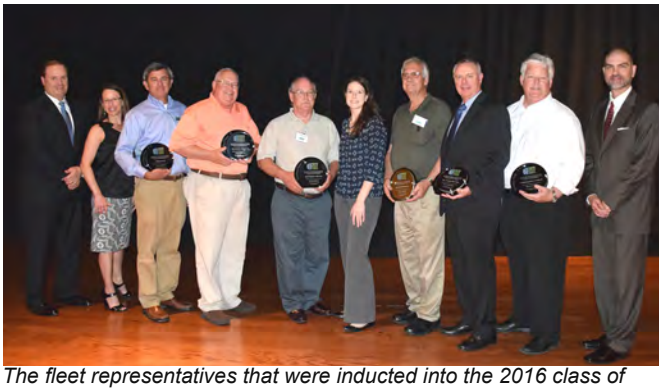
Fuels Coalitions during 2014 and 2015, it became necessary for ETCleanFuels to step in and assist both those coalitions and DOE to not lose their activities in Tennessee. Over the last year plus, ETCleanFuels staff have held board meetings, managed events, communicated heavily with DOE and overtaken the management of those coalitions, and then worked with board members and DOE to alter how the coalitions exist in Tennessee. Where we formerly had three coalitions, each of which served one of the three grand divisions in Tennessee, due to complexities with DOE this was reduced to two coalitions .This change brought the entire state into a "designated" status with the Clean Cities Program. Those two coalitions are now the "Middle-West Tennessee Clean Fuels" and "East Tennessee Clean Fuels" (and nonprofits), and they split the state in two in service to fleets of all types in those regions.

New logos for the two coalitions and the "unified" logo that covers both coalition for statewide service

Hall of Fame award

A significant amount of time was spent managing this evolution of the Clean Cities Program in Tennessee. The new logos that go with each coalition are shown below, as is the a new logo that is not a business unit but is a combined efforts logo for both coalitions under the name "Tennessee Clean Fuels."

ETCleanFuels Wins Several Awards—The coalition was fortunate to garner several significant honors in the past year. At the 2015 National Clean Cities Meeting in Chicago, IL, coordinator Jonathan Overly was inducted into the U.S. DOE Clean Cities program's Hall of Fame. Also, in May 2016, we were provided one of the Tennessee Department of Environment and Conservation's "Governor's Environmental Stewardship Awards." Tennessee Clean Fuels was honored with the "Excellence in Clean Air" award for 2016.



The fleet representatives that were inducted into the 2016 class of the Tennessee Green Fleets program.

ETCF receiving the GESA award (left to right: Governor Haslam; Kristy Keel-Blackmon and Jonathan Overly, ETCF; and TDEC Commissioner Bob Martineau)

Center for International Networking Initiatives/GLORIAD

(PI: Greg Cole, Research Director, ISSE)

With the July, 2015 addition of a new $1M award from the US National Science Foundation (NSF) for GLORIAD's work on performance measurement, the NSF and US Agency for International Development (USAID) have provided a total of $23M in funding for the Global Ring Network for Advanced Application Development (GLORIAD) to build and manage cyber-infrastructure connecting over 15 million end-point users in science and education communities across the globe. Also in July 2015, the NSF no-cost extended the current 5-year, $5.6 million ProNET award through April, 2016.

GLORIAD/ProNet Project

The US team assisted Chinese and Korean teams establish new physical infrastructure in Seattle and Chicago to handle both short- and long-term needs for managing network equipment and for accommodating several upgrades for Korea/KISTI (including new 10G link from Chicago to Amsterdam).

In December 2014, GLORIAD established a network node at the Vancis facility (formerly SARA) at Science Park in Amsterdam. This was part of an upgrade to the US-Russia link to 10Gbps, but also connected and peered with networks in the Middle East, including ENSTInet (Egypt) and QNREN (Qatar) as well as European networks including SURFnet/NetherLight and NORDUnet.

The Amsterdam node is housed in a single 19" rack cabinet, and is similar in design to GLORIAD's exchanges at StarLight in Chicago and Pacific Wave in Seattle. Routing equipment consists of previously acquired Force 10 6-slot E300 router, capable of supporting1GE and 10GE connections, and a Juniper M10 router, which was moved from Chicago and terminates STM-4 (622 Mbps) connection to Cairo, Egypt. Other equipment in the rack includes a 1RU 24-port Cisco switch for various server connections, an Argus probe (Dell R710 server), 10GE PerfSONAR node (Dell R220 server), a KVM system, and a remote console server (Mac-mini).

The primary connection between GLORIAD's Chicago and Amsterdam nodes was a new 10 GE trans-Atlantic circuit procured from Global Netwave and Level3. It is a relatively low-latency path that follows AC-1 submarine cable into NYC area and follows a land path to Chicago via NYC, PHI, DCA and CLE. The new path is shorter than the previous path, a 1GE link between Chicago and Amsterdam, by 15 ms RTT.

The primary connection is backed up by 3x1 GE etherchannel, which was consolidated from previous connections to Amsterdam, including a 1GE US-Russia, carried from Amsterdam to Chicago by NORDUnet, and US-Egypt (upgraded from STM-4 to full 1GE in the process) and US-India 1 GE links, both provided by SURFnet-NetherLight and CANARIE. All three GE paths followed different trans-Atlantic submarine cables, and the land path between NYC and Chicago was diverse to the primary 10GE link path, and included a route via NY, Canada and onward via Detroit to Chicago, provided by CANARIE on two of the three GE connections, and the third GE, carried entirely by NORDUnet, is on an alternate path inside the U.S.

The failover mechanism between the primary and the backup link is automatic, and is designed with OSPF for fast convergence, detecting link failure within 1 second, or 40 seconds if the issue is only on Layer 2, and failing over traffic to backup link and back to primary connection when the primary link is restored. This design increased potential reliability of the U.S.-Russia and U.S.-Egypt links to near "five-nines" (99.999%). Maintenance work by Level3 has successfully tested failover mechanism.

By moving/splitting the U.S.-Egypt link from a dedicated 622M light path Chicago-Cairo to Amsterdam-Cairo and Amsterdam-Chicago backbone link, no significant complexity was added, but due to increased reliability of the Chicago-Amsterdam segment, improvements to overall uptime are expected and also the ability to split over Egypt traffic destined to Europe and Middle East in Amsterdam, thus dramatically decreasing RTT time, and thus improving performance on flows to/from Egypt.

The main router in Amsterdam was connected to the NetherLight exchange in Amsterdam via 10GE connection that carried most of the peerings with various R&E networks present in Amsterdam. Also in place were a 1GE connection to Qatar (QNREN) and 1 GE to NORDUnet.

As mentioned earlier, the primary role for the establishment of the Amsterdam node was to deliver a 10G connection to Russia. The first external connection to the node was a new 10GE connection to RUNnet-operated router in Amsterdam. RUNnet decided to make available their 10GE connection from Stockholm (and Moscow) to Amsterdam for all U.S.-Russia traffic, so peering with RIPN/RBNET was almost immediately increased from 1GE to 10GE (on a shared link), and also a peering with RUNnet was established for the first time, thus capturing now most of the Russian R&E community.

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Monitoring of the new connection was done both in Chicago and Amsterdam and was available via GLORIAD's InSight passive measurement system and incorporated into other monitoring tools available on the GLORIAD website.

This project was completed April 30, 2016 and the network was decommissioned.

Network Decommissioning and Services Transition: Network engineer Predrag Radulovic has completed the following decommissioning activities on the US infrastructure, reflecting transition of GLORIAD services to international and domestic partners. All essential services are transitioned to other providers, resulting in no down-time or service loss to US R&E community.

Preparations for network shutdown started in early 2016. Research was conducted to determine alternate paths for GLORIAD's US and international network connectivity and 60-day notification of network shutdown was sent to all peers and partner networks in late February 2016.

For trans-Pacific connectivity, to include connections to China (CSTnet) and Korea (Kreonet/KISTI), solution was provided by GLORIAD's partners on their own, as they both established own colo space and equipment with presence in Seattle at Pacific Wave Exchange and in Chicago at Starlight. Since then, KISTI has also upgraded US connectivity to 120G, including 100GE link between Korea and Starlight, as well as 2x10 GE between Starlight and Amsterdam, continuing on to Geneva (CERN).

More work was necessary for offload of US-Russia and US-Egypt links. Partner networks including ESnet, Internet2, Nordunet, CANARIE, Surfnet, and ANA consortium were contacted to help with the traffic transition. As of this writing, agreement for continuous support for LHCONE and general US-Russia connectivity was reached with ESnet, and similar is still in progress with Internet2. Both ESnet and Internet2 have now 340G and 100G connectivity (respectively) to Amsterdam and will be able to easily absorb all the traffic that GLORIAD has carried in the past. Also, Internet2, in collaboration with Netherlight, was approached by Egypt's ENSTInet network, to continue direct US-Egypt connectivity at STM-4 (622 Mbps) level after GLORIAD network is shutdown,on April 27, 2016.

Due to its age, all GLORIAD equipment at colo facilities in Seattle, Hong Kong, Chicago and Amsterdam will be decommissioned shortly after the network shutdown and disposed of by GLORIAD partners and vendors at respective locations.

GLORIAD/Insight Project

The GLORIAD/InSight effort, a passive measurement system developed during the past three years, delivered in year-5 a stable, reliable system for passive monitoring of GLORIAD infrastructure in the US – providing deep and thorough analysis of end-to-end flow utilization and performance – and delivering an early reputation-based system for identifying anomalous behavior and threat analysis.

Further development work and experimental deployment of InSight has been funded by the NSF (August 1, 2015 – January 31, 2018) under a special IRNC AMI award (ACI-1450959).

In January 2016, the project PI, Greg Cole, retired from the University and this project was transferred to UT's Department of Electrical Engineering and Computer Science for completion.

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Initiatives Co-Sponsored with the UT Office of Research and Engagement

Initiative for Food, Water, Energy (IFWE): A 2015 Organized Research Unit

(Team: Thanos Papanicolaou and Christopher Wilson, Civil and Environmental Engineering)

Summary of Activities: Most available biogeochemical models focus within a soil profile and cannot adequately resolve contributions of the lighter size fractions of organic rich soils for Enrichment Ratio (ER) estimates, thereby causing unintended errors in Soil Organic Carbon (SOC) storage predictions. These models set ER as constant, usually equal to unity. The goal of this study is to provide spatiotemporal predictions of SOC stocks at the hillslope scale that account for the selective entrainment and deposition of lighter size fractions. It is hypothesized herein that ER values may vary depending on hillslope location, Land Use/ Land Cover (LULC) conditions, and magnitude of the hydrologic event. An ER module interlinked with two established models, CENTURY and WEPP, was developed as part of the study that considers the effects of changing runoff coefficients, bare soil coverage, tillage depth, fertilization, and soil roughness on SOC redistribution and storage.

In this study, a representative hillslope is partitioned into two control volumes (CVs): a net-erosional upslope zone and a net-depositional downslope zone. We first estimate ER values for both CVs I and II for different hydrologic and LULC conditions. Second, using the improved ER estimates for the two CVs we evaluate the effects that management practices have on SOC redistribution during different crop rotations. Overall, LULC promoting less runoff generally yielded higher ER values, which ranged between 0.97-3.25. Eroded soils in the upland CV were up to 4% more enriched in SOC than eroded soils in the downslope CV due to larger interrill contributions, which were found to be of equal importance to rill contributions. The chronosequence in SOC storage for the erosional zone revealed that conservation tillage and enhanced crop yields begun in 1980s reversed the downward trend in SOC losses, causing nearly 26% of the lost SOC to be regained.

Key take-home points:

- Enrichment ratio and bulk density vary spatially and temporally in intensively managed fields
- Management practices and hillslope location affect soil organic carbon dynamics
- Conservation tillage and enhanced crop yields produce gains in soil organic carbon

Initiative for Sustainability Mobility

(Team: Asad Khattak and David Greene, Civil and Environmental Engineering)

Progress towards 2015-2016 goals—Initiative for Sustainable Mobility (ISM) has made excellent progress in developing the concepts and practice of sustainable mobility via active research collaborations of faculty, staff, students, industry, and national laboratory researchers. We seek to understand how intelligent systems, big data and computational power can be used to develop the most effective sustainable strategies and how engineering and economic analysis can improve public policy decisions. Our work is interdisciplinary, involving experts in various branches of engineering, business, policy and planning, economics, and other related disciplines. Via this Initiative, we are strengthening our research, education, and outreach mission by integrating resources and pursuing new opportunities, which would not be possible without ISM.

How ISM activities have contributed?

Interdisciplinary projects: In our first year, we have leveraged our research synergies within ISM by developing and submitting several proposals. Six interdisciplinary (engineering and policy) proposals were submitted in year 1, showing a return on investment of 9:1. Two new proposals were funded, based on work done in year 1. One is on driving volatility, ($399,793 for 3 years) funded by the National Science Foundation. Another is on "Green Generates Green" ($163,224) funded by the Tennessee Department of Transportation. Some of the larger proposals are still under review.

Creation of intellectual property: There are products related to ISM that are being considered for IP products and commercialization. One is based on providing consumers who wish to purchase a vehicle, information about vehicle fuel economy estimates that are customized to their driving patterns. A case-based reasoning methodology was developed for this purpose. Another product under consideration is providing real-time alerts and warnings to drivers who are exhibiting volatile driving behavior. This can potentially calm down the drivers, with positive impacts on driver safety, energy consumption and vehicle emissions. The other one is to develop a strategy to minimize the fuel economy of vehicles running in three categories of driving situations (according to the driver behaviors): aggressive, normal, or calm. An Equivalent Consumption Minimization Strategy was developed.

Support of economic development: Practically, a research team will be working with the Tennessee Department of Transportation to examine how sustainable

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projects implemented within TDOT generate economic benefits:

There are several important links of sustainable mobility to economic development: 1) Policies and operational strategies that help transition to a low-carbon energy economy have positive economic benefits in terms of new investments in infrastructure, development of new technologies, travel modes/vehicles, and renewable energy. 2) Through the development of innovative strategies, (e.g., electronically connected alternative fuel vehicles) resources can be used more efficiently to reduce costs of energy consumption and emissions on human health. 3) Sustainability is an area of priority and investment for US Department of Transportation (e.g., award of University Transportation Centers with sustainability theme). As such, visibility in this area can support economic development within the University.

Number of graduate students supported: In the first year, the ISM directors and faculty fellows advised and supported approximately 18 graduate students; faculty mentor graduate and undergraduate students who participate in relevant seminars and meetings as well as activities involving Institute of Transportation Engineers. Faculty fellows are integrating sustainable mobility and intelligent transportation systems in curricula.

External recognition of the research outcomes: The key metrics of external recognition are invited presentations (including keynote and plenary sessions). Dr. Greene and Dr. Khattak alone had several invited presentations, Dr. Greene (7), Dr. Khattak (2), and 3 major outreach activities—Dr. Greene was quoted in *Science* magazine, on NPR, and at the Tennessee Environmental Conference.

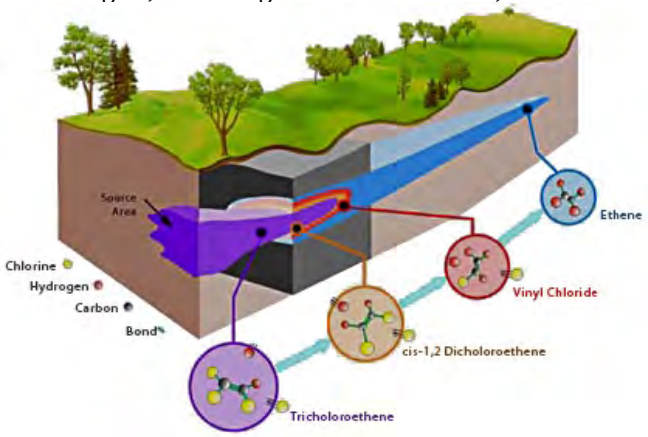
(From left to right) Drs. Greene David, Asad Khattak and Jun Liu in a poster session with their poster at the 2016 Transportation Research Board's 95th Annual Meeting in Washington, DC.

Other Projects and Initiatives

A Practical Approach for Remediation Performance Assessment and Optimization at DNAPL Sites for Early Identification and Correction of Problems Considering Uncertainty

(Team: Jack Parker, UT; and Ungtae Kim, Cleveland State University)

Objective: The objective of this project is to develop and test a methodology to periodically assess and optimize groundwater remediation systems and monitoring of dense nonaqueous phase (DNAPL) contaminated sites that currently have remedial actions in place. Methods will be developed to model cost and performance of source zone and dissolved plume remediation technologies, including thermal treatment, chemical



Dissolved chlorinated solvent plume in groundwater and daughter products associated with natural or engineered biodecay.

oxidation, and enhanced bioremediation, and to optimize system operation and monitoring to meet user-defined cleanup criteria with minimum total life cycle cost, considering the potential for failure resulting from uncertainty in performance predictions using a stochastic optimization approach. All physical, chemical and biological processes expected to significantly affect performance will be incorporated in the model, including effects of back-diffusion from low permeability zones, such as clay layers or matrix zones in fractured rock.

Technical Approach: Methods have been developed to model remediation performance and cost for electric resistance heating, thermal conduction heating, steam injection, in situ chemical oxidation, enhanced bioremediation using electron donor injection, and monitored natural attenuation. Effects of back-diffusion from low permeability zones are considered using a computationally efficient upscaled approach with options to output either resident or flux concentrations as

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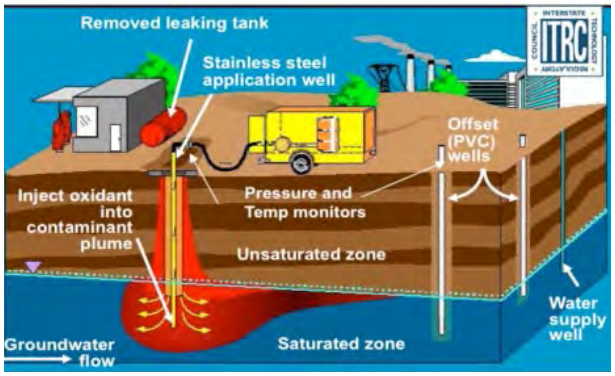
needed to correspond to field data obtained by various means. An robust inverse solution has been implemented to estimate model parameters and their uncertainty from available field and lab data and a stochastic optimization technique determines optimum operational and monitoring variables to minimize cost averaged over multiple equally probable Monte Carlo realizations of uncertain parameters.

Methods have been developed and tested to periodically refine model calibration taking into account new data from monitoring; to assess the probability of the current operations to meet cleanup objectives and cost to completion; and to reoptimize system operation and monitoring variables to minimize expected cost-to-complete taking into consideration performance and cost uncertainty.

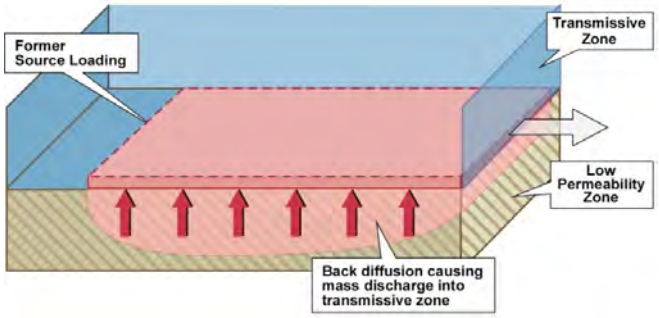
We are currently working on testing the methodology on several field sites and implementing a use-friendly interface.

Benefits: Although most Department of Defense sites have or should soon have remedial action plans in progress, most will not achieve regulatory closure for many years. Some planned remedies will likely not perform as expected and will require modification or, in some cases, implementation of a different remedial action plan. This project will provide tools to periodically assess remediation performance, identify and rectify problems, and optimize remediation operations and monitoring to minimize life cycle costs while meeting remediation objectives. By explicitly optimizing operations to minimize probability-weighted cost to completion taking into account uncertainty in site characterization, model predictions, and remediation technology performance, as well as measurement "noise," numerous nonlinear interactions and tradeoffs are taken into account that conventional approaches would never consider. Based on previous studies, we anticipate average savings in cost to complete across all sites of 10 to 30%.

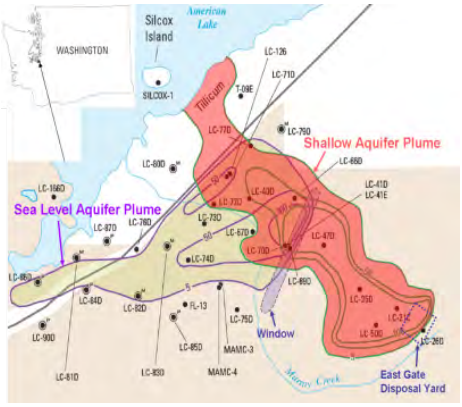


Operation of steam injection system for thermal recovery of chlorinated solvent.

Operation of steam injection system for thermal recovery of chlorinated solvent.



Schematic of back-diffusion problem which can prolong remedial action duration



Study site at joint Army and Air Force base with a large solvent plume.

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Cooperative Agreement between National Park Service and University of Tennessee: Impacts of Acid Deposition on Water Quality and Aquatic Biota

(PI: John Schwartz, Civil and Environmental Engineering)

Project Description and Annual Activities—For decades, acidic air pollutants from regional and local sources have been transported by prevailing wind currents, and deposited onto high-elevation watersheds in the Great Smoky Mountains National Park (GRSM), on the Tennessee/North Carolina border (Figure 1). In order to investigate the potential effects of acid deposition on stream water quality, the GRSM began a Water Quality (WQ) Monitoring Program in 1991 consisting of: 1) detailed hydrologic and biogeochemical monitoring at Noland Divide Watershed (NDW), a high-elevation forested site, and 2) Park-wide stream survey monitoring for spatial mapping and temporal trend analysis of stream acidification. Figure 2 shows photos at the NDW monitoring station. In addition to the routine monitoring, special studies are conducted to investigate questions that remain on the fate, biogeochemical transformation, and transport of acid/base ions and dissolved metals. This past year two special studies are on-going; they are: 1) a sulfate isotope analysis to quantify the mass flux of sulfate generated from the high-elevation Anakeesta pyritic shale formation in comparison to acid deposition inputs; and 2) a throughfall chemistry mapping, which has been over 15 years since the last GRSM effort by Dr. Kathleen Weathers at Cornell University (Fig. 3). We work together with Dr. Charles Driscoll at Syracuse University, in which his research team developed and uses the BGC-PnET model for estimating critical loads in the GRSM.

One of the most interesting investigations is the observed responses in deposition and stream chemistry due to emission reductions from local and regional coal-fired power plants. Many geochemistry parameters of wet/dry deposition at the monitoring site show strong and direct responses to emissions reductions: measured deposition amounts decreased, precipitation pH and ANC increased, and nitrogen speciation in precipitation samples shifted; all within the same 2008-2009 time frame. Through fall sulfate deposition has declined from above 1,500 eq/ha/yr before 2007 to approximately 500 eq/ha/yr after which. However, the changes in deposition have not yet translated to significant changes in stream sulfate concentrations or annual mass exports. It appears the lack of response in stream sulfate is influenced by the biogeochemistry in associated with the nitrogen cycle dynamics, base cation availability, and carbon-sulfate dynamics.

Figure 1. High-elevation landscape view within the Great Smoky Mountains National Park

Figure 2. Photos of the Noland Divide Watershed, high-elevation monitoring station in the Great Smoky Mountains National Park. From upper left to lower right, MS student Andrew Veeneman calibrating a water quality sonde at a H-flume, and installing a new pressure transducer at the same site; Dr. John Schwartz at one of the two 3-ft H-flumes, and the instrumentation in the soil lysimeter pit.

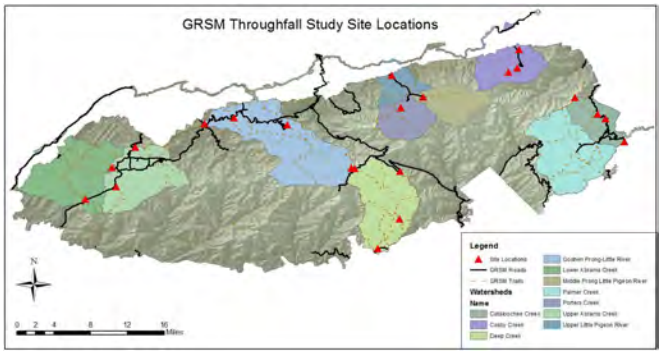

Figure 3. Map of the Great Smoky Mountains National Park showing the 23 throughfall monitoring sites, and the watersheds sampled on a bimonthly basis per grab samples and analyzed for acid anions, base cations, and dissolved metals.

During 2015 at the NDW site precipitation volumes collected from the throughfall (TF) and open-site collection (OS) sites were 241 cm and 141 cm, respectively. Mean pH of samples collected at TF and OS sites was 5.18 ± 0.5 and 5.24 ± 0.1, respectively. Total sulfate deposition at TF for 2015 was 394 equivalents per hectare (eq ha-1), or 18.9 kilograms per hectare (kg-SO4 ha-1). Total inorganic nitrogen (T.I.N.; sum of ammonium & nitrate) deposition at TF was 696 eq ha-1, or 32.0 kg-TIN ha-1. Soil water pH at the NDW monitoring station was 4.53 ± 0.16, 4.64 ± 0.02, and 4.63 ± 0.14, in the upper, middle and lower soil horizons, respectively. The NE and SW streamlets during 2015 had an annual average pH of 5.77 ± 0.02 and 5.97 ± 0.02, respectively. These streamlets had a mean acid neutralizing capacity (ANC) of 7.3 ± 0.4 and 14.2 ± 0.8 microequivalents per liter (μeq L-1), respectively.

Of the Park-wide stream survey sites monitored in 2015, 35 of the 265 samples had a pH below 6.0 and an ANC below 20 μeq L-1. These were collected from a few sites historically observed with low pH and ANC stream water, including Double Springs Gap Shelter, Cosby-Rock creek watershed, and Porter-Cannon creek watershed. Total dissolved aluminum (Al) in only six samples (collected from only three sites) in 2015 was ≥ 0.08 mg L-1, a toxicological threshold concentration very near the analytical reporting limit of 0.05 mg/L. These sites are also associated with the lowest measured stream water pH and ANC, consistent with dissolution of aluminum from soils and bedrock minerals. The water pH at Vital Signs stream monitoring sites in 2015 was 6.30 (overall mean; N = 265) and ranged between 5.24 and 7.53. A combination of factors in individual GRSM watersheds, i.e., bedrock geology, soil, and vegetation appears to define the how biogeochemical processes influence the fate and transport of acid deposition pollutants migrating through the soils and entering streams.

Integrated watershed management in Oostanaula Creek watershed, Tennessee: stakeholder education, improving targeting and understanding of stakeholder behavior to improve implementation of best management practices for water quality

(PI: John Schwartz, Civil and Environmental Engineering)

Project Description and Annual Activities—Excessive fine sediment is a leading cause of loss of biological integrity in rivers and streams nationally, and in the Oostanaula Creek watershed where it is 303(d) listed by the state of Tennessee as water quality impaired due to siltation. Causes of the excessive sediment appears to be from multiple factors, including soil erosion from agricultural field, increased flood flows from urbanization in the city of Athens area, stream banks, and grazing fields where concentrated runoff occurs from hillslopes down cattle trails directly to the stream. Research focused on better understanding 1) stream bank erosion processes and channel degradation in this southern Appalachian region examining the potential influence of urbanization on increased erosion, 2) how vegetation and bedrock influence bank stability, and 3) estimating yields specifically generated from cattle trails along pasture hillslopes.

Channel and Bank Erosion—Methods to study bank erosion processes include stream geomorphic audits (rapid geomorphic assessments, RGA) along a gradient of watershed urbanizations, and continuous sediment sampling in Cedar Springs Creek, a tributary of Oostanaula Creek in order to calibrate a SWMM and CONCEPTS model of that watershed. Statistical results from the stream audit data found that the dominant controls influencing bank erosion is the distance to a hydraulic grade control, either natural (bedrock outcrop) or artificial (bridge abutment, placed rock or other hard point), and bank vegetation. These geomorphic controls had a greater influence on channel stability than from increased urbanization; however without bank vegetation excessive stream power from urbanization increased the risk of excessive bank erosion. The coupled SWMM and CONCEPTS models are applied in the Cedar Springs Creek watershed to investigate a cost relationship between constructing upslope runoff controls versus applying stream restoration techniques in the channel.

Bank Stability and Spatial Structure of Resistance Elements—Bank stability is dependent on both types of erosion; however, few studies have attempted to correlate the driving and resisting forces between the two. This research examined whether 1) streambanks possess a spatial structure and dependence of non-erodible resistant structures such as root masses and rocks; 2) streambanks naturally "armor" themselves from fluvial erosion with a combination of hard points and resistive soil; and (3) the stability of the streambank can be predicted by the amount of composite fluvial resistance, thereby connecting fluvial resistance and geotechnical stability. Eighteen streambanks sites with cohesive sediment structures in the Eastern Tennessee Ridge and Valley Ecoregion were sampled, including the Oostanaula Creek. Methods included extensive field analysis of the stream banks and data analysis by spatial and multivariate statistics. Field data included: in-situ erodibility and critical shear stress as well as the spatial distribution of non-erodible hard points. Using a combination of nearest neighbor, join count,

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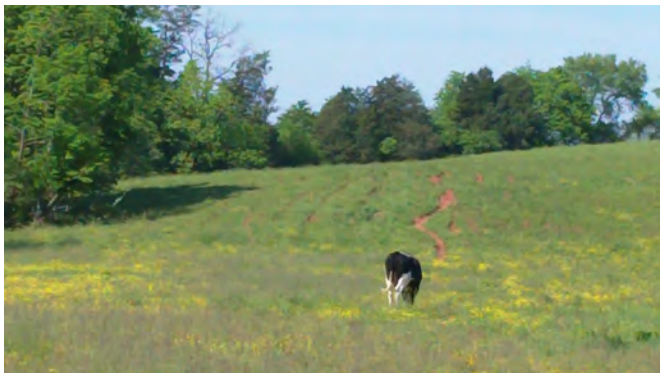
and indicator variogram statistics it was discovered that streambanks in this region possess natural clusters of these non-erodible structures. Multiple linear regression was utilized to compare all streambanks, with the results indicating that the density of these clustered hard points displays a positive linear relationship with the critical shear strength of the surrounding soil matrix, suggesting a coordination between the two and possible natural armoring of the composite bank structure. Additionally, the USDA Bank Stability and Toe Erosion Model (BSTEM) was utilized to determine the relative stability of these streambanks. With this information, both discriminate analysis and multiple linear regression were applied to determine that stable streambanks are controlled by a combination of the respective stream power, average soil critical shear strength, standard deviation of the critical shear strength, bank height, and cluster density of non-erodible structures. This information helped derive relevant interactions for stable stream bank analysis including possible stream restoration where it was found that spacing of hard points (rock and roots) needs to be on average 1.4 m for a bank to be stable.

Sediment Yields from Cattle Traits—This purpose of this study was to evaluate the influence cattle trails have on the hillslope, particularly with regards to event based runoff and sediment transport. While it has been well established that cattle trails can significantly alter the soil structure of the hillslope, there was little research indicating the extent to which these changes would influence event-based runoff and sediment transport. This study not only served to highlight the extent to which cattle trails transport runoff and sediment, but also served to elaborate on the processes that cattle trails influence. Two farm sites were selected in the Oostanaula Creek watershed, which for each study site included a control monitoring location, and a treatment (1 or 2 cattle paths). Runoff and sediment collection was completed by using a bucket, separator weir device, commonly referred to as Pinson buckets.



Cattle trails and a dairy cow in a pasture field within the Oostanaula Creek watershed

As expected, the cattle trails transported significantly higher runoff volumes and sediment loads, per storm event than the control sites. Average sediment yields per storm event for the control sites were 0.01 and 0.75 kg, and the three cow path sites were 5.67, 14.59, and 20.00 kg. It was also determined that runoff did not contribute a significant amount of sediment to the cattle trail, but served merely as a transport mechanism for cow path sediment. Finally, it was shown that hydrologic parameters duration, and volume did not have a significant influence on the difference in total runoff or sediment load between cow path and control sites, though it appears rainfall intensity may be a factor.

Seed Grant Projects from Prior Years

Microenvironments, Vulnerability, and Resilience in the City of Knoxville: A Comparative Study of Four Urban Neighborhoods

(Team: Kelsey Ellis, Geography; Jon Hathaway, Civil and Environmental Engineering; and Lisa Reyes Mason, Social Work)

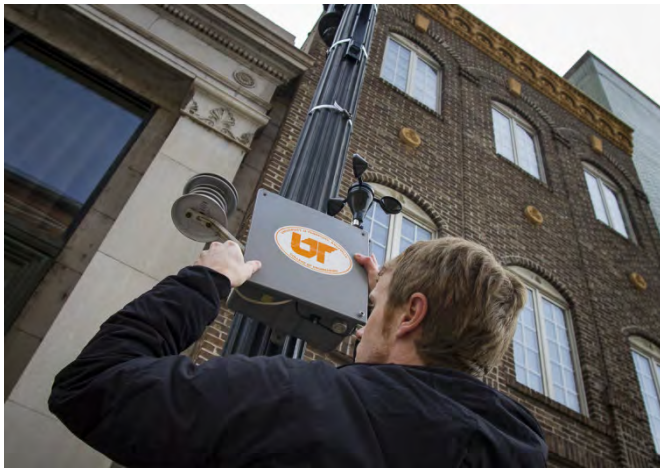
As urbanization escalates, understanding the impact of expanding cities is of extreme importance to human and environmental well-being. This study used a multidisciplinary approach to monitor urban environmental conditions and understand their impact on diverse populations in the City of Knoxville.

To launch the study (2014–2015), 10 sensor-based monitoring stations (Phase I) were mounted in four neighborhoods (West Hills, Burlington, Vestal, and Lonsdale), with control stations in Downtown Knoxville and Ijams Nature Center. Over a two-year period, stations recorded temperature, humidity, and wind data in five-minute increments. Complimentary social research examined people's perspectives and experiences with environmental conditions–such as temperature extremes, air quality, and urban green space–and considered their interests and preferences for accessing more localized environmental data.

During 2015–2016, three peer-reviewed journal articles were accepted for publication in International Journal of Environmental Research and Public Health, Theoretical and Applied Climatology, and Journal of Community Practice. Faculty and graduate students gave six conference presentations at regional and national meetings. Project outreach included a presentation of the team's multidisciplinary approach to the University of Tennessee College of Social Work Board of Visitors and dissemination of a research brief to City of Knoxville officials and community stakeholders. In addition, we submitted two competitive, though unfunded, pro-

posals to the U.S. Forest Service and National Science Foundation.

A highlight of this project in 2015–2016 was significant media coverage including a front page article in the Knoxville News Sentinel, an article in The Knoxville Mercury, television news coverage by WBIR, and a radio interview with WIVK.



Toxicity profiling of dioxin-like pollutants and other aryl hydrocarbon receptor agonists using a high-throughput yeast bioassay

(Team: Gary Sayler and Tingting Xu, Center for Environmental Biotechnology; Joe Zhuang, Biosystems Engineering and Soil Science, UTIA; Terry Hazen, Civil and Environmental Engineering; Jiangang Chen, Public Health)

Project Description: Dioxin and dioxin-like compounds (DLCs), a group of structurally related halogenated aromatic hydrocarbons, account for a quarter of the 'dirty dozen" Persistent Organic Pollutants internationally recognized as chemical pollutants with a high priority for environmental cleanup, reduction of release, and restricted production. While the commercial production and use of some DLCs is banned in the United States, other DLCs continue to be generated as unintentional by-products of municipal, medical, and industrial waste incinerations, forest fires, cremations, oil spills, and many industrial manufacturing processes. This is especially troublesome because these compounds are extremely stable, highly resistant to degradation and metabolism, and persistent in the global environment. They are also prone to accumulation in animals, and therefore biomagnify along the food chain towards human consumption. Despite their structural variations, DLCs are of toxicological concern to human health because they induce a common pattern of biological and toxicological responses via their interaction with a crucial signaling protein. Perturbations of this signaling protein have been linked to a variety of adverse health effects, including deficiencies in reproduction and development, disruption of the endocrine system, neurotoxicity, immunotoxicity, cancer, and metabolic diseases.

Due to their stability in the environment, ability to bioaccumulate, and substantial toxicological effects, it is critical to monitor and quickly detect DLCs in the environment and provide a rapid tier 1 toxicity evaluation for environmental security and public health risk assessment. The current gold standard for DLC detection is an analytical chemical approach which offers superior sensitivity but with significant cost and complexity. Meanwhile, although the analytical chemical method can identify individual compounds based on their structures, it is complicated and often difficult to determine the overall biological impacts. To facilitate faster, easier, more economical, and higher-throughput tier 1 sample analysis for safeguarding environmental security and public health, the goal of this project is to develop an improved low cost tier 1 bioassay for reagent-free DLC detection using humanized yeast bioreporters that autonomously generate a high resolution optical signal in response to bioavailable DLCs. Using the robust yeast as the host organism also offers a convenient and rapid assay format while still maintaining the toxicological relationships with human exposure endpoints. This new assay, by virtue of its autonomous reporting capabilities, will also be amenable to automation and high-throughput sample analysis, making it a vastly improved candidate for large scale use for not only environmental monitoring and risk assessment but also food supply biosurveillance and high-throughput toxicological screening of DLCs for protection of

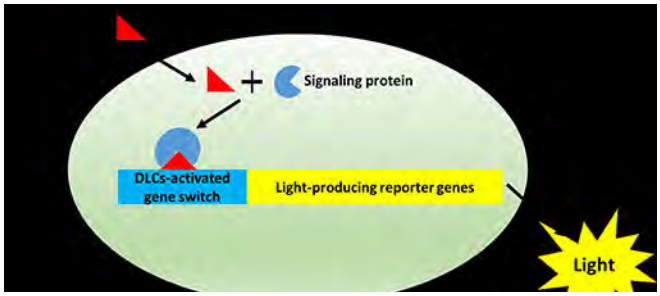


Figure 1. Diagram of the autonomous dioxin bioassay. The objective of this project is to develop a yeast-based bioassay for high-throughput, rapid, and cost-effective toxicity profiling of dioxin-like compounds (DLCs). The yeast cells will be engineered to express light-producing reporter genes under the regulation of a DLC-responsive gene switch. Exposure to DLCs will activate the gene switch and turn on the reporter genes to produce an autonomous optical signal without any external stimulation. In addition to simply detecting the presence of DLCs, the whole-cell bioassay also provides valuable information on their bioavailability and biological impact.

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human and animal health. This autobioluminescent reporter system will also serve as a proof-of-concept 'plug-and-play' platform that can be expanded to a suite of high-throughput bioassays using both yeast and human cells as hosts to profile the impact of a wide range of environment pollutants.

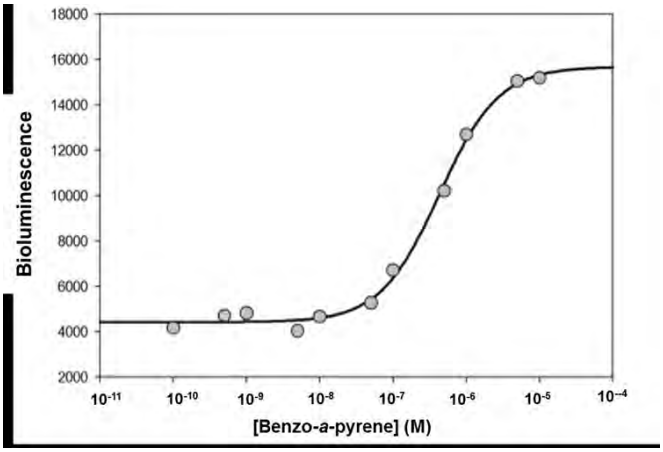


Figure 2. Dose-responsive curve of the bioluminescent output responding to benzo-a-pyrene exposure. Exposure to the known DLC benzo-a-pyrene (BaP) induced the expression of the bioluminescent reporter signal in a sigmoidal dose-responsive manner. This bioreporter has been shown to be able to report the presence of BaP ranging from 1×10^{-7} M to 1×10^{-5} M with an EC50 detection of approximately 4.3×10^{-7} M.

Publications and Presentations: This research project has to date generated one publication and one manuscript in preparation (see "ISSE-related Publications," below), and three conference presentations, two of which include an undergraduate co-author (see "ISSE-related Presentations, below").

Outreach Activities: This research project has to date trained four high school interns from local and neighboring high schools and eight undergraduate research assistants, including two participants funded through the university's Educational Advancement Program Annual Summer Institute whose goal is to promote academic and personal success of first generation, low income or disabled students. In June 2016, this project was also selected as a research demonstration for 70 high school students from East Tennessee during a three-day visit as part of the inaugural Possibilities in Postsecondary Education & Science (PiPES) summer program. This project will continue to invest in high school and undergraduate researcher training in the coming semester.

External Funding Activities: During the one-year period, we have successfully accomplished the genetic engineering of the dioxin bioreporter strain and performed initial assays against known dioxin-like compounds. These results will be leveraged as strong preliminary data for research proposals to be submitted to the NIH National Institute of Environmental Health Sciences and/or the National Institute of Food and Agriculture in Fall 2016/Spring 2017.

Investigation of Crown Ether-Modified Diatoms for the Removal of Alkali Metals from Aqueous Solutions

(Team: Angelica Palomino and Kimberly Carter; Civil and Environmental Engineering; Brian Long, Department of Chemistry)

Material Characterization—We have developed procedures for and completed initial characterization measurements of the untreated diatoms including identifying the presence of mineral surface end groups (Figure 1), total organic carbon (TOC) content, and sodium ion adsorption. Our next steps are to repeat these measurements with the functionalized diatoms to evaluate the effectiveness of the modified materials.

Diatom Modification with Crown Ether—The crown ether modified diatoms was completed in good yield following a simple synthetic route from starting diatoms to activated crown ether-modified product. The raw diatoms were activated through a two-step process; first the diatoms are stirred in a mixture of methanol and concentrated hydrochloric acid and then subsequently filtered and washed. Next, the off-white powder was re-suspended in a solution of water and ammonium hydroxide, followed by addition of hydrogen peroxide over a 30-minute time period. The activation process was necessary to ensure the diatom surfaces were fully hydroxylated, which is critical for the subsequent crown ether immobilization.

The now "activated," or hydroxylated, diatoms were suspended in a toluene solution and 3-glycidoxypropyltrimethyloxysilane was added. This mixture was refluxed over-night and yielded the epoxy-functionalized diatoms as an off-white powder in overall good yield. The epoxy-substituted diatoms were then suspended in toluene and the appropriate crown ether added. After this reaction reached completion, the solution was filtered, washed, and dried to produce the crown ether functionalized materials as light purple solids in good yield (Figure 2).

Student Participation—One high school student and one graduate student worked directly on this project. The high school student, Puxin Xuanyuan, was recruited by Dr. Long and worked directly under the supervision of Dr. Long and his graduate student, Nolan Mitchell. Jordan Hicks is a Master's student in the Department of Civil & Environmental Engineering

and was supported as a GRA for this project. Jordan works under the direct supervision of Dr. Angel Palomino. Dr. Carter also provides significant guidance for Jordan's efforts in this study. Jordan is expected to graduate December 2016.

Laura Matzek and Katherine Manz, two Doctoral students working under the supervision of Dr. Carter, provided training and assistance for sodium analysis using ion chromatography and TOC analysis.

Anticipated Manuscripts/Proposals—One manuscript is currently in preparation and will be based on the results obtained from this study. We plan to submit the manuscript in December 2016. We anticipate submitting one proposal to NSF by January 2017.

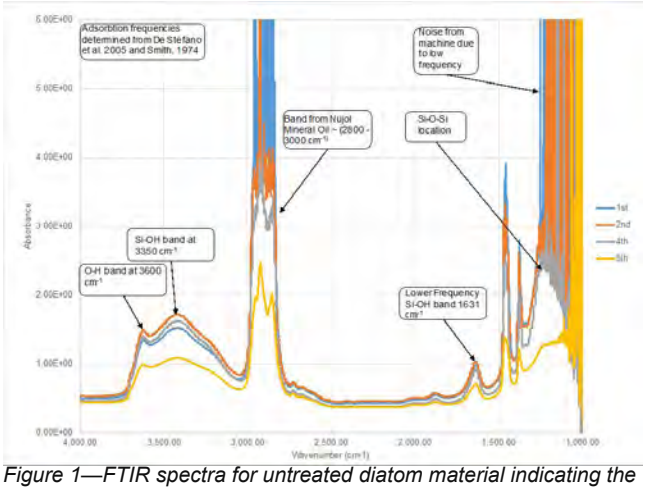
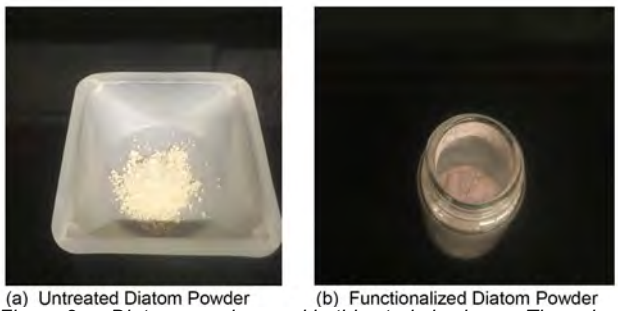


Figure 1—FTIR spectra for untreated diatom material indicating the presence of Si-O-Si, O-H, and Si-OH surface end groups



(a) Untreated Diatom Powder (b) Functionalized Diatom Powder

Figure 2 — Diatom powder used in this study is shown. The color change from off-white to light purple indicates the crown either attachment

International Center for Air Pollution and Energy Studies (iCAPES)

(PI: Joshua Fu, Civil and Environmental Engineering)

It is well known that the NOX (NO + NO2) emission has been reduced steadily in the United States during the past years. However, the emission of NH3 is less regulated and has increased by 11% from 1990 to 2010. In addition, there is no direct measurement of dry nitrogen deposition and organic nitrogen compounds. The latter one was reported to be responsible for 12-40% of the NOy budget in the United States by the previous literature. Therefore, the assessment of total (wet + dry) nitrogen deposition in the United States remains crucial.

In our work, we use the multi-model mean (MMM) results from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) to calculate the total oxidized (NO + NO2 + HNO3 + HNO4 + NO3 + N2O5 + PAN + other organic nitrates) and reduced (NH3 + NH4+) nitrogen depositions. The 10-year simulation starts at 2000 suggests that if the organic nitrates and other oxidized nitrogen compounds are taken into account, 86.64% of areas of the contiguous United States are dominated by the oxidized nitrogen deposition.

Although we strongly agree that the reduced nitrogen deposition has become important in recent years in the United States, the MMM results still indicate that oxidized nitrogen is the dominant form of total nitrogen depositions in the United States. We also suggest to have the measurement of organic nitrates in order to provide a more comprehensive insight into the total nitrogen deposition and its associated impact on the ecosystem in the United States.

The International Center for Air Pollution and Energy Studies (iCAPES) conducted further development of the Streamlined Edition of Air Benefit and Cost Analysis and Attainment Assessment System (ABaCAS-SE). ABaCAS-SE includes four modules that run sequentially. CoST-CE estimates the emission costs associated with future-year control strategies. RSM-VAT/CMAQ takes the emissions reduction from CoST-CE to provide a real-time air quality response of emissions change. Then SMAT-CE combines the monitoring data as well as the air quality data from RSM-VAT/CMAQ to assess if the attainment air quality goal has been reached. Subsequently, BenMAP-CE uses the air quality surface generated from SMAT-CE to estimate the health and economic benefits resulting from changes in air quality. Finally, ABaCAS-SE will integrate the results from these four modules to provide assessments of emissions control cost and their associated air quality, health, and economic benefits as well as estimate the cost/benefit ratio ($ benefit per $ cost).

On June 15, Dr. Joshua Fu made a presentation about the emission control cost analysis system at the 2016 ABaCAS Conference held in Shanghai, China. The main achievements of his lecture include: (1) Use the Taiwan Emission Cost Analysis System (TECAS) as a

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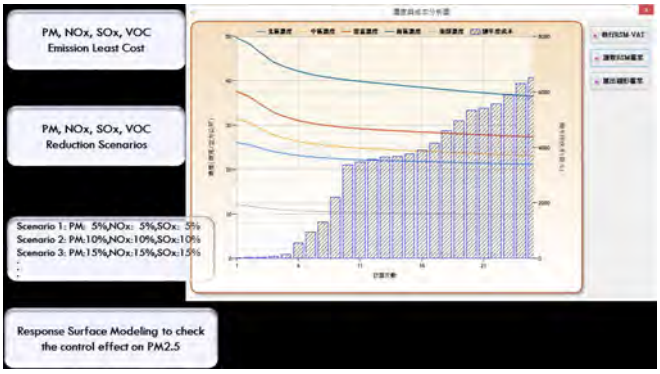
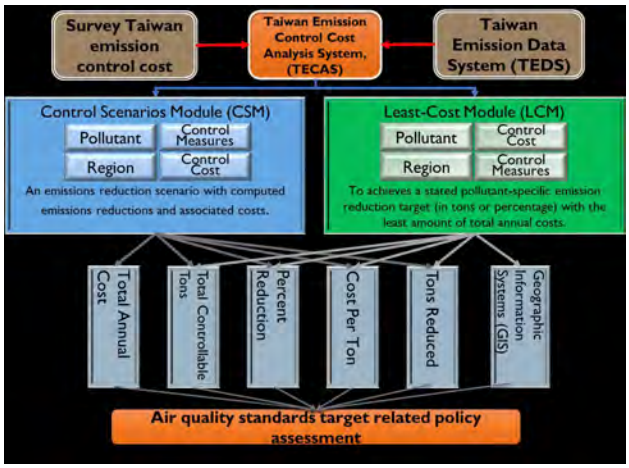
demonstration to show the dataset structure including the control efficiency and cost of different control technologies. ABaCAS-CE may borrow the similar structure to develop the emission control cost dataset for China. (2) Make a comparison of the control efficiency and cost for NOX, SO2 and PM2.5 among Taiwan, US and China, which was valuable to the policy- and decision-makers. (3) Link to RSM-VAT to examine the effects of different control scenarios, which is the key idea of calculating ambient least cost.





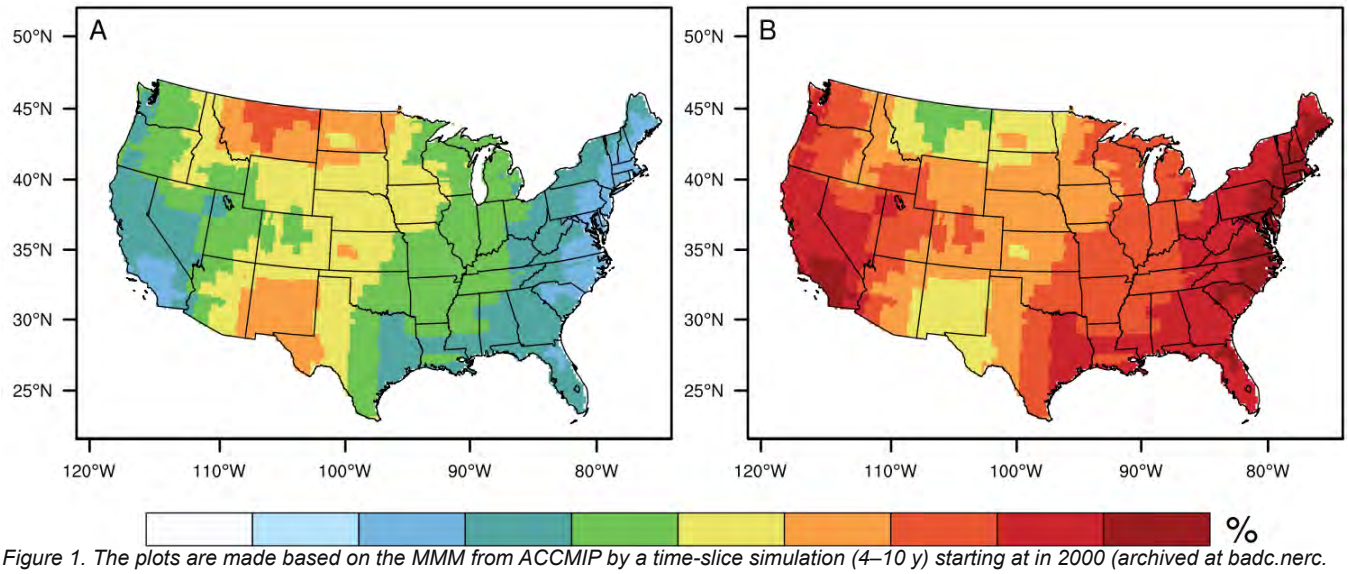


Figure 1. The plots are made based on the MMM from ACCMIP by a time-slice simulation (4–10 y) starting at in 2000 (archived at badc.nerc.ac.uk/home/index.html). (A) The fractional total nitrogen from reduced nitrogen deposition (NH3 + NH4+) to the total nitrogen deposition [NH3 + NH4+ + oxidized nitrogen (NO + NO2 + HNO3 + HNO4 + NO3 + N2O5 + PAN + other organic nitrates)]. (B) The same as in A, but for the total nitrogen from oxidized nitrogen deposition. The unit is percentage.

(2) ABaCAS for China air benefit and cost and attainment system funded by Energy Foundation

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Sustainable E-bikes: Naturalistic Behavior Approaches to Assess Sustainability

(Team: Christopher Cherry, Civil and Environmental Engineering; Daniel Costinett, Electrical Engineering and Computer Science; Paul Frymier, Chemical and Biomolecular Engineering)

Electric bicycles (also called e-bikes) are bicycles with a small battery-powered electric motor, used to assist the rider by adding power in conjunction with physical pedaling. E-bikes have gained recent popularity as an energy-efficient motorized mode of transportation. Over 150 million e-bikes were sold in Europe and Asia in the past ten years. The US market has been slower to adopt the new technology; only 200,000 were sold in 2013. The emergence of e-bikes in our transportation systems raises many questions not previously present in the absence of e-bike technology. The research team will develop widely deployable instrumentation to collect naturalistic behavioral data from e-bike riders. We will then use this data and survey results to make inferences about sustainability, safety, and operational sophistication (e.g. vehicle connectivity).

Outreach performed: During the year 2015-2016, outreach was conducted covering academic researchers, manufactures, and companies (summarized as below).

- Engaged Bosch USA on developing a proposal for National Science Foundation (NSF)
- Collaborated with researchers from Electronic Engineering, and Chemistry Engineering to work on system requirements for an app-based data acquisition system.
- Collaborated with identified programmer from Computer Science for iOS app development to interface with bike for data logging.
- Engaged with sensor providers to establish data collection processes
- Contacted StagesCycling to explore methods to get user-power data and motor power data from Bosch driven e-bike.
- Outreach with industrial partners from Bewegen Company to explore future collaboration and research opportunities, building a research team that includes faculty from Portland State University, University of Alabama Birmingham and UT.
- Led effort to develop and pass state legislation (SB 1705 – HB 1711) to allow e-bikes on the road, necessary to enable field research. This effort included interfacing with national advocacy organizations, industry, statewide organizations, personal testimony to senate the transportation committee and relevant educational outreach efforts. This law was signed by the governor in May 2016.

Four presentations were made by the research team:

- Consumers' attitude towards e-bikes and review of other studies in North America. WEBIKEC 2016: workshop on electric bicycle commuting, Ghent Belgium, June 9-10, 2016
- Electric Bikes: Opportunities and Policy Challenges. Technical Society of Knoxville. Knoxville, TN. October 26, 2015
- China's mobility path: disruptive technologies and their sustainability impacts. Lawrence Berkeley National Lab China Energy Seminar, Berkeley California, April 27, 2016
- China's mobility path: disruptive technologies and their sustainability impacts. UC Davis STEPS seminar, April 26, 2016

During 2015-2016, the research team submitted seven proposals, of which four were funded ($266,000 total), two wererejected, and no proposals are under review. The success rate is 57% so far. Also, the research team are working on several proposals targeted to NSF and NIH.

Funded proposals:

- Implementing Connected E-bikes: Naturalistic Behavior Development and Safety Analysis-Southeastern Transportation Center ($75,000)
- Light Electric Vehicle Education and Research (LEVER) Initiative: Year 3 ORU ($50,000)
- Alternative Vehicles in Last-mile Freight-Tennessee Department of Transportation ($98,000)
- People for Bikes and the National Institute of Transportation and Communities (NITC) ($43,000) (most funding goes toward partner at Portland State University

Assessment of Methane Resources from Municipal Wastewater in Chile

(Team: Qiang He, Chris Cox, and Gregory Reed, Civil & Environmental Engineering; Christian Seal, Department of Civil Engineering, Universidad de Santiago de Chile)

Research Summary—In order to reduce the release of methane as a potent greenhouse gas and curb global warming, methane emission from various anthropogenic sources has been extensively evaluated. However, municipal wastewater treatment facilities (WWTFs) as a significant source of methane emission has not

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received attention from the Global Methane Initiative (GMI), making it critical to systematically assess technologies and management practices for the reduction and recovery of methane from wastewater. Notably, most of the methane from wastewater is generated in developing countries and countries with economies in transition, where wastewater is often poorly or not treated at all, resulting in large amounts of methane emission. Thus, it is essential to assess technological options most suitable for these countries for the reduction of methane emission from the wastewater sector.

Economic and technical feasibility typically represents the primary obstacles to the implementation of efficient wastewater treatment processes in developing countries to reduce methane emission. With the ability to capture methane as renewable fuel instead of releasing methane as a greenhouse gas, anaerobic digestion is an established technology with great potential in reducing the disposal costs for municipal waste sludge (MWS) generated from wastewater treatment and the recovery of biogas/methane as a renewable energy, providing a promising technical option for improved implementation of wastewater treatment and reduction in methane emission. Notably, the biogas-fueled combined heat and power (CHP) technology could further augment the economic and environmental benefits of anaerobic digestion, which warrants a comprehensive assessment in tandem with anaerobic digestion for methane recovery.

Therefore, using Chile as a model GMI partner country, this project evaluated the potential of anaerobic digestion and CHP technology for the recovery of methane from municipal WWTFs as a clean fuel. The following tasks have been completed by the joint U.S.-Chile team: 1) Evaluation of MWS as significant methane resources in Chile; 2) Technical evaluation of anaerobic digestion for methane recovery from MWS; 3) Evaluation of the potential of anaerobic digestion for reducing methane and CO2 emission in Chile. Analyses of wastewater treatment performance were conducted on wastewater utilities in all regions of Chile. Results show that while a considerable portion of the available methane potential has already been recovered, primarily due to the adoption of anaerobic digestion technology in the largest wastewater utilities, such as those in the Metropolitan Region, an equally significant portion, approximately 50% of the available methane resources, remain untapped in Chile. Further analysis indicates that the majority of the wastewater in Chile is both technically and economically feasible for methane recovery with anaerobic digestion technology. Results from feasibility analysis of the use of combined heat and power (CHP) show that it would be cost effective to install a CHP system for a wastewater treatment plant with a flow rate greater than 30,000 m3/day.

As a part of this project, the PI and collaborators in Chile organized Simposio Internacional Emisiones de Metano, Medio Ambiente y Sustentabilidad at Santiago, Chile on June 17-18, 2015. The aim of this symposium is to strengthen national and international research of public and private partnerships in the field of sustainable development, minimizing emissions of greenhouse gases and energy recovery through the management of liquid and solid waste. More than 200 leading scientists, program leaders, governmental officials, stakeholders, and students attended this international symposium. The PI served as the chairperson of the symposium and gave a keynote presentation titled "Wastewater as Resources". US EPA project manager Mr. Christopher Godlove was also invited to give a keynote speech on the Global Methane Initiative.

Results from this project were highlighted by GMI as an internet webinar presented by the PI on Biogas Recovery in the Wastewater Sector to GMI subcommittee delegates and Project Network members on November 23, 2015. The title of the webinar presentation is "Wastewater as Resources: Water, Energy, and Food Nexus". The webinar is also posted on the GMI website: http://globalmethane.org/news-events/event_detailsByEventId.aspx?eventId=461

Supported partly by this project, two peer-reviewed technical papers have been published (see "ISSE-related Publications, below). A manuscript titled "Performance of Wastewater Treatment Facilities in Chile" is being prepared and will be submitted in three months.

Developing Sustainable Technologies for the Beneficial Reuse of Bauxite Residue

(Team: Baoshan Huang and Qiang He, Civil and Environmental Engineering)

Bauxite residue has been continuously produced since the inception of the aluminum industry in the late nineteenth century. The global inventory of bauxite residue reached an estimated 2.7 billion tonnes in 2007, still increasing at 120 million tonnes per annum. This growth highlights the urgency to develop and implement improved means of storage and remediation, and to pursue large-volume utilization options of bauxite residue as a toxic industrial waste product. Current disposal practices include long-term storage in lagoon-type impoundments or dry stacking. The most immediate and apparent of the environmental impact of bauxite residue is its high alkalinity and sodicity. The sustained alkalinity is the result of complex solid-state and solution phase interactions while its sodicity arises

from the use of strong base in the production process. A detailed understanding of the complex buffering and neutralization chemistry of bauxite residue remains the key to improved management, both in terms of reduced environmental impact for current storage practices, legacy costs and for the utilization of the material as an industrial by-product for other applications. In spite of years of continuous industrial production, the nature of bauxite residue and the chemistry of remediation is still poorly understood, making it challenging for the application of bauxite residue in beneficial use.

On-going research efforts focused on the characterization of chemical and physical properties of bauxite residue collected from multiple aluminum production facilities and the modeling of the potential of bauxite residue and impact of primary process parameters for the neutralization of sulfur dioxide in flue gas. The particle morphology of red mud was visualized using Scanning Electron Microscopy (SEM), elemental composition was quantified with Energy-dispersive X-ray spectroscopy (EDX), and mineralogy was characterized with X-Ray Diffraction Analysis (XRD). Elemental analysis shows that the primary elements of the bauxite residue included aluminum, iron, calcium, silicon, sodium, and titanium. Carbon and oxygen were also identified at significant levels in all bauxite waste samples, suggesting these two elements were present as inorganic carbonates resulting from the slow reaction between caustic alkalinity in the original bauxite waste and carbon dioxide in the atmosphere during drying, transportation, and storage. The identification of calcium in the form of calcite provides support that inorganic carbonates result from acid-base reaction followed with the formation of calcite when calcium was present. An important finding is that the lack of calcium could have major implication on the performance of red mud in desulfurization and geopolymer synthesis.

Based on the chemical properties obtained, the stoichiometry of acid/base neutralization was assessed mathematically to assess process parameters for the use of bauxite residue for flue-gas desulfurization. All bauxite residue samples could be rapidly neutralized by sulfur dioxide to pH below 4.0 without inflection points, indicating that the alkalinity in red mud was mostly from strong bases. Batch experiments show that the greatest buffering capacity of the red mud was reached at pH lower than 4.0. Thus, the acid neutralizing capacity of the red mud would not be exhausted at typical operational end points, which typically would be above pH 4.0. In preliminary pilot testing, there was indication that greater desulfurization efficiency was observed at higher temperature, which is likely an indication of the presence of gas-liquid mass transfer limitation which tends to subside at higher temperature. Future efforts in pilot testing will aim to improve process efficiency by potentially reduce mass transfer limitation and optimize the impact of temperature on desulfurization efficiency. Future work includes pilot testing according to results from both experimental and modeling efforts detailed above.

New 2016-17 Seed Grant Projects

(These new seed grant projects were awarded in June 2016 for one-year, July 2, 2016-June 30, 2017)

Appalachian Dark Skies Network

(Team: Tim Ezzell, Political Science/ISSE; and Catherine Wilt, ISSE)

As awareness of light pollution increases, dark sky areas are becoming more significant for both Yisitors and the research community. These areas, however, are increasingly hard to find -particularly near the urban centers of the Eastern and Central United States.

The vast majority of the handful remaining accessible sites are largely found in the Appalachian Mountain region. Recognition of this fact has increased in recent years and a number of communities and facilities are beginning to market themselves as night-sky destinations. In spite of this fact, there have been almost no efforts at communication or cooperation between these sites. Sites have little awareness of one another and communities often view one another as competitors rather potential partners and allies.

In an effort to remedy this, we propose the creation of an Appalachian Dark Skies Network. This network would be composed of the region's dark skies destinations, night sky advocates, and other important stakeholders. These stakeholders might include as telescope and lighting manufacturers, regional colleges and universities, government agencies, and philanthropic organizations.

Socially Responsible Stormwater Management in the Face of Climate Change Uncertainty

(Team: Anahita Khojandi and Xueping Li, Industrial & Systems Engineering; Lisa Reyes Mason, Social Work; Kelsey Ellis, Geography; and Jon Hathaway, Civil & Environmental Engineering)

This study is an interdisciplinary analysis of urban system resiliency to climate change that integrates methods from the social, hydrologic, and systems sciences. Specifically, this study focuses on urban flooding, a common occurrence that will be exacerbated by climate change, and the benefits of green infrastructure

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for flood abatement. Instead of traditional designs that aim to merely mitigate excess runoff or its associated economic costs, this study aims to incorporate the disproportionate effect of weather events and their associated hazards on communities with less social and economic advantages, highlighting the need to integrate these communities in flood abatement and resiliency planning.

Sustainable Treatment of Wastewaters Generated during Unconventional Oil and Gas Production with Production of Renewable Hydrogen

(Team: Abhijeet Borole, Chemical and Biomolecular Engineering/ORNL; and Terry Hazen, Civil & Environmental Engineering/ISSE)

Over the last decade, significant increase in oil and gas production has resulted via unconventional oil and gas production methods. This includes hydraulic fracturing and shale-derived oil and gas extraction. These methods result in production of significant amounts of wastewater, which contains salt and organic contaminants. Energy efficient methods are required for removal of these contaminants and for safe disposal of the wastewater into the environment. This proposed research investigates the use of microbial fuel cells and electrolysis cells (MFC/MEC) for production of electricity and hydrogen from waste streams in the upstream oil and gas industry. The renewable energy generated can then be used to power devices to remove salt from the wastewater, resulting in synergistic removal of salt and organic contaminants.

Enzymatic degradation of biodegradable plastic polymers by fungi and/or bacteria

(Team: Todd Reynolds, Microbiology; and Jennifer DeBruyn, Biosystems Engineering & Soil Science)

We have entered what some are calling the "age of plastics". The vast majority of plastics that are produced are non- or poorly biodegradable, and rely on non-renewable petrochemicals for production. Thus, there is considerable interest in identifying bio-based and biodegradable alternatives to traditional plastics. Polylactic acid (or polylactide) (PLA) is a bio-based biodegradable polymer derived from renewable plant feedstocks (typically corn or sugarcane), and has attracted much attention for its good optical properties, strength, and compostability. PLA is commonly used in the production of compostable food service items, packaging and agricultural biodegradable plastic mulch films. While this polymer has demonstrated degradability under industrial compost conditions, municipal composting programs are still very limited in the U.S., and much of this PLA is expected to end up in other environments (e.g. soils, landfills) where it's fate is unknown. Thus, as production of PLA is anticipated to continue to increase, there is a need to reveal the microbial mechanism of breakdown of these polymers.

Several isolates of fungi and bacteria have been identified that can degrade PLA. It has been suggested that protease-type enzymes are responsible for the initial depolymerization of PLA, however the mechanism is not well characterized. Thus, the specific objective for this project is to identify microbial (fungal and/or bacterial) enzymes involved in the degradation of PLA. The central hypothesis is that fungi involved in the initial degradation of PLA will secrete enzymes (possibly proteases) that can be isolated, and then their cognate genes identified through reverse genetics.

Multi-scale optimization methods for electric distribution systems with renewables

(Team: Jim Ostrowski, Industrial and Systems Engineering; and Hector Pulgar, Electrical Engineering & Computer Science)

This research will develop multi-scale models to optimize the performance and reliability of the power grid. Power systems are evolving to a scenario with a higher penetration of renewable energy to reduce global warming and fossil fuel dependency. For example, the DOE is projecting that by 2050 up to 35% of the United States' electricity could come from wind generation alone. Such a high penetration of renewable generation would be extremely beneficial to the environment. However, renewable generation is much more variable than traditional generation. Maintaining a reliable power grid with so much uncertainty will require the development of new mathematical models and optimization techniques (something the DOE is keenly aware of). This research will enhance UTK's ability to do just that, and in doing so, will develop a multidisciplinary team that will be able to compete for future research funds.

Evaluating sustainability and resilience in agricultural systems using an integrated, web-based app for on-farm self-assessment and resource discovery

(Team: Virginia Dale, Ecology and Evolutionary Biology/ORNL; and Don Hodges, UTIA Forestry, Wildlife and Fisheries)

This project will use a framework of sustainability indicators, selected during a current CIMMYT/ORNL project, to develop a web-based assessement tool (an "App") for farmers and agriculturalists. A sustainble farm protects environmental resources while increas-

ing ecosystem services, supporting healthy farmers and communities, and improving farm profits over the long term. Farm systems of all types and sizes can incorporate better management proctices that enhance sustainability, food security, and resilience. In addition to current production techniques, farmer goals, preferences, and concerns must be prioritized in order to achieve long-term environmental and food security improvements.

Other Activities

The Center for Sustainable Business and Development (CSBD)—CSBD is led by Dr. Rachel JC Chen. During 2015-2016, seven undergraduate and graduate students across the colleges of Business, Law, and Human Sciences were working on various projects under the direction of Dr. Chen. Several projects have been funded and are in progress:

- Tennessee Welcome Centers, $9,500 funded by Department of Tourist Development in 2015-2016, 2015-2016 funding in progress
- Data Management and Mapping for the East Tennessee, $57,500 funded by Department of Transportation, Tennessee, completed
- Center for Sustainable Business and Tourism education, scholarship, and research efforts, $50,000 donation by Ruby Falls LLC., Chattanooga, Tennessee, in progress

Worker Health and Safety Training at Department of Energy (DOE) Facilities—In 2015-2016, Dr. Sheila Webster, Research Director and Rex Short, Senior Research Associate, facilitated training for approximately 1700 DOE workers at DOE locations across the country including: Oak Ridge Operations, Savannah River Site, and Portsmouth Site. Worker trainees included technicians, supervisors, and professionals, who are required to complete 29CFR1910.120 certification or recertification, Radiation II, Practical Factors Training, and various OSHA and EPA regulatory training courses. An online course option, approved by the National Institute of Environmental Health and Sciences (NIEHS), was tailored to increase accessibility and maximize training options for increased worker health and safety training delivery. The training, funded by a grant from NIEHS and administered by the Partnership for Environmental Technology Education (PETE), met the grant goal of providing safety training to 1500+ workers, thirty of which utilized the online program. The ISSE will evaluate and revise the course based on:

- Data collection of student performance
- End of course evaluations by students
- One year follow-up surveys for students to assess how training has been used on the job
- One year follow-up for employers to assess how training has improved workplace health and safety outcomes

ISSE assisted with planning and implementation of the yearly DOE Advisory Committee meeting in Raleigh, NC on May 4, 2016. The meeting focused on the scope of work for the newly awarded grant for a five-year grant cycle. Committee members from DOE facilities and educational institutions throughout the US were present. Representatives from NIEHS provided guidance on goals and priorities. This long-standing program celebrates its 50th anniversary this year.

The DOE worker-training program has proven to be a national leader in reducing work-related illnesses and injuries on the job. Training increases participants' knowledge to improve the work health and safety conditions through active engagement. It also provides tools for stimulating communication with other employees and employers to integrate safety awareness into the DOE culture.

China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC)—The China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC) was established in 2006 to enhance collaboration among Chinese and US scientists in environmental research and education. The center's partners include the University of Tennessee (UT), Oak Ridge National Laboratory (ORNL), Purdue University, the Chinese Academy of Sciences (CAS), and the University of Science and Technology of China (USTC). In 2011, the Center was accepted into the China-US EcoPartnership program, which was established by the US Department of State and the China National Development and Reform Commission.

The ninth annual China-US symposium (also the 5th annual symposium of the Ecopartnership) was hosted by Purdue University and held on October 22-24, 2015 in West Lafayette, Indiana, USA. The theme of the

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conference was "Critical Zone Science, Sustainability and Services in a Changing World." The conference was organized with a common plenary session each morning followed by afternoon thematic symposia and workshops. More than 150 scientists, students, and industry and government leaders attended the conference. A total of 84 presentations (4 keynotes, 42 orals, and 38 posters) were made through three workshops.

ISSE continues to support the JRCEEC by supplying administrative support and support for its annual workshop through travel funds.

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Awards

Faculty/Staff Awards

- The Office of Research Integrity presented seven faculty members with Service Excellence and Leadership Awards during a special celebration at Tyson House in April 2016. Among the recipients was ISSE Director Terry Hazen, who, as the first chair of the institutional laboratory safety committee, has implemented important improvements in laboratory safety and has generated discussion regarding the pathway to improve the culture of lab safety on campus.
- ISSE Researcher Jon Hathaway, assistant professor of civil and environmental engineering and ISSE researcher, recently earned a prestigious CAREER Award from the National Science Foundation for his work in sustainable urban water management.
- Rachel Chen, Director of ISSE's Center for Sustainable Business and Development, was honored as one of UT's "Women with Big Idea."
- Jonathan Overly (ETCF Director) and ISSE's East Tennessee Clean Fuels, were one of the recipients of the Governor's Environmental Stewardship Award. The award recognizes those whose efforts protect Tennessee's scenic beauty, promote environmental education, or improve the overall environment.
- The UTK Hydraulics & Sedimentation Lab (HSL) is featured in the journal *Hydrolink* (2016, Issue 1), published by the International Association for Hydro-Environment Engineering and Research, as one of the top hydraulics labs around the world. Thanos Papanicolaou, TNWRRC Director, heads the HSL.
- NSF's *ScienceNation* online magazine (dated March 21, 2016), features TNWRRC Director Thanos Papanicolaou's involovement with the NSF Intensively Managed Landscapes Critical Zone Observatory.

Student Awards

- Sheridan Brewer (undergraduate student working with ISSE Director Terry Hazen) received Honorable Mention Poster in the College of Arts and Sciences at the 2016 Exhibition of Undergraduate Research and Creative Achievement (EUReCA) , University of Tennessee, Knoxville, April 14, 2016.
- Jian Sun, an ISSE graduate research assistant to Professor Joshua Fu, won best student paper at the 109th Annual Conference and Exhibition of the Air & Waste Management Association (AWMA) in New Orleans on June 20-23, 2016. Sun's paper was titled "Climate-driven exceedance of combined nitrogen and sulfur depositions at forested areas over continental U.S."
- Hannah Woo was chosen as one of ninety students in the United States and Canada to receive a $15,000 Scholar Award from the Philanthropic Educational Organization Sisterhood. "Environmental Engineering Student Wins Prestigious Award to Pursue Biofuel Research."
- Hannah Woo (graduate student working with ISSE Director Terry Hazen) was selected to participate in the first Annual Research Symposium (ARC) organized by the School of Engineering, University of Dayton from April 19-21, 2016. She was one of the 18 selected from a total of 58 applicants. The symposium was held at the University of Dayton and the Emerson Climate Technologies Helix Innovation Center.
- Dr. Andrea Rocha (post-doc working with ISSE Director Terry Hazen) chosen as one of 32 women worldwide to be profiled in the magazine's "Latinas at Tech Giants" edition.

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ISSE Related Publications

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Greene, D.L. and C.Z. Liu. 2015 (June 10). U.S. Oil Dependence 2014: Is Energy Independence in Sight? *Energy Policy* 85:126-137 (published on line at http://www.sciencedirect.com/science/article/pii/S0301421515002104)

Hass, A. L., K. N. Ellis, L. R. Mason, J. M. Hathaway and D. A. Howe. 2016. Heat and humidity in the city: Neighborhood heat index variability in a mid-sized city in the United States. *International Journal of Environmental Research and Public Health* 13: 117, (DOI: 10.3390/ijerph13010117)

Hazen, T. C. and G. S. Sayler. 2016. Environmental Systems Microbiology of Contaminated Environments, p 5.1.6-1-5.1.6-10. In Yates M, Nakatsu C, Miller R, Pillai S (ed), *Manual of Environmental Microbiology*, 4th Edition. ASM Press, Washington, DC. (doi: 10.1128/9781555818821.ch5.1.6)

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Huang, K. J. S. Fu, V.Y. Prikhodko, J. M. Storey, A. Romanov, E. L. Hodson, J. Cresko, I. Morozova, Y. Ignatieva. 2015. Russian anthropogenic black carbon: Emission reconstruction and Arctic black carbon simulation. *Journal of Geophysical Research – Atmospheres* 120 (21): 11306-11333 (doi: 10.1002/2015JD023358)

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Papanicolaou, A. N. (T), K. M. Wacha, B. K. Abban, C. G. Wilson, J. L. Hatfield, C. O. Stanier, and T. R. Filley. 2015. From soilscapes to landscapes: A landscape-oriented approach to simulate soil organic carbon dynamics in intensively managed landscapes. *Journal of Geophysical Research Biogeosciences* 120: 2375–2401 (doi:10.1002/2015JG003078)

Paradis, C.J., S. Jagadamma, D. B. Watson, L. D. McKay, T. C. Hazen, M. Park, and J. D. Istok. 2016. In situ mobility of uranium in the presence of nitrate following sulfate-reducing conditions. *J. Cont. Hydro.* (doi 10.1016/j.jconhyd.2016.02.002)

Parker, J. and U. Kim. 2015. An upscaled approach for transport in media with extended tailing due to back-diffusion using analytical and numerical solutions of the advection dispersion equation. *Journal of Contaminant Hydrology* 182: 157-172

Qiu, X., Y. Zhu, C. Jang, C.-J. Lin, S.X. Wang, J. S. Fu, J. Xie, J. Wang, D. Ding, S. Long. 2015. Development of an integrated policy making tool for assessing air quality and human health benefits of air pollution control. *Front. Environ. Sci. Eng.* 9 (Issue 6): 1056-1065 (doi: 10.1007/s11783-015-0796-8)

Rocha, AM, Q. Yuan, D. Close, K. B. O'Dell, J. Fortney, J. Wu, and T. C. Hazen. 2016. Rapid Detection of Microbial Cell Abundance in Aquatic Systems. *Biosensors & Bioelectronics* 85:915-923 (http://dx.doi.org/10.1016/j.bios.2016.05.098)

Shi, Y., N. Yu, and R.J.C. Chen 2015. After 2008 Olympic Games: From a Glorious Mega-event to a Sustainable Destination Brand. *Journal of Hospitality and Tourism* 13(1): 48-57

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Wu, L., Y. Yang, S. Chen, M. Zhao, Z. Zhu, S. Yang, Y. Qu, Q. Ma, Z. He, J. Zhou, and Q. He. 2016. Long-term successional dynamics of microbial association networks in anaerobic digestion processes. *Water Res.* 104: 1-10 (doi: 10.1016/j.watres.2016.07.072)

Xu T, *Marr E*, Sayler G, Ripp S. Monitoring endocrine disrupting contaminants using high-throughput bioluminescent yeast assays. *Methods in Molecular Biology*, in press.

Yoon, D.H. and R.J.C. Chen. 2016. A Green Shadow: the Influence of Hotel Customers' Environmental Concern, Knowledge, and Education Level on Green Marketing Skepticism and Behavioral Intentions. *Tourism Analysis* (in press)

Yu, N. and R.J.C. Chen. 2016. Hotel Guests' Preferences and Choices: Baby Boomer, X, and Y Generations. *Journal of Hospitality and Tourism* (in press)

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Zhou, Q., C.T. Driscoll, S.E. Moore, M.A. Kulp, J.R. Renfro, J.S. Schwartz, M. Cai., and J.A. Lynch. 2015. Developing critical loads of nitrate and sulfate deposition in the Great Smoky Mountains National Park, United States. *Water, Air, and Soil Pollution* 226:255 (doi: 10.1007/s11270-015-2502-7.)

ISSE-Related Presentations

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. April 13-14, 2016, Knoxville, TN. University of Tennessee Exhibition of Undergraduate Research and Creative Achievement (EUReCA).

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. April 7, 2016, Asheville, NC. National Council Undergraduate Research Annual Meeting

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. ontributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. March 12, 2016, Knoxville, TN. 3rd Annual Southeastern Biogeochemistry Symposium

Buchanan, J.R., B.N.Perez, and J.M.DeBruyn. 2015. Engineered Strategy to Remediate Trace Organic Contaminants using Recirculating Packed-Bed Media Biofilters at Decentralized Wastewater Treatment Systems. WEFTEC, Chicago, IL, September 26-30.2015

Burchett J, Xu T, Sayler G, Ripp S. 2016. Evaluating the cytotoxic effects of cellulose nanocrystals (CNCs) using autobioluminescent yeast and human cells. Society of Toxicology Annual Meeting, New Orleans, LA.

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. Contributed. Environmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. ontributed. Evironmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. arch 15, 2016, San Diego, CA. ACS Annual Meeting

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. Contributed. Environmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Chen, C., G. Pan, W. Shi, F. Xu, S. M. Techtmann, S. M. Pfiffner, and T. C. Hazen. Contributed. How does clay flocculation of harmful algal blooms affect microbial community composition in water and sediment. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Christian, L.E., J.M. Hathaway, and T.H. Epps. 2016. Exploring the Influence of Urban Watershed Characteristics and Antecedent Climate on In-stream Pollutant Dynamics. In Proceedings of the 16th Annual Meeting of the American Ecological Engineering Society, Knoxville, TN, June 7-9, 2016.

Epps, T.H., J.M. Hathaway. 2015. Assessing Spatial Relationships of Distributed Urban Land Cover Compositions and In-stream Flow Regime in Knoxville, TN. In Proceedings of the Twenty-fourth Annual Water Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN, pp.B1-6.

Epps, T.H., J.M. Hathaway. 2016. Runoff Uncertainty Related to Fine-Scale Spatial Variability in Urban Watersheds. In Proceedings of the 25th Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN, pp.1B-3

Epps, T.H., J.M. Hathaway. 2016. Refining Urban Hydrologic Models: Incorporating the Spatial Variability of Rainfall, Vegetation, and Soil Infiltration. In Proceedings of the World Environment and Water Resources Congress, West Palm Beach, FL.

Gonzalez, A., and J.S. Schwartz. 2016. Biogeochemical processes occurring in forested mountain catchments deduced from chemical and sulfur isotopic composition of drainage water. 7th SETAC World Congress/ SETAC North America 37th Annual Meeting. Session title: Environmental Chemistry Perspectives from Around the Globe. Orlando, Florida. November 7-10, 2016.

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Harik, A-M. and T. C. Hazen. Contributed. Methanotrophically Mediated Bioaggregation to Control Sand Dust. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

Hazen, T. C. Invited. Paradigm change? Predicting water geochemistry from microbial community structure. June 8, 2016, Knoxville, TN. American Ecological Engineering Society Annual Meeting

Hazen, T. C. Invited. Microbial Community Structure Predicts Groundwater and Marine Geochemistry. March 16, 2016, Houghton, MI. Department of Biological Sciences, Michigan Technological University

Hazen, T. C. Invited Seminar. Deepwater Horizon Oil Spill. February 19, 2016, Managua, Nicaragua. Seminar to 12th grade science classes at Lincoln International Academy

Hazen, T. C., Smith, M. B., Rocha, A. M., Smillie, C. S., Olesen, S. W., Paradis, C., Wu, L., Campbell, J. H., Fortney, J. L., Mehlhorn, T. L., Lowe, K. A., Earles, J. E., Phillips, J., Techtmann, S. M., Joyner, D. C., Elias, D. A., Bailey, K. L., Hurt, R. A., Preheim, S. P., Sanders, M. C., Yang, J., Mueller, M. A., Brooks, S., Watson, D. B., Zhang, P., He, Z., Dubinsky, E. A., Adams, P. D., Arkin, A. P., Fields, M. W., Zhou, J., and Alm, E. J. Keynote. Microbial Community Structure Predicts Groundwater Geochemistry. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Hazen, T. C. Plenary. Phenotypic and Genomic Heterogeneity among Colwellia psychrerythraea Strains from Distant Deep-Sea Basins. September 11, 2015, Florence, Italy. 3rd Conference of Phenotype MicroArrays, University of Florence

Hazen, T. C. International Scientific Advisory. 3rd Conference of Phenotype MicroArrays. September 10-12, 2015, Florence, Italy, University of Florence.

Hazen, T. C. Section Chair. Genotype/Phenotype 3rd Conference of Phenotype MicroArrays. September 11, 2015, Florence, Italy, University of Florence.

Hazen, T. C. Invited Seminar. Deepwater Horizon Oil Spill: Do Microbial Communities at other Deep Water Drilling Sites around the World Respond the Same? July 16, 2015, Nanjing, China. Nanjing University.

Hazen, T. C. Invited Seminar. Methane: the Good, the Bad and the Ugly. July 15, 2015, Shenyang, China. China Agriculture Institute.

Hazen, T. C. Invited Seminar. Methane: the Good, the Bad and the Ugly. July 13, 2015, Beijing, China. China Agriculture Institute.

Hazen, T. C. Plenary. Deepwater Horizon Oil Spill: Do Microbial Communities at other Deep Water Drilling Sites around the World Respond the Same? July 1, 2015, Chania, Crete, Greece. European Bioremediation Conference VI

Kim, U., J.C. Parker, and R.C. Borden. 2015. Cost and Performance Assessment of In-situ Chemical Oxidation for Intermittent and Continuous Oxidant Injection. 2015 American Geophysical Union Fall Meeting

Liu, J., J. L. Fortney, S. M. Techtmann, D. C. Joyner, and T. C. Hazen. Contributed. Microbial Community changes and Crude Oil Biodegradation and Microbial Community Changes in Deep Oceans. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Papanicolaou, A.N., K. Basnet, B. Abban, C. Giannopoulos, J. Schwartz, J. Hathaway, S. Hawkins, and C.G. Wilson. 2016. Assessing water availability in the Hiwassee River basin using a hydrologic budget. 2016 Tennessee Water Resources Symposium, Burns, TN, April 11-16, 2016

Pelle, A., A.N. Papanicolaou, B. Abban, C. Giannopolous, and C.G. Wilson. 2016. Investigating Non-stationarity in the Obion Watershed. 16th Annual Meeting of the American Ecological Engineering Society, Knoxville, TN, June 7-9, 2016

Perez, Brittani, 2015.Removal of Trace Organic Compounds in Domestic Wastewater using Recirculating Packed-Bed Media Filters. MS Dissertation, Department of Biosystems Engineering and Soil Science, College of Agriculture and Natural Resources, the University of Tennessee, Knoxville, TN. pp.137

Ripp S, Xu T, Close D, Sayler G. 2016. The toolbox of bioreporter and biosensor technologies - from environmental monitoring to the protection of human health, China-US Joint Workshop on Environmental Remediation and Watershed Restoration, Changchun, China.

Schwartz, J., R. Woockman, and C. Clark. 2016. World Environmental & Water Resources Congress. "Urban Stream Restoration Planning: Towards Cost-Effective Mitigation of the Effects of Hydromodification," West Palm Beach, Florida

Schwartz, J.S., and P.V. Simmons. 2016. Spatial analysis of streambank structural heterogeneity and its contribution to bank stability in eastern Tennessee. ASCE/ EWRI World Water & Environmental Resources Congress; West Palm Beach; May23-26, 2016

Seiden, Z.T, and J.S. Schwartz. 2015. Characteristics of fine sediment transport along hillslope concentrated flow pathways caused by cattle traffic. ASCE/EWRI

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Watershed Management Symposium; Reston, Virginia; August 5-7, 2015

Veeneman, A. J.S. Schwartz, and M.A. Kulp. 2016. Throughfall chemistry study in the Great Smoky Mountains National Park. TN AWRA 25thTennessee Water Resources Symposium, Burns, Tennessee; April 2016.

Walker, F.R., C.D. Clark, J. DeBruyn, M. Essington, S. Hawkins, D.M. Lambert, A. Layton, A Ludwig, J.S. Schwartz, and L. Reynolds. 2015. Watershed scale project in Oostanaula Creek, East Tennessee. USDA NIFA Soil Water Conference, Greensboro, NC. July 27-29, 2015.

Woo, H. L. and T. C. Hazen. Contributed. Using high throughput sequencing methods to identify keystone bacterial species in recalcitrant terrestrial organic matter transformation. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Woockman, R., and J. Schwartz. 2015. ASCE/EWRI Watershed Management Symposium. “Excess stream power management in small urban stream systems of the ridge and Valley province in Tennessee, “Reston, Virginia

Woockman, R., and J. Schwartz. 2016. 25th Tennessee Water Resources Symposium. “Reach Scale Sediment Source Potential in Small Urbanizing Stream Systems,” Burns, Tennessee.

Woockman, R., and J. Schwartz. 2016. American Ecological Engineering Society. “Channel Protection: Surplus Stream Power, Channel Erosive Resistance Elements, and Sediment Source Potential,” Knoxville, Tennessee.

Xu T, Marr E, Sayler G, Ripp S. Monitoring endocrine disrupting contaminants using high-throughput bioluminescent yeast assays. *Methods in Molecular Biology*, in press.

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Research Accounts

Account #	Project Name	Project Title	PI	Award Begin	Award End	Award Amount	2016 Expenditures
R012531077	Racheff Environment Fund	Unrestricted Research Support	Hazen, Terry C	5/31/1985	12/31/2047	NA	$ 438.25
R011347010	COE-ISSE Xu Toxicity	Toxicity Profiling of Dioxin-like Pollutants and Other Aryl Hydrocarbon Receptor Agonists Using a High-throughput Yeast	T. Xu, G. Sayler	7/1/2015	6/30/2015	34,785.00	$ 28,735.23
R011347011	COE-ISSE He ARBs/ARGs	Understanding ARGs/ARB Release from Municipal Wastewater Treatment Facilities	He, Qiang	7/1/2015	6/30/2015	44,838.00	$ 28,132.46
R011347012	COE-ISSE Cherry-Sustainable E Bikes	Sustainable E Bikes: Naturalistic Behavior Approaches to Assess Sustainability	C. Cherry	7/1/2015	6/30/2015	57,556.00	$ 28,856.61
R011347013	COE-Palomino-Crown Ether Modif.	Investigation of Crown Ether-modified diatoms for the Removal of Alkali Metals from Aqueous Solutions	A. Palomino	7/1/2015	6/30/2015	50,000.00	$ 33,566.93
R013601030	ISSE Support Fund	Unrestricted Research Support	Hazen, Terry C	4/15/2007	12/31/2047	NA	$ 10,541.54
R013601136	NSF OCI-0963058-Cole	IRNC Pronet: Gloriad YRS 3-5	Cole, Gregory S.	8/1/2010	4/30/2016	1,907,541.00	
R013601137	NSF OCI-0963058-PSC	IRNC Pronet: Gloriad YRS 3-5	Cole, Gregory S.	8/1/2010	4/30/2016	40,000.00	
R013601138	NSF OCI-0963058-Main	IRNC Pronet: Gloriad YRS 3-5	Cole, Gregory S.	8/1/2010	4/30/2016	19,240.00	
R013601139	Ruby Falls CSBT Fund	Unrestricted Research Support for Center for Sustainable Business and Tourism	Chen, Jui-Chi	9/17/2010	12/31/2047	50,000.00	$ 2,078.01
R013601144	USDI-USGS-G11AP20107	WRRIP Application for TN Water Resources Center	Gangaware, Timothy R	3/1/2011	2/29/2016	120,880.65	$ 1,079.05
R013601145	USDI-USGS-G11AP20107	WRRIP Application for TN Water Resources Center	Gangaware, Timothy R	3/1/2011	2/29/2016	90,504.00	$ 3,448.81
R013601154	East TN Clean Fuels Coalition	Admin Support for East Tennesee Clean Fuels Coalition 2015	Hazen, Terry C	7/1/2011	12/31/2016	516,237.00	$ 163,215.84
R013601157	NSF OCI-0963058-Cole	IRNC Pronet: Gloriad	Cole, Gregory S.	8/1/2010	4/30/2016	3,568,710.00	$ 726,711.30
R013601158	NSF OCI-0963058-PSC	IRNC Pronet: Gloriad	Cole, Gregory S.	8/1/2010	4/30/2016	89,400.00	
R013601159	NSF OCI-0963058-Main	IRNC Pronet: Gloriad	Cole, Gregory S.	8/1/2010	4/30/2016	22,350.00	
R013601172	MeadWestvaco	Air Quality Assessment to MeadWestvaco on potential VOC emission controls in Beijing, China	Fu, Joshua Sing-Yih	8/1/2012	4/30/2016	218,304.00	$ 92,520.15
R013601173	USDA NIFA 2012-51130-2046	Renewal of Integrated Watershed Management in Oostanuala Creek Watershed, Tennessee	Schwartz, John	9/1/2012	8/31/2015	144,777.00	$ 32,747.89
R013601184	EPA - XA-83539201	Assessment of Methane Resources from Municipal Wastewater in Chile	He, Qiang	1/1/2013	12/31/2015	99,748.00	$ 50,202.19
R013601186	USACE W912HQ-13-C-0069	A Practical Approach for Remediation Performance Assessment and Optimization at DNAPL Sites for Early Identification and Correcion of Problems Considering Uncertainty	Parker, John Charles	9/26/2013	9/27/2017	789,190.00	$ 196,351.29
R013601190	USDI-USGS-G11AP20107	WRRIP Application for TN Water Resources Center	Gangaware, Timothy R	3/1/2014	2/29/2016	53,379.00	$ 24,376.61
R013601192	COE-ISSE Ellis	Microenvironments, Vulnerability and Relience in the City of Knoxville	K. Ellis, J. Hathaway, L. Mason	7/1/2014	6/30/2016	124,699.00	$ 66,109.78
R013601194	USDI-NPS-GRSM-CESU P14AC00867	Improving the GRSM's Understanding of its Natural Resources and Processes and Thereby Enhancing Protection of the Park's Resources	Schwartz, John Steven	6/18/2014	6/18/2019	277,500.00	$ 110,071.80
R013601195	USDA-Forest 14-DG-11132540-098	Stormwater Goes Green? Investigating the Benefit and Health of Urban Trees in Green Infrastructure Installations	Hathaway, Jon	8/22/2014	12/31/2018	200,322.00	$ 150,068.67
R013601198	TDEC -TN Healthy 32701-02110	Regenerative Stormwater Conveyances: An Innovative Watershed Management Tool for Tennessee	Hathaway, Jon	9/1/2014	12/31/2016	113,000.00	$ 100,075.38
R013601199	TDEC -TN Healthy 32701-02110	Regenerative Stormwater Conveyances: An Innovative Watershed Management Tool for Tennessee	Hathaway, Jon	9/1/2014	12/31/2016	108,643.00	$ 21,166.30
R013601200	Natl Partnership (PETE) 10514	Worker Training at DOE Facilities	Webster, Sheila	9/1/2014	8/31/2015	116,152.00	$ 34,040.55
R013601202	TN dept of Agric 32510-160-15	Urban Riparian Buffer Handbook	Gangaware, Timothy R	11/1/2014	9/30/2015	22,200.00	$ 13,396.17
R013601203	Energy Foundation G-1410-22233	Enhancing Air Quality Management and Assessment Capacity Building and Training in China	Fu, Joseph	10/1/2014	9/30/2015	50,000.00	$ 46,559.22
R013601204	Hebei Institute of Desulfurization	Assessing Applications of Red Mud from Bayer Process in Flue-Gas Desulfurization and Geopolymer Formation in Shandong, China	Huang, Baoshan	1/1/2015	12/31/2016	202,000.00	$ 83,320.00
R013601205	Hebei Institute Desulfurization He	Assessing Applications of Red Mud from Bayer Process in Flue-Gas Desulfurization and Geopolymer Formation in Shandong, China	He, Qiang	1/1/2015	12/31/2016	198,001.00	$ 41,800.48
R013601206	Knox County 14-395 Work Order 3 Gangaware	Assistance for Knox County MOU Beaver Creek 319 Grant	Gangaware, Timothy R	3/1/2015	5/31/2016	30,000.00	$ 29,783.44
R013601207	TN Dept of Tourist Visitor Center	Research services pertaining to the Tennessee Welcome Centers	Chen, Rachel	7/1/2015	6/23/2016	9,500.00	$ 7,534.78
R013601208	NSF ACI-1450959 Cole	IRNC:AMI The InSight Advanced Performance Measurement System	Cole, Gregory	8/1/2015	1/31/2018	703,403.00	$ 211,234.21
R013601209	Knox County 14-395 Work Order 4 Gangaware	Knox County MOU Stormwater Education and Outreach Coordination	Gangaware, Timothy R	7/1/2014	6/30/2017	83,950.00	$ 82,544.05
R013601210	Natl Partnership (PETE) 10532 Webster	Worker Training at DOE Facilities	Webster, Sheila	9/1/2015	8/31/2016	150,000.00	$ 132,833.29
R013601211	USDI USGS G16APOOOG4 - Gangaware	2016 WRRIP Application for TN Water Resources Ctr	Gangaware, Timothy R	3/1/2016	2/28/2021	92,335.00	$ 7,470.76
R013601214	Energy Foundation G-1604-24542 FU	Enhancing Air Quality Management and Assessment Capacity Building and Training in China: Comparison of Emission Control Measures in China, Taiwan and US	Fu, Joshua Sing-Yih	5/1/2016	4/30/2017	50,000.00	
R013601215	USDI USGS G16APOOOG4 -Fu	2016 WRRIP Application for TN Water Resources Ctr	Fu, Joshua Sing-Yih	3/1/2016	4/30/2017	12,941.00	
R013601217	USDI USGS G16APOOOG4 -Hathaway	2016 WRRIP Application for TN Water Resources Ctr	Hathaway, Jon	3/1/2016	4/30/2017	3,000.00	
R013601219	USDI USGS G16APOOOG4 -Schwartz	2016 WRRIP Application for TN Water Resources Ctr	Schwartz, John Steven	3/1/2016	4/30/2017	5,000.00	
R013601220	USDI USGS G16APOOOG4 -Papanicolaou	2016 WRRIP Application for TN Water Resources Ctr	Papanicolaou, Thanos	3/1/2016	4/30/2017	5,000.00	
	Other ISSE Supported Projects						
	ORU Match						
	Institute for Sustainable Transportation	Institute for Sustainable Transportation	Asad Khattak	7/1/2014	6/30/2016	$ 10,000.00	
	Green Economy Initiative	State of the Knoxville Area's Green Economy	Sheffner, Jon	7/1/2014	6/30/2016	$ 6,000.00	
	Food, Water, Energy Nexus	Food, Water, Energy Nexus	Papanicolaou, Thanos	7/1/2014	6/30/2016	$ 10,000.00	
	Equipment Cost Share						
	Civil and Environmental Eng	TOC Analyzer	Cox, Chris	7/1/2014	6/30/2016	$ 5,000.00	
	Meeting and Speaker Support						
	Baker Center Speaker Series	Baker Center Energy and Environment Forum	Sims, Charles	7/1/2014	6/30/2016	$ 3,000.00	

Summary of Faculty and Student Particpation

Faculty Actively Engaged in ISSE Research

Name	Affiliation
Brian Alford	Forestry, Wildlife and Fisheries
Christopher Boyer	Agricultural Economics
Joseph Bozell	Forestry, Wildlife and Fisheries
John Buchanan	Biosystems Engineering and Soil Science
Qing Charles Cao	Electrical Engineering and Computer Science
Kimberly Carter	Civil and Environmental Engineering
Subhadeep Chakraborty	Mechanical, Aerospace and Bio-Medical Engineering
Jiangang Chen	Public Health
Rachel Chen	Retail, Hospitality and Tourism Management
Christopher Cherry	Civil and Environmental Engineering
Christopher Clark	Agricultural Economics
Daniel Costinett	Electrical Engineering & Computer Science
Chris Cox	Civil and Environmental Engineering
Mark Dean	Electrical Engineering and Computer Science
Jennifer DeBruyn	Biosystems Engineering and Soil Science
Kelsey Ellis	Geography
Timothy Ezzell	Political Science
Paul Frymier	Chemical and Biomolecular Engineering
Joshua Fu	Civil and Environmental Engineering
Jens Gregor	Electrical Engineering and Computer Science
Jon Hathaway	Civil and Environmental Engineering
Shawn Hawkins	Biosystems Engineering and Soil Sciences
Terry Hazen	Civil and Environmental Engineering; Earth and Planetary Sciences; Microbiology
Qiang He	Civil and Environmental Engineering
Don Hodges	UTIA Forestry, Wildlife and Fisheries
Baoshan Huang	Civil and Environmental Engineering
Mingzhou Jin	Industrial and Systems Engineering
Asad Khattak	Civil and Environmental Engineering
Anahita Khohandi	Industrial and Systems Engineering
Ungtae Kim	Civil and Environmental Engineering, Cleveland State
Dayton Lambert	Agricultural Economics
Jaehoon Lee	Biosystems Engineering and Soil Sciences
Xueping Li	Industrial and Systems Engineering
Brian Long	Chemistry
Andrea Ludwig	Biosystems Engineering and Soil Sciences
Lisa Reyes Mason	Social Work
Shashi Nambisan	Civil and Environmental Engineering
Jim Ostrowski	Industrial and Systems Engineering
Angelica Palomino	Civil and Environmental Engineering
Thanos Papanicolaou	Civil and Environmental Engineering
Hector Pulgar	Electrical Engineering and Computer Science
Todd Reynolds	Microbiology
Steven Ripp	Center for Environmental Biotechnology
Gary Sayler	Microbiology
John Schwartz	Civil and Environmental Engineering
Sean Schaeffer	Biosystems Engineering and Soil Science
Charles Sims	Economics
Richard Strange	Forestry, Wildlife and Fisheries
William Sutton	Dept. of Ag and Env Sciences, Tennessee State Univ
Christopher Wilson	Civil and Environmental Engineering
DeEtra Young	Dept. of Ag and Env Sciences, Tennessee State Univ

Post Docs and Graduate Students Involved in ISSE Research

Graduate Students	Department
Abban, Benjamin	Ph.D., Civil & Environmental Engineering
Antonelli, David	MS, Civil & Environmental Engineering
Brown, Vincent	MS, Geography
Campa-Ayala, Maria	Ph.D., Civil & Environmental Engineering
Chen, Si	Ph.D., Civil & Environmental Engineering
Christian, Laurel	MS, Civil & Environmental Engineering
Dhakal, Niebesh	MS, Civil & Environmental Engineering
Epps, Thomas	MS, Civil & Environmental Engineering
Gonzalez, Adrian	MS, Civil & Environmental Engineering
Harrison, Taylor	MSSW, Social Work
Hass, Alisa	Ph.D., Geography
Hass, Vincent	MS, Geography
Hicks, Jordan	MS, Civil and Environmental Engineering
Howe, Drew	MS, Civil and Environmental Engineering
Hromadka, Michael	MBA/JD, Haslam Business/College of Law
Humphrey, Laura	MS, Political Science and Sustainability
Keckler, Amy	MSSW, Social Work
Ling, Ziwen	Ph.D., Civil & Environmental Engineering
Yinan Liu	Ph.D., Economics
Manz, Katherine	Ph.D., Bredesen Center
Matzek, Laura	Ph.D, Civil and Environmental Engineering
Mitchell, Nolan	Chemistry
Murray, John	MS, Electrical Engineering & Computer Science
Pelle, Angela	MS, Civil & Environmental Engineering
Sun, Jian	Ph.D., Civil & Environmental Engineering
Taboada, Luis	MS, Civil & Environmental Engineering
Tan, Jiani	Ph.D., Civil & Environmental Engineering
Tobin, Jacob	MA, Electrical Engineering & Computer Sciences
Thompson, Jessica	Ph.D., Civil & Environmental Engineering
Tirpak, Richard	Ph.D. Civil & Environmental Engineering
Veeneman, Andrew	Ph.D. Civil & Environmental Engineering
Wali, Behram	Ph.D., Civil & Environmental Engineering
Walton, Thomas	MS, Civil & Environmental Engineering
Wang, Yongfeng	Ph.D., Civil & Environmental Engineering
Woockman, Robert	MS, Civil & Environmental Engineering
Yang, Lu	Ph.D., Civil & Environmental Engineering
Zhang, Meng	Ph.D., Civil & Environmental Engineering
Zhu, Xiufen	MS, Civil & Environmental Engineering
Post-Docs	
Dong, Xinyi	Civil and Environmental Engineering
Liu, Jun	Civil and Environmental Engineering
Rocha, Andrea	Civil and Environmental Engineering
Wang, Xin	Civil and Environmental Engineering
Xu, Tingting	Center for Environmental Biotechnology

Undergraduate Students Involved in ISSE Research

Undergraduate or Hourly	Department
Alcala, Aliyah	Biochemistry & Molecular and Cellular Biology
Arnholt, Kelly	Biochemistry & Molecular and Cellular Biology
Barnette, Lauren	Civil and Environmental Engineering
Beeler, Brett	Civil and Environmental Engineering
Benavidez, Joshua	Civil and Environmental Engineering
Brewer, Sheridan	Civil and Environmental Engineering
Burchett, Julianna	Environmental Science
Cecil, Alisha	Center for Transportation Research
Delalla, Jacob	Biological Sciences
Gipson, Amie	Civil and Environmental Engineering
Goldfarb, Phillip	Civil and Environmental Engineering
Harrison, Taylor	Social Work
Huang, Vicki	Civil and Environmental Engineering
Humphrey, Laura	Political Science and Sustainability
Keckler, Amy	Social Work
Keyser, John	Civil and Environmental Engineering
Manka, Brandy	Civil and Environmental Engineering
Mann, Joseph	Electrical Engineering & Computer Science
Marr, Enolia	Microbiology
Mohler, Roderick	Civil and Environmental Engineering
Myers, Kalie	Business Administration
Patel, Bindiya	Food Science and Technology
Nicole Pearlman	Civil and Environmental Engineering
Quistorff, Cassidy	Civil and Environmental Engineering
Sherwin, Erin	Biochemistry & Molecular and Cellular Biology
Shires, Mary	Social Work
Smith, Payton	Civil and Environmental Engineering
Young, Anna	Biomedical Engineering