July 2014 - June 2015 Annual Report

and

July 2016 - June 2017 Appropriation Request

to the

Tennessee Higher Education Commission

September 2015

THE UNIVERSITY OF TENNESSEE KNOXVILLE
INSTITUTE FOR A SECURE & SUSTAINABLE ENVIRONMENT

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INTRODUCTION

Dr. Chris Cox, ISSE Director

Fiscal year 2014-2015 marked a number of changes for the Institute for a Secure and Sustainable Environment. In November, ISSE began to operate as a center under the UT College of Engineering. Although ISSE's mission and intellectual domain of environmental sustainability remains interdisciplinary, ISSE researchers are drawn from five of UT's nine colleges. The increased efficiency of the new reporting structure will be beneficial to both ISSE and the College of Engineering.

Secondly, ISSE is undergoing a change in leadership. Effective August 1, 2015 I returned to full time service in the Department of Civil and Environmental Engineering as its new Head, at which time Dr. Terry Hazen, Governor's Chair Professor at the University of Tennessee, was appointed as the new director of ISSE. Dr. Hazen has appointments in the departments of Civil and Environmental Engineering, Microbiology, and Earth and Planetary Sciences. He is well known for his contributions to the fields of environmental microbiology, microbial ecology, and environmental remediation, and has led a number of interdisciplinary research teams both in academia and at Department of Energy National Laboratories. Through his joint appointment with Oak Ridge National Lab, Dr. Hazen will also bring new opportunities and partnerships to ISSE.

Thirdly, Dr. Hazen has recently appointed Dr. Thanos Papanicolaou, Goodrich Chair in Civil and Environmental Engineering, as the director of the Tennessee Water Resources Research Center. Water issues are among the most challenging that our nation will face during the current century. Dr. Papanicolaou's reputation as a leading researcher in this field will enable UT, ISSE, and the TNWRRC to play an expanding role in the national research agenda for this area of growing importance. Tim Gangaware will continue in his role as assistant director of the TNWRRC, with major responsibilities in outreach engagement and training.

In the midst of these changes, ISSE has continued to expand its range of sustainability research and outreach at the University of Tennessee. The pages of this report provide an update of the activities carried out by ISSE staff and ISSE-affiliated faculty, including more than a dozen externally funded research projects, five water resources projects funded through the USGS 104(b) program and administered through the TN Water Resources Research Center, ten internally funded, faculty-led seed projects, and three research initiatives co-supported by ISSE and UT's Office of Research and Engagement. In addition, this report summarizes more than 20 different engagement activities aimed at educating, training, and empowering the citizens and businesses of Tennessee in a wide range of sustainability topics.

Since I began serving as director in October of 2011, ISSE has sought to increase its engagement with the broader community of academic researchers working in the sustainability arena. During my first year as director, ISSE increased its collaborations to include 23 faculty, one post doc, 14 graduate students and one undergraduate student. In the years since, its base of affiliated faculty and students has continued to expand to now include

Introduction (cont)

47 faculty, three post docs, 39 graduate students, and 14 undergraduate students. This level of faculty and student participation has greatly increased ISSE's leadership position in the environmental sustainability research community at UT, thereby creating a platform for future growth in interdisciplinary externally funded research.

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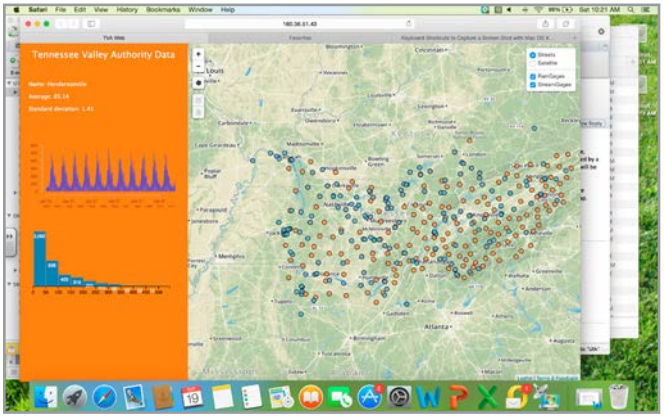
Tennessee Water Resources Research Center (TNWRRC)

TVA Database Development Project

(PIs: Liem Tran, Geography, and John Schwartz, Civil and Environmental Engineering. Additional team members: Carol Harden and Kelsey Ellis, Geography; Richard Strange and Ben Keck, Forestry, Wildlife and Fisheries; Ungtae Kim and Jon Hathaway, Civil and Environmental Engineering)

Efforts in 2014-2015 were to continue to develop and maintain the GIS-based, integrated database initially set up in 2013-2014, and to increase the number of layers and their metadata in the geodatabase (87 layers by the end of 2014-2015). More common GIS tools for data display, classification, attribute and spatial queries have been added to the GIS web interface. In addition, an all-new web application for TVA using the latest and most popular open-source solution has been developed during 2014-2015. This application is used to query and visualize and spatial and temporal data in the TVA region. Compared with the previous implementation based on ESRI products, this version is mainly based on open source software but much faster and more efficient. For example, the new web application is able to provide time series plots and histograms of precipitation and stream gauge data.



Raingages and streamgages on a street basemap with time series plot and histogram of selected station shown on the left panel

The TVA geodatabase has laid the groundwork for collaboration between the watershed group and the Landscape Architecture Program in developing a specialized database for a water quality project in southeast Tennessee (e.g., adding more GIS data, e.g., sewer system, greenways, mining operations, etc., and developing tools for spatial analysis serving water planning purposes). In addition, continued effort with the TVA River Operations group includes interfacing with their new initiative to use Deltare database software for hydrology data.

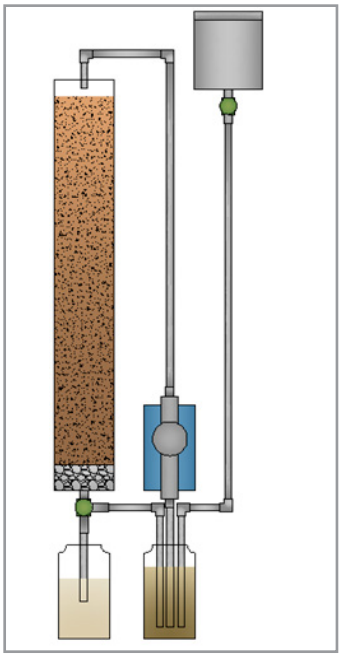
USGS Projects

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 include:

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)

A packed-bed media biofilter is a slow-rate, fixed-film (or attached-growth) unit process used for secondary and tertiary wastewater treatment. This process passes primary-treated 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, effluent is divided between the recirculation tank (for additional passes through the media) and to 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. Four laboratory-scale recirculating media filters systems were constructed to determine the removal efficiencies of three target trace organic contaminants: triclosan—an endocrine disrupting compound, and ibuprofen and naproxen—two non-steroidal anti-inflammatory drugs. Each system included a supply tank, a 51-cm tall by 10-cm diameter column filled



Layout of bench-scale recirculating media filter

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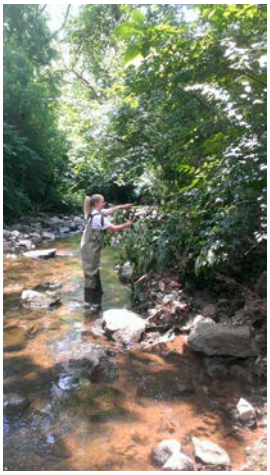
with media (3-5 mm fine gravel), a recirculation tank, and a final product tank. Primary-treated wastewater from a community-scale decentralized treatment system served as the wastewater source. The supply tanks emulated the discharge from primary treatment (liquid/solid separation) and fed into the recirculation tank on a diurnal basis—representing the higher wastewater flows that occur during mornings and evenings. Effluent in the recirculation tank was then micro-dosed to the column five times per hour. The discharge of the column flowed through a three-way valve that determined whether the effluent flowed back to the recirculation tank or to the final discharge. The recirculation rate was five to one. Every fifth time the recirculation pump dosed the column, the three-way valve switched state, and the column effluent drained to the final discharge. Septic tank effluent from a near-by housing development was used as the wastewater source for these secondary-treatment devices. The subject compounds were present in the source water. To gain more information about removal efficiencies, one system was spiked with triclosan, the second with naproxen, the third with ibuprofen, and the forth system was a non-spiked control. Overall, the laboratory-scale recirculating packed-bed media filters removed 70% of the ibuprofen, 79% of the naproxen, and 82% of the triclosan. This preliminary data indicates that this decentralized wastewater treatment technology can potentially remove these three compounds with the same efficiency as larger municipal-scale systems. Further investigations are needed to determine whether the removal process is by microbial degradation or by sorption to the media.

High Resolution Monitoring of Urban Stormwater Quality: Phase 2

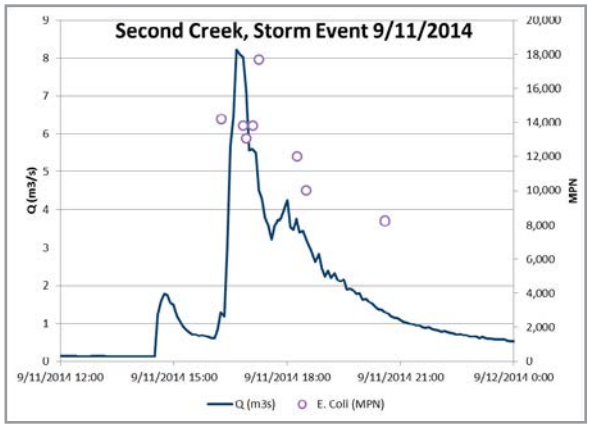
(Team: Jon Hathaway and Kimberly Carter, Civil and Environmental Engineering)

Project Summary: 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. 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 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. This testing will take place in three urban streams in Knoxville, Tennessee.



Surveying of Second Creek Cross Section

Progress: Since sampling began in September 2014 at Second Creek, samples from eleven storm events have been collected. Samples from an additional three storms each have been collected for Third and Williams Creeks where monitoring began in June 2015. Over 10 samples per storm event were typically collected, resulting in well-defined pollutagraphs for the storm events monitored (see figure below). 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 18,000 MPN/100 ml during the storm event on 9/11/2014. This is over 140 times the average concentration desirable for primary contact in recreational waters. Organics analysis failed to result in positive identification of organic pollutants in the storm flows sampled in the latter part of 2014 and the beginning of 2015, However, phenol was found in trace amounts during the samplings from June and July of 2015 and may be from the vegetation near the stream. Additional analysis were performed to determine the presence of other organic species, including perfluorinated compounds, but showed no detectable amounts using the methods available. Further analyses are being performed to determine the concentration of any other potential contaminants. Future analyses will relate pollutant magnitudes and variability to various antecedent environmental conditions, allowing an understanding of factors influencing fate and transport in urban systems.



Example pollutagraph from Second Creek – E. coli concentrations and flow from 9/11/2014 storm event

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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)

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 US Southeast, which has some of the highest mean annual ET in the country, it is one of the least systematically measured parameters.

In this study, we are working to help address two critical gaps in our current ET monitoring and modeling capabilities: (1) the lack of understanding about the effect of soil moisture on ET in regions exhibiting high landscape heterogeneity; and (2) a limited ability to transfer this information from relatively small scales to larger scales of societal importance. Past research has used meteorological properties (such as solar radiation, air temperature, relative humidity, and wind speed/direction) and reference crop corrections to determine potential ET, but neglected the role of soil moisture at the soil boundary surface (i.e., top 30 cm) on actual ET.

We are focusing this study in Eastern Tennessee, which is experiencing gradual urbanization at the interface of existing agricultural areas leading to highly variable land covers and soil conditions. A mobile array of state-of-the-art sensors is being 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 will measure ET, Leaf Area Index (LAI), and soil moisture changes. It will provide 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.

To date the different monitoring sensors have been ordered. Upon receipt, they will be assembled and calibrated in-house under controlled conditions (see figure). We will conduct select field measurements using a systematic protocol and the mobile array at different land uses in the area. Our monitoring protocol has been developed to capture the heterogeneity of moisture patterns and ET emissivity and is complemented with measurements of soil properties and infiltration.

For each monitoring location, our ultimate goal is to quantify water budgets. In addition, we will compare the measured ET, LAI, and soil moisture data to satellite-based, remote sensing data (from MODIS) for ground-truthing. We have begun collecting some this remote sensing data. The results from this comparison will be an initial step for scaling ET across Eastern Tennessee.

Currently no students have been funded; we are waiting for the sensors to arrive. This work was essential in developing a larger 104G proposal related to water budgets as well as providing verification data for larger modeling efforts with the USDA.

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)

Acid rock drainage (ARD) from iron-sulfide bearing geologic formations in road cuts and road construction can have negative impacts on receiving streams due to low pH, occurrence and transport of metals from the site, and the potential impact of these hazards on biota. The iron-sulfide minerals that cause acid-mine drainage (pyrite, marcasite, pyrrhotite) are commonly found in southeastern United States shale formations. Consequently, ARD typically releases coinciding metals, as well as acidity to aquatic ecosystems. During the warm, dry season, the ARD escarpments continue to seep acidic waters, rich in minerals that reflect the geochemistry of the rock. The reduction in rain and increase in air temperature leads to evaporation and concentration of acidic seepage waters, resulting in the temporary storage of highly soluble efflorescent sulfate salts. Our study proposes to evaluate the potential environmental and biological consequences of ARD at each of two total sites in the Chattanooga and Fentress shale formations in Middle Tennessee. Overall, the primary objectives of the investigation are to identify chemical and hydrologic conditions that affect the release of acid and minerals from ARD sites into headwater streams and evaluate biological impacts of ARD on stream-dwelling fauna, primarily streamside salamanders. Collectively, our study will couple the geochemistry of first-flush aquatic inputs and the downstream impacts of ARD inputs on stream biological integrity. The results of this

study will provide information on the impacts of ARD and potential remediation strategies that can be used by local, state, and federal agencies to diminish negative environmental impacts. In addition, as amphibian populations are in decline globally, our study will fill in distributional gaps in our knowledge of Middle Tennessee amphibian populations and aid in the identification of vulnerable and declining populations of stream-dwelling salamanders.

*Cave Salamander (*Eurycea lucifuga*) captured during stream salamander surveys*

Charactering Stream Sediment Source Potential in Small Urbanizing Watersheds

(PI: John Schwartz, Civil and Environmental Engineering)

Project Summary: Streams in urbanizing watersheds are impacted by hydromodification due to increased impervious surfaces and development activates. Urbanization causes widespread changes to stream hydrology and channel processes. Historically, attempts to mitigate these impacts have been through stormwater control measures (SCMs) designed to attenuate peak flows and match some pre-existing conditions. However, many MS4 communities still face channel erosion problems leading to excessive instream sediment and biological impairment. Understanding how alteration to watershed hydrology, resulting from increased urban land-uses, impacts channel processes is necessary to either preserve or restore ecologic integrity and reduce sediment yield. However, the linkages between urbanization, stormwater management/policy, and stream channel response are still poorly understood over the range of watershed settings. The goal of this research is to improve our understanding of the relationships between urbanization, fluvial geomorphology, and stormwater management/policy in order to improve the efficacy of invested mitigation funds.

Progress: This project consists of five basic phases: 1) field surveys for characterization, 2) in-situ data collection, 3) laboratory analysis, 4) model calibration and validation, and 5) scenario analysis. The first three phases are almost complete. Although some efforts are still required, the bulk of fieldwork has been completed and the majority of laboratory analysis as well. This has led to a recent shift in focus to model calibration and validation. Following the model calibration and validation efforts, research efforts will shift to scenario analysis. The bulk of these efforts are expected to begin early spring 2016.

Student Brandy Manka conducting pebble count at Greasy Rock Unnamed Tributary

Pistol Creek in Maryville, Tennessee in-situ data collection site

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 1,473 people attending.
- The Level II Design Principles for Erosion Prevention & Sediment Control for Construction Sites

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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 seven times in four communities with 311 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 16 times in 11 communities with 1,683 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 48 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 first refresher courses were offered in 2014; four course were offered across the State with 62 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 downloaded from the new Tennessee Stormwater Training Program website (http://tnstormwatertraining.org/index.asp).

In addition, TNWRRC with support from faculty the Department of Civil and Environmental Engineering (CEE) and the Department of Biosystems Engineering and Soil Science (BESS), has developed and delivered new training courses that will inform local officials, administrators, design professionals and consultants, and private sector companies on the use of the manual to develop, implement, and maintain the permanent stormwater control measures and practices described in the manual. The Permanent Stormwater Management Design course is a one-day course designed for engineers, landscape architects, stormwater plan preparers, and local government plan reviewers. The course describes how to create stormwater management systems using green infrastructure and evaluate performance with the Tennessee Runoff Reduction Assessment Tool (TNRRAT) so that stormwater management plans for new and redevelopment projects meet the requirements of the TN MS4 permit. The PSW Design course was conducted five times in 2015 with 135 persons attending.

The two-day Stormwater Control Measure Inspection and Maintenance course will be piloted in fall 2015 with regular public offerings of the course to begin in early 2016. Course information and registration for both courses can be found on the Tennessee Stormwater Training Program website.

Watershed Initiatives

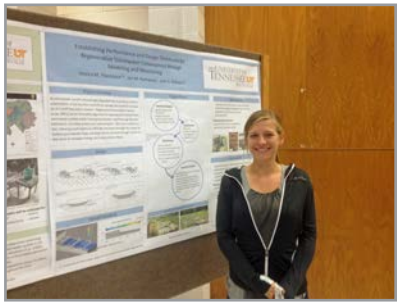
In FY15 TNWRRC served as project manager for two watershed initiatives, one in the Beaver Creek Watershed and one in the Stock Creek Watershed. TNWRRC uses the partnerships cultivated during these initiatives to provide opportunities for research and service learning activities for students and faculty. TNWRRC also assisted Jessica Thompson, Civil and Environmental Engineering, with a Regenerative Stormwater Conveyance project in the Baker Creek Watershed and assisted in the development of a watershed plan for Flat Creek.

Beaver Creek

TNWRRC became project manager for a new Beaver Creek Watershed grant in 2015. A highlight of this

grant is the construction of a large bio-retention basin in a local subdivision with flooding problems. The project will be constructed in the third quarter of 2015. Dr. Andrea Ludwig, Bio-Systems Engineering and Soil Science, has collected three years of water quality and quantity data from the subdivision to be compared with post-construction data. Pervious parking will also be installed at Harrell Road Park this fall. In addition, BMPs are being installed on six farms in Beaver Creek this year.

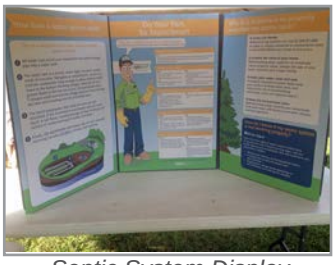
TNWRRC helped Dr. Jon Hathaway and Dr. John Schwartz in Civil and Environmental Engineering to secure a 2015 grant to install a regenerative stormwater conveyance in Beaver Creek. Jessica Thompson, PhD candidate with Dr. Hathaway, will use this grant to support her dissertation.



Jessica Thompson displays Baker Creek Regenerative Stormwater Conveyance project at UTs Watershed Symposium

Stock Creek

TNWRRC continued work with the Knox County Stormwater and the Knox County Soil Conservation District during FY15 to generate interest for installation of farm BMPs in Stock Creek. Three farms will complete installation of BMPs in 2015. As part of this grant TNWRRC created a septic system maintenance display to be used across the region for watershed restoration initiatives.



Septic System Display

Knox County Adopt-A-Watershed Program

The 2014/15 Knox county Adopt-A-Watershed (AAW) Program involved 1666 students from 15 middle and high schools in hands-on learning activities to prepare them to conduct an activity that would improve the well-being of their schools' watersheds. 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. Of the students involved in AAW this past year, approximately 60% received six hours or more of class and field instruction on watershed concepts and processes to prepare them for their service event and about 90% received three hours or more of service preparatory instruction.

Service learning projects completed this year included planting native trees and shrubs and removing exotic invasive plants along streams in order to re-establish healthy riparian buffer habitat; stabilizing eroding hillsides; maintaining demonstration rain gardens; and diverting parking lot debris from streams. Students across Conner Creek, First Creek, Stock Creek, and Ten Mile Creek Watersheds collectively removed about 3.7 tons of invasive, exotic plant material and installed about 975 plants. A portion of these plants were germinated and raised in a greenhouse by Halls High agriculture classes; some were purchased through a local grant; while other were provided through the first annual statewide "50,000 Trees Across Tennessee" initiative.

Hardin Valley students and community members plant native seedlings along Conner Creek

South Doyle High students removing invasive plants in the Stock Creek Watershed

Classes in six schools participated in an ongoing "stormdrain insert" project. Students install a fabric "pocket" insert in the school's parking lot stormdrains that then catches debris (e.g., asphalt particulates) that would have otherwise accumulated in stormwater con-

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veyances or been deposited in a local stream. In total, the students removed one-half ton of debris.

AAW students also participated in research projects during 2014/2015. West High students embarked on an exciting partnership with the UT Civil and Engineering Department. Working with UT doctoral student Andrew Tirpak, the students helped to set up an outdoor research lab on their campus, investigating the impacts of stormwater on urban trees. This is part of a research project titled "Stormwater Goes Green: Investigating the Benefit and Health of Urban Trees in Green Infrastructure Installations," being conducted under the auspices of Dr. Jon Hathaway. Funded by the USDA Forest Service, this three-year project will be continued by AAW students over the next two years and will include data gathering and analysis. West Valley Middle students across the sciences, math, language arts, and social studies disciplines participated in a research project analyzing the costs and benefits of installing three different walking trail surfaces on their campus including the evaluation of stormwater impacts. This project was conducted with the support of the Tennessee Society of Professional Engineers and Cannon & Cannon Inc.

Grace Christian Academy students help to maintain a rain garden located at the Knox County Stormwater Demonstration Park

Carter High students install a stormdrain insert for the collection of parking lot debris

UT doctoral student instructs West High students on their role in installing a UT-based research lab on the West High campus

West Valley Middle students install three test trail sections in their outdoor classroom

Tennessee Smart Yards

Tennessee Smart Yards (TNSY) is a jointly conducted program between the TN Water Resources Research Center and UT Extension. Its mission is to support homeowners across the state in applying sustainable landscaping practices that are protective of Tennessee's waterways. TNSY has completed a three-year rain garden outreach project in partnership with the Lower Clinch Watershed Council that was funded by the Tennessee Department of Agriculture 319 Program. The project included developing a six-hour Homeowner Rain Garden Workshop that included a garden installation component. The workshop was conducted eight times in the Lower Clinch Watershed in conjunction with the installation of four demonstration rain gardens. The rain gardens are located at Oak Ridge High School, Claxton Elementary School, the Oak Ridge Rowing Association on Melton Hill Lake in Anderson County and in the Harrison Springs development in West Knox County. In conjunction with these installations, Tennessee Smart Yards designed on-site educational kiosks. The grant culminated in July, 2015 with presentations to sponsors, partners, and local decision makers about the rain garden project along with a tour of the gardens. The rain garden workshop materials are now being used by stormwater and Extension programs across Tennessee.

Six-Hour Rain Garden Workshop developed by Tennessee Smart Yards

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Oak Ridge High School rain garden

On-Site Educational Rain Garden Signage

Closing Rain Garden Tour with funders, partners, and local decision makers

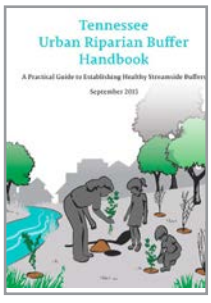
Rain Garden Presentation grant-closing event with funders, partners, and local decision makers

Rain Garden Tour (right to left: Berny Ilgner, LCWC Board President; April Nitzsche, LCWC Director; Ruth Anne Hanahan, TNSY Co-Director; Sam Marshall, TDA 319 NPS Program Manager

TNWRRC staff have developed a Tennessee Urban Riparian Buffer Handbook for the Tennessee Department of Forestry (TDOF) that supports the installation of riparian buffers across Tennessee's urbanizing landscapes. This Handbook is intended for local governments, nongovernmental organizations, community groups, and waterside property owners and contains:

- information needed to establish a riparian buffer in a range of urban settings;
- a step-by-step guide on how to plan, conduct, and evaluate a volunteer riparian planting; and
- a set of handouts that can be used when preparing volunteers and community partners for the coordination and implementation of riparian plantings.

The Riparian Buffer Handbook was devised to provide a framework along with practical tips and resources for those wanting to organize volunteer urban planting events. It also includes a Tennessee-specific riparian plant list along with a supplementary resource list. It is not a regulatory handbook; however, it can be used as an aid in meeting municipal buffer requirements.



The Handbook is a component of the TDOF Riparian Buffer Program Initiative that began in 2011 as a collaborative federal, state, and local effort to promote water quality in urban landscapes through conservation activities that included establishing riparian buffers in eight priority watersheds and through the promotion of volunteerism. This Handbook captures the knowledge gained from these pilot plantings so this information can be used by communities across Tennessee to increase the number of healthy urban riparian buffers while also fostering a new generation of buffer advocates.

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China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC)

BACKGROUND

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.

ACTIVITIES AND PROGRESS IN FY 2015

JRCEEC 2014 Annual Conference

- The eighth annual China-US symposium (also the 4rd annual symposium of the Ecopartnership) was hosted by USTC and held on October 26-28, 2014 in Hefei, China. The theme of the conference was "Energy, Water, and Ecosystem Sustainable Development." More than 120 scientists, students, and industry and government leaders attended the conference. A total of 52 presentations (four plenary, 11 keynotes, 13 orals, and 24 posters) were made through three workshops:
- Workshop 1: Sustainable Water Resources—with emphases on water health, water saving, and wastewater processing and utilization;
- Workshop 2: Integrated Energy Strategies—with emphases on biomass conversion, waste recycling, and alternative energy; and
- Workshop 3: Environmental Safety and Sustainability—with emphases on molecular toxicology, pollution control, contaminated land remediation, ecosystem services, and sustainable policy biological processes of pollution and remediation.

The vice president of USTC, Dr. Shu-Sheng Chen, made the opening speech. The welcome was given by other Chinese and US leaders, including Dr. Chun-Xia Wang (NSFC manger), Dr. Gui-Bin Jiang (CAS Academician and Director of CAS's Research Center for Eco-environmental Sciences), and Dr. Gary Sayler (CEB Director). Approximately 15 faculty and scientists from UT, Purdue, ORNL, University of Oklahoma, and Florida International University presented their research and participated in the pre- and post-conference exchange, such as group meetings, and field trips.

Collaborative Research Group

The collaborative research group (CRG) on Biogeochemistry & Climate Change, led by Sean Schaeffer (UTIA faculty) and Xudong Zhang (CAS professor), has conducted a series of scientific exchanges and collaborative activities. Primary outcomes of the activities include: 1) the fourth group-based workshop in Shenyang, China on March 9-11, 2015; 2) three joint manuscripts in peer-review or in preparation; 3) a Chinese PhD student finished a 1.5 year-long research project in the laboratories of Drs Schaeffer and Radosevich; 4) a joint research proposal was resubmitted to the US NSF and NSF of China. The proposal was ranked number three out of 11 proposals but not funded due to keen competition. The proposal might be resubmitted in next solicitation cycle.

Topical Workshops

In the first half of 2015, JRCEEC organized three workshops or special forums. The activities not only facilitated creation of new opportunities for research collaboration and data/sample exchange but also promoted UT's international reputation. The workshops/forums are:

- China-US Joint Workshop of Biogeochemistry and Climate Change, Shenyang, China, March 9-11, 2015, hosted by the Institute of Applied ecology, Chinese Academy of Sciences
- The Special Forum of China-US Ecopartnership "Scientific Innovation and Early Career Development," hosted by Shenyang Agricultural University, Shenyang, China, March 12-13, 2015
- The Special Forum of China-US Ecopartnership "Frontiers in Soil Ecology," hosted by Inner Mongolia Agricultural University, Huhhot, Inner Mongolia, China, March 13-15, 2015

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The 100 PhD Program

The 100-PhD program has recruited a total of nine students; three started in 2014 and six in 2015. Approximately 40 students were interviewed in July 2015 in China by UT leaders and professors. The program plans to recruit 10 students in 2016, and relevant work is ongoing now. Once a student is recruited by UT, the China Scholarship Council (CSC) will provide a four-year scholarship to cover stipends and health insurance ($20,400/year), while in-state tuition is paid by the UT mentor. The indirect financial contribution of this program to UT is $816,000 per year if ten students are recruited every year. A web site and a university-wide committee have been established to manage the program. Faculty collaboration is in development.

Joint Research Proposal

A joint research proposal was resubmitted to the US NSF, "Dimensions US-China: Linking viral and bacterial biodiversity to agroecosystem function: an intercontinental investigation" ($1,722,276; PIs: Mark Radosevich and Hui Xu). The proposal was not funded but received high ranking.

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East Tennessee Clean Fuels Coalition (ETCleanFuels)

(PI: Jonathan Overly, Research Associate, ISSE)

Clean Cities National Parks Initiative

For the past year, ETCleanFuels has successfully collaborated with Great Smoky Mountains National Park (GRSM) and the neighboring Clean Cities coalition, Land of Sky Clean Vehicles Coalition, to put alternative fuels to use in the park. The Clean Cities National Parks Initiative (CCNPI) was formed to provide funding assistance to parks and demonstrate how alternative fuels and vehicles can complement the National Park Service's mission of promoting the use and enjoyment of the national parks while preserving natural and historic resources. A number of important changes have occurred at the park since the start of this CCNPI program.

- Electric vehicle chargers (EVSE) were installed at the Oconaluftee (North Carolina side) and Sugarlands (Tennessee side) Visitor Centers. The installations include one DC Fast Charger (480V) and one Level 2 charger (220V) at each location.
- Five Gravely zero-turn mowers were converted to run on propane autogas instead of gasoline.

- Three gasoline-powered vehicles were replaced with low-speed electric vehicles.
- GRSM is also implementing several other facets of an overall program that will further advance their efforts to reduce emissions from their vehicles while encouraging visitors to do their part. Information on the EVSE is being included on the park Website and in signage and materials inside the Visitor Centers. Anti-idling signs are also being installed in parking areas in the park.

This project will provide air quality benefits in a sensitive, Class I ecosystem in the US, but also—through CCNPI—the park will become the first national park in the US to offer DC fast charging equipment, the fastest electric vehicle charging equipment available, to its visitors.

A second year's funding has been awarded and GRSM is in the process of retiring four older, medium-duty pickup trucks and replacing them with four new Roush Ford F250 propane-powered trucks. Propane fueling infrastructure is also being installed on the TN and NC sides of the park for refueling the vehicles.

Growing Propane Mower Use

In addition to GRSM, many other regional landscaping companies and other organizationas and municipalities are seeing the benefits of using propane-powered mowers. Some examples of propane mower use include:

- Common Grounds Landscaping (Powell, TN)
- Lawn Butler (Knoxville, TN)
- City of Knoxville, TN
- City of Kingsport, TN
- Turf Managers (Nashville, TN)

Reasons to switch to propane include reduced operating costs, reduced fuel theft, reduced spillage or leakage, and reduced emissions.

EPA Crossroads Truck Stop Electrification Grant

This two-year EPA grant will result in the installation of truck stop electrification (TSE) equipment at six sites across five southeastern states: Kentucky, Tennessee, Alabama, Georgia, and Florida.

TSE technology allows vehicles to turn off their engines and still receive access to electrical power, Wi-Fi, HVAC, and more through window-mounted units or electrical plugs. The elimination of engine idling reduces vehicle emissions that contribute to poor air quality

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and human health concerns in areas where federal air quality standards are not being met.

One of the six sites has already been completed for Covenant Transport based in Chattanooga. By the time all six sites have been completed, there will be a total of 129 additional TSE units available for use across the five participating states.

Other major components of this project include outreach and education. These efforts are being addressed by a project website: www.TeamTSE.us. Team TSE is a group of individuals, industry representatives, Clean Cities coordinators, and others who support the use of TSE to improve air quality, human health, and to reduce unnecessary diesel fuel use. Team members can sign a TSE pledge on the site to show their support. TSE resources and information, as well as location maps, can also be found here.

Drive Electric Tennessee & Tennessee Workplace Charging Challenge

DriveElectricTN.org is the new home for Tennessee's Workplace Charging Partnership (TWCP). The site provides basic information about electric vehicles (EVs) and EVSE. TWCP is a state-based program that is an outgrowth of the national program out of the Department of Energy that encourages employers to offer electric vehicle charging for employees at work.

By participating in this program companies earn LEED credits, reduce their carbon footprint, and attract and retain forward-thinking employees. ETCleanFuels, together with the Office of Energy of the Tennessee Department of Environment and Conservation, will be showcasing the opportunity to Tennessee businesses in order to expanding the program in 2016.

CNG Rally Across Tennessee

ETCleanFuels assisted the Tennessee Gas Association (TGA) in organizing and executing the first-ever "CNG Rally Across Tennessee" in 2015, which was an educational partnership with the TGA and utilities across the state. The week-long event featured a caravan of natural gas vehicles traveling across the entire state, from Memphis to Sevierville, hosting ribbon cuttings, press events, and learning opportunities along the way.

Publications

ETClean Fuels produces two publications: a statewide alternative fuels newsletter, *The Tennessee Clean Fuels Advisor*, and the Clean Cities-powered ezine, *Fuels Fix*. *The Clean Fuels Advisor*, produced through partnership with the Tennessee Department of transportation, is printed twice yearly and is mailed to nearly 3,000 recipients in 46 states. Fuels Fix is a nationwide publication that reflects progress made by Clean Cities coalitions and their stakeholders. It includes alternative fuel success stories, notifications of industry events, and technological advances from national partners.

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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 cyberinfrastructure connecting over 15 million endpoint 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.

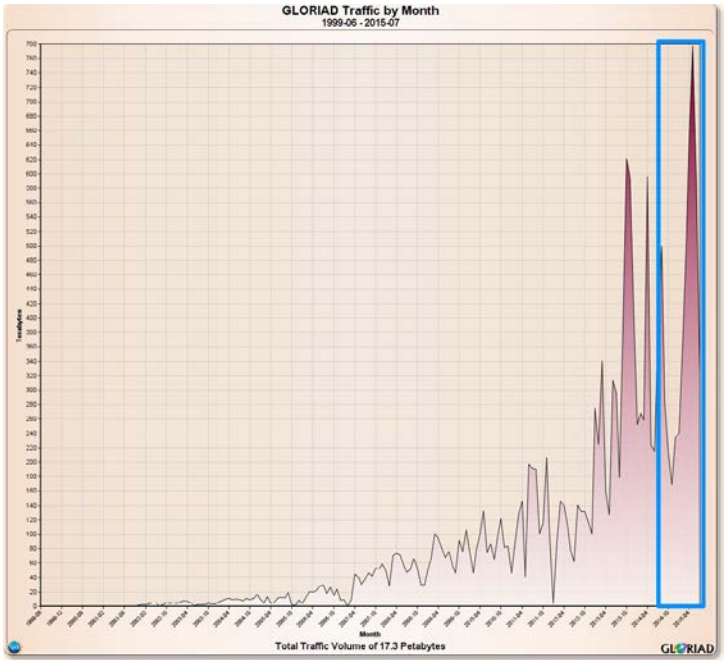

Figure 1. GLORIAD's monthly traffic volume spiked to the highest level ever during the past program year, approaching one Petabyte in May, 2015. This graph illustrates traffic volume from the project's inception in 1999 through July, 2015. The NSF program year ending July, 2015 is highlighted in blue rectangle. Note: heavy traffic (for its time) was experienced in earlier years of GLORIAD (1999-2002) but the representation on above graph is overshadowed by the larger volume of recent years.

GLORIAD is one of the largest internationally collaboratively funded science instruments of its kind. While the UT-based leadership continues to direct the international project and chairs the global board, GLORIAD's international partner investment far exceeds US investment—a total of over $230M. GLORIAD represents an over $250M investment in international science collaboration—and the underlying infrastructure to support it.

GLORIAD enables open science cooperation via carefully organized collaboration and co-funding with public and private sectors in North America, Europe, Asia, and Africa. The science communities served by the GLORIAD program, funded by the US NSF since 1997, now circle the northern hemisphere. Partners include Russia, China, Korea, the Netherlands, Canada, the five Nordic countries, Egypt, India, Malaysia, Singapore and, new this year, the State of Qatar in the Arab Gulf region. The GLORIAD network serves every knowledge discipline—from high-energy physics to atmospheric and climate change science to renewable energy research to nuclear non-proliferation to genomics and medicine to economics and history. The current (2015) GLORIAD map is shown on the next page.

In addition to its day-to-day work managing network services between partners, the GLORIAD team worked on re-engineering network services across North America, supporting ever-increasing work with the Chinese Academy of Sciences—changing the current network architecture to support single flows up to 10 Gbps. They also worked with Korean partners on facilitating new capacity for Korea science (from a total of 25 Gbps last year to 35 Gbps this year), completed work with Russian, Nordic and Dutch partners on a 10-Gbps upgrade of the current US-Russia network (now, the largest international network serving Russian collaborative science), contributed network equipment to new partners in Malaysia, completed connection and peering with new partners in Qatar (which connected at 10 Gbps in late 2014) and continued dialog with other partners in the Arab Gulf region on establishing a series of regional exchanges.

The GLORIAD team has worked during the past year to dramatically improve the new InSight measurement, monitoring and security system at https://insight.gloriad.org/. This work has expanded the partnership with Cisco Systems and Qosient—leveraging more than $1M in equipment contributions from Cisco and deploying advanced Argus technology throughout the GLORIAD-US infrastructure, enabling rich insight into utilization and performance of the GLORIAD network. The work on GLORIAD's new monitoring and security system has been extensive—resulting in $1M in new investment this year by the National Science Foundation on a new 2.5 year program based at UT CINI—from August, 2015–January, 2016.

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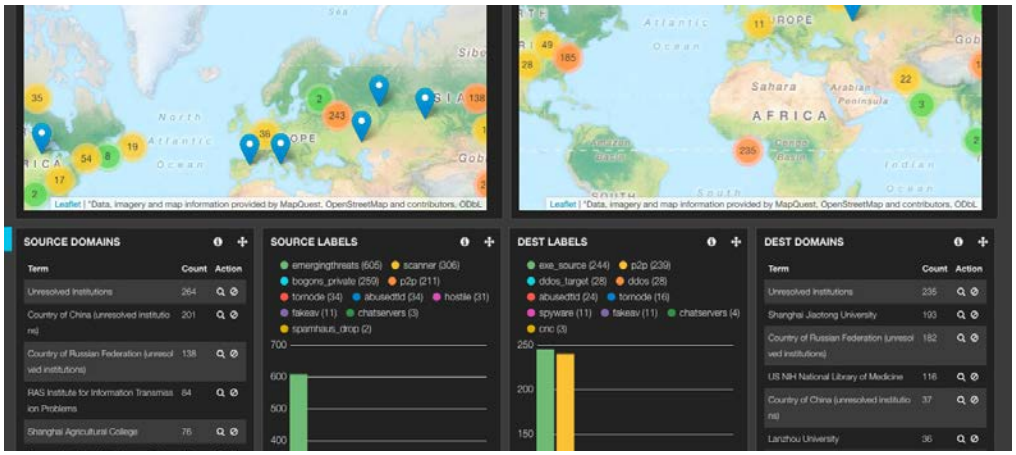
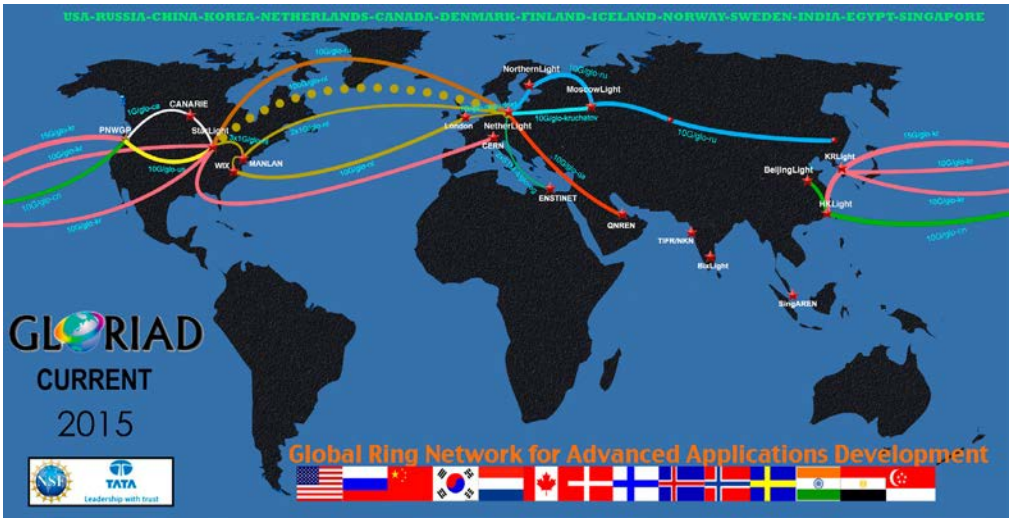
The team is already working with partners around the globe on deploying InSight on R&E networks—including in Korea, Australia, Canada, Qatar, Malaysia and China. A screenshot illustrating GLORIAD's new reputation-assignment system for identifying anomalous behaviors and cyber threats is included below. This is building the potential for "crowd-sourcing" traditional closed work on cybersecurity—addressing one of the most critical technical and social issues of our day.

Current Year Plans

GLORIAD's annual board meeting is being held in Prague, Czech Republic in late September, 2015. The meeting of representatives from over 15 countries will focus on a new GLORIAD mission statement outlining services and architecture to meet needs of a much more demanding global environment for science infrastructure. It will also focus on establishing InSight measurement capabilities across GLORIAD, a new performance verification system and the distributed virtual network operations center (dvNOC) for maintaining a robust but de-centralized operations model globally. The new program year will focus on re-engineering GLORIAD network services to support US science community work with Korea, China, Russia, India, North Africa, West Africa, Southeast Asia, the Gulf Region—and to/with partners in the US, Canada, Netherlands and the 5 Nordic countries.

Additionally, the GLORIAD team has already begun work on the new NSF-funded InSight project and will continue its close work with Cisco and Qosient to advance the state-of- the-art in network measurement, monitoring and cybersecurity and extend this work with both international and domestic partners.





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

The Green Economy Project

(PI: John Shefner, Sociology)

The Green Economy Project progressed significantly this year. We conducted over 60 interviews and a dozen focus groups, and held a number of small meetings aimed at examining sectoral needs that, if addressed, will help build the regional green economy. That work was facilitated by ISSE funding of our Highlander Transitions Fellow, Tom Torres. The data collected is summarized in a series of short papers that will make up the material for discussion at our second Green Economy Forum, to be held on Oct. 27, 2015. The intention of that forum is to present those summary papers as drafts of a roadmap that can be used by industry, government, non-profits, UT, other educational institutions, and others to track needs, advocate policy, and articulate directions for the growth of the regional green economy. The drafts will receive comments from representatives from sectors such as construction, economic development, waste management, government, and agriculture, among others. Those comments will be integrated into the document and then made available to local researchers, governments, utilities, and others. This document will also serve as a basis to plan a variety of research possibilities based on engagement with different stakeholders.

We have examined a variety of foundations, and will target several for letters of inquiry and proposals this academic year. Our reach has expanded beyond the Knoxville area with our partnership with the regional economic development group, East Tennessee Quality Growth. We hope to partner with that organization again to house a Highlander Transition Fellow in order to repeat our successful experience of last year.

In addition, we played an important role in the City of Knoxville Smarter Cities Project, and are continuing in that role. In addition, we have been contracted by the City of Knoxville Sustainability Office to conduct evaluation research on outreach intended to attract interest in the new TVA-funded energy efficiency renovations. Successful completion of this work positions us for further social science evaluation work on the TVA project. This work should also increase our ability to market ourselves to do more work in this area.

ISSE support was important in securing UT ORE funding of a second year of the Green Economy ORU.

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

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

Ever-increasing demands from urban, agricultural, and industrial sectors are spreading thin available water resources, resulting in more frequent shortages. These changes in demand can be significant, especially in adjoining urban and agricultural areas, which are increasing in the Southeast.

To better prepare ourselves for potential problems at the nexus of food-water-energy systems, we have developed an organized research unit on campus called the Initiative for Food, Water, and Energy (IFWE). IFWE is orchestrating like-minded UTK scientists and engineers, with modeling and observational expertise, to achieve the following goals: (1) enhance understanding of the nature-human couplings within complex food-water-energy systems to assess systems-level responses under different market and climate stressors, and (2) develop an integrated network of earth and human observation systems to collect water quality and quantity information at unprecedented scales.

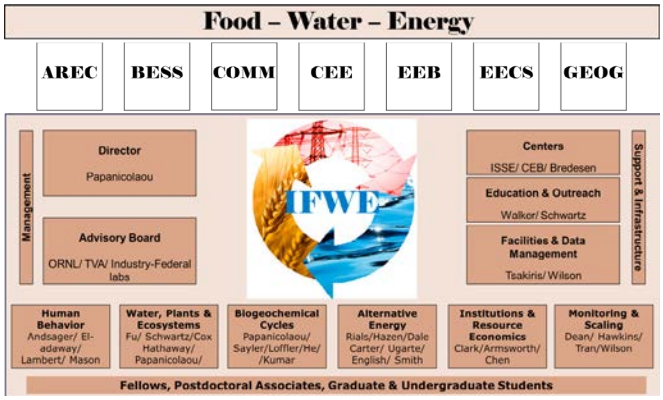
We have established six cross-disciplinary thematic areas (see figure) to accomplish these goals. In addition, we will work with centers on campus, like ISSE and CEB, towards developing smart sensors for assessing food-water-energy interactions across different spatial and temporal scales. For this research, we must re-examine how our systems respond to collective changes in climate, ecology, economics, and policy, as well as how we interact with the natural world. It is not enough that this re-examination is based on sound science, but it must also incorporate multiple points-of-view to ensure that the overall analysis is integrative.

Progress in integrated modeling will offer new ways to capture interactions between decision-makers and natural resources, as well as the level of spatial variability, in more detail than individual models. Advances in collecting micro-level and interaction data (implementing conservation practices with champion farmers, focus groups, social networking apps, choice experiments, soil erosion, and carbon storage measurements) may help specify theoretically solid and empirically justified adaptive decision rules and evolution of stakeholder attributes.

The data and models produced as part of this research will be made available to resource managers to help them understand the long-term effects of alternative management strategies. Research team members will work with these managers to help them use these models and interpret the results properly. IFWE will

facilitate this research to equip us better for managing our critical resources in response to the challenges ahead.

Building policy to promote sustainable outcomes across the food-water-energy nexus requires an understanding of how people interact with and value the natural systems that sustain life. This research will provide an understanding of why different stakeholders respond, or fail to respond to changing conditions, new opportunities, and new threats to long-term sustainability. This study will also enhance our understanding of how different management strategies will affect resilience, adaptability, and sustainability under dynamic natural and human forces in representative watersheds of the Southeast.



Initiative for Sustainability Mobility

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

The Initiative for Sustainable Mobility (ISM) has made excellent progress in developing the concepts and practice of sustainable mobility via active research collaborations with 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. 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.

In our first year, we submitted several proposals. Six interdisciplinary (engineering and policy) proposals were funded in year one, showing a return on investment of 9:1. Two new proposals were funded, based on work done in our first year. One is on driving volatility, ($399,793, for 3 years) funded by the National Science Foundation. Another is "Green Generates Green" ($163,224), to be funded by the Tennessee Department of Transportation, where a research team will be examining how sustainable projects implemented within TDOT generate economic benefits. Some larger proposals are still under review.

We have also been working on developing the Southeastern Smart Mobility consortium with the Tennessee Department of Transportation operations office for implementation of connected vehicle mobility solutions, which, if funded, will pilot test technologies in the Knoxville area.

Our researchers have gained external recognition through invited presentations (including keynote and plenary sessions—seven by Dr. Greene and two by Dr. Khattak. Additionally, Dr. Greene was quoted in Science magazine, on National Public Radio, and at the Tennessee Environmental Conference.

Dr. David Greene and Dr. Asad Khattak co-hosted a luncheon at the Baker Center on Friday, June 12, 2015. The luncheon provided an opportunity to meet colleagues, peers, thought leaders, and experts with common interests in sustainable mobility and intelligent technologies.

Other Projects and Initiatives

Renewable Production of Chemical Feedstocks and Value-Added Chemicals

Team: Joseph Bozell and Nicole Labbe, Forestry, Wildlife and Fisheries; Brian Long, Chemistry; and Cong-Trinh, Chemical and Biomolecular Engineering. This project was jointly funded with the Sustainable Energy Education & Research Center [SEERC])

Converting renewable carbon (agricultural materials, forest resources, etc.) into high-value organic chemicals (HVOs) is of key importance to the success of the emerging biorefining industry. The ability to integrate the production of these high value chemicals along with

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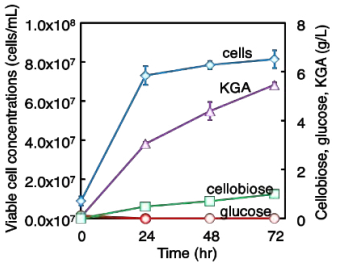
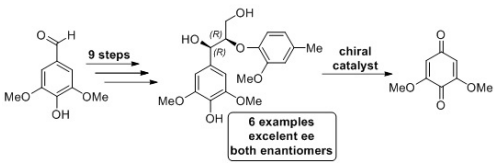
high-volume, low value biofuels from lignocellulosic biomass will result in an overall profitable operation that will also reduce the nation's dependence on foreign supplies of strategic raw materials. Additionally, the environmental footprint of their chemical manufacture will be diminished and their contribution to the domestic rural economy of the nation's industrial sector will be dramatically increased. With the joint support of the Institute for a Secure and Sustainable Environment (ISSE) and the Sustainable Energy Education and Research Center (SEERC), we have assembled a multidisciplinary and multi-institutional team of chemists and biochemical engineers from the Center for Renewable Carbon to tackle these issues.

Our collaborative research team has advanced fundamental knowledge regarding the interaction between catalytic and biocatalytic systems with respect to the conversion of biomass, specifically carbohydrates and lignin, into useful feedstocks and materials. First, we have successfully demonstrated a methodology by which the Krebs cycle in *Yarrowia lipolytica* can be engineered "mid-stream" to overproduce alpha-ketoglutaric acid (KGA) as the single product from cellulose. Second, the KGA produced by the engineered *Yarrowia lipolytica* has proven to be an ideal chemical target for conversion into useful biomaterials, and we have demonstrated proof-of-principle experiments that KGA may be converted into useful bio-based polymers. Lastly, we have recently reported the first ever synthesis of enantiomerically pure lignin model compounds. Ready access to these compounds is of significant importance to be able to understand how lignin is broken down by both chemical and biochemical means.



Productivity and yields of KGA generated by Y. lipolytica



Synthesis of enantiomerically pure lignin model compounds

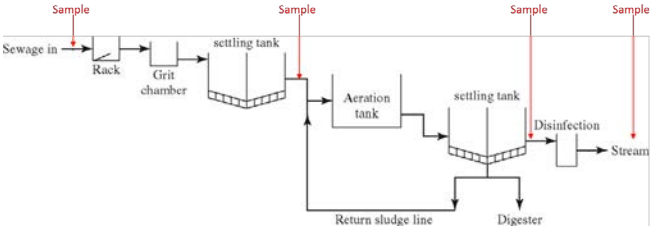
Understanding the Spread of Antibiotic Genes from Wastewater Treatment Plants

(Team: Qiang He, Civil and Environmental Engineering, and Terry C. Hazen, Civil and Environmental Engineering/Earth and Planetary Science/Microbiology)

The intensive use of antibiotics for humans and animals has resulted in their continuous release into the environment. The main concern for the release of antibiotics into the environment is the development of antibiotic-resistant genes and antibiotic resistant bacteria, which threaten the effective prevention and treatment of an ever-increasing range of infectious diseases.

One major knowledge gap for the identification of strategies and actions to effectively mitigate antibiotic resistance is the lack of understanding of the prevalence and mechanisms of antibiotic resistance development in the environment. Municipal wastewater is the primary channel for the release of consumed antibiotics into the environment. Therefore, wastewater treatment plants, where bacteria are used for treatment, are believed to be probable hotspots for antibiotic resistance development because of the simultaneous presence of residual antibiotics and an extremely large number of bacteria. Thus, effluents from wastewater treatment plants are suspected to be among the main sources for antibiotic-resistant genes to spread into the environment.

With the primary objective of this project to prevent antibiotic resistance via the optimization of wastewater treatment processes to mitigate the spread of antibiotic-resistant genes, the specific aims of this project is to identify key processes linked to the development of antibiotic-resistant genes in wastewater treatment plants using cutting-edge metagenomics technology. The research team will take samples of wastewater and treated effluent from a wastewater treatment plant at multiple points (see figure below). The samples will be analyzed and compared using metagenomics techniques to identify the presence of potential antibiotic-resistant genes. The use of metagenomics approaches is greatly advantageous as compared to conventional culture-based techniques, which suffer from the limita-



Sampling Points in Wastewater Treatment Plants

tion that the large majority of microorganisms in the environment are non-culturable.

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)

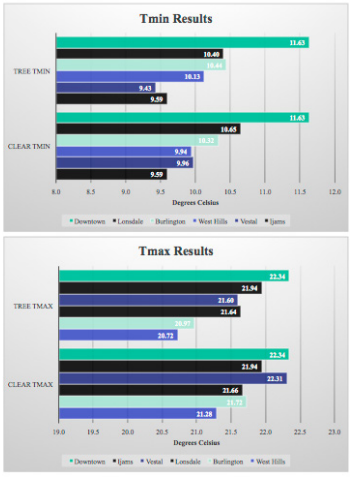
Project Summary: As urbanization escalates, understanding the impact of expanding cities is of extreme importance to human and environmental well-being. This study uses a multidisciplinary approach to monitor urban environmental conditions and understand their impact on diverse populations in the City of Knoxville. To launch the study, 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. Study neighborhoods were chosen for geographic and topographic reasons, as well as for social and economic diversity. West Hills is a predominantly white and middle-to-upper-income neighborhood. Burlington, Vestal, and Lonsdale are more racially and ethnically diverse, and in general house more lower- to middle-income residents. Since July 2014, stations have recorded temperature, humidity, and wind data in five-minute increments. Ongoing social research examines people's perspectives and experiences with environmental conditions—such as temperature extremes, air quality, and urban green space—and considers their interests and preferences for accessing more localized environmental data.

Weather station in Burlington

Progress: Since launching Phase I, a complete year of monitoring data has been collected. In consultation with Dr. Mark Dean (Electrical Engineering and Computer Science, EECS), a senior undergraduate design team developed a Phase II monitor with additional sensor capabilities, which was further refined by an EECS graduate student. The Phase II monitor will be pilot tested on the University of Tennessee campus. A monitor with a mesh-network design enabling communication among stations and remote access of data will now be developed for Phase III. Completed social research includes in-depth interviews (N=20) with residents of the four study neighborhoods; phone surveys (N=200) with a random sample of City of Knoxville residents; and focus groups (N=6) with residents from different geographic areas of the city.

Initial Results and Implications: Based on the first complete year of monitoring data, neighborhoods experienced statistically significant temperature differences, operating somewhere between the warm Downtown and cooler IJAMS observations. Within a given neighborhood, tree cover helps negate daytime heat but does not have as large of an influence on minimum temperature. Results suggest that distance from the city center does not impact temperature as much as land use factors. Social research also points to interesting differences among neighborhoods. Qualitative themes include: (1) social and economic effects of weather extremes, (2) air quality concern and assessment, (3) green space and urban development, and (4) attitudes and resources for environmental action. One noted difference among neighborhoods is greater concern about the social, health, and financial impacts of extreme weather among Burlington, Vestal, and Lonsdale participants (i.e., those with comparatively less advantages) than those from West Hills. Another is a concern about neighborhood air quality among some Vestal and Lonsdale participants, but little to no air quality concerns among participants from West Hills or Burl-

Neighborhood Comparisons 7/2/14-7/2/15



Tmin: All neighborhood Tmin means fall between the Downtown and Ijams values.

Tmax: Neighborhood Tmax means are all less than Downtown control, but the Ijams station did not produce the lowest mean Tmax value.

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ington. Taken together, monitoring and social data may help identify priority areas for policies and programs that improve urban environmental conditions for those most adversely affected.

Stormwater Goes Green? Investigating the Benefit and Health of Urban Trees in Green Infrastructure Installations

(Team: Jon Hathaway and John Schwartz, Civil and Environmental Engineering; Jennifer Franklin, Forestry, Wildlife and Fisheries; and Bill Hunt, Biological and Agricultural Engineering, NC State)

Project Summary: Trees have many important functions within the urban environment including air quality improvements, wildlife habitat, and mitigation of the heat island effect; however, their contribution to stormwater management is not well understood. The goal of this project is to demonstrate the role of trees in stormwater treatment systems in the eastern United States and beyond, and to make recommendations regarding treatment system design and tree species selection to maximize functionality and health. Tree health and function will be quantified using: (1) a field survey of existing stormwater treatment systems, (2) a laboratory experiment to compare tree performance to other types of vegetation, and (3) a field performance study of tree-specific stormwater treatment devices. Based on the results of these studies, design guidelines will be developed which explain how best to integrate trees into stormwater treatment systems.

Progress: During this period, substantial advances were made on the project including completion of the sites visits to support the field survey, laboratory design and concept testing, and surveying / design tasks for the field study. Outreach has also begun between project partners and students/staff from West High School in Knoxville, Tennessee. Six mesocosms were constructed with the help of the high school students to test differences in tree growth based on the presence or absence of a submerged ponding zone. Presentations and hands-on learning were provided to the students to allow a better understanding of tree health analyses and the water quality degradation that has been observed due to urban stormwater runoff in the United States.

Mesocosm design construction at UT

Ph.D. student Andrew Tirpak explains mesocosm construction to West High students

Degradation of Organic Constituents in Fracturing Fluids Using Combined Electrochemical-Biological Oxidation

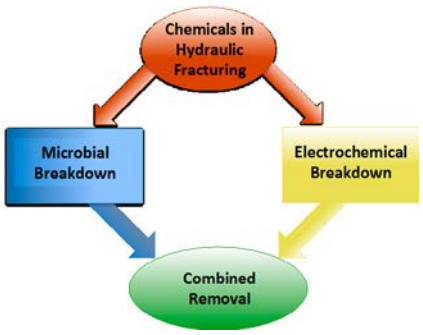
(PI: Kim Carter, Civil and Environmental Engineering)

The oil and gas industry experienced an increase in natural gas production in the United States due to the advances in horizontal drilling and hydraulic fracturing. The process, which requires millions of gallons of water and various additives to be injected into the subsurface, has caused many in the environmental community to be concerned because of the industry's previous lack of transparency concerning the ingredients in the chemical additives making up the hydraulic fracturing fluid. Chemicals such as friction reducers, biocides, and anti-scaling agents are used to optimize the hydraulic fracturing process. However, when the spent water returns after fracturing is complete, both the chemical constituents used to fracture the well and the minerals from the shale formation return too. This waste has been known to cause water quality issues, as previous methods allowed the water to be released into municipal wastewater treatment plants.

This ISSE-supported project has been used to investigate specific chemicals in fracturing fluids and the potential for microorganisms to use these chemicals as electron donors/acceptors, in order to remove them from water. Specifically, this project has been looking at the microbial degradation of 2-Butoxyethanol and 3-Furfuraldehyde using microorganisms from a wastewater treatment plant's aerobic digester. Over the last

year, we have developed a method to extract and detect 2-Butoxyethanol from water and water containing high levels of sodium chloride. Using this method, we have been able to determine the amount of the 2-Butoxyethanol and 3-Furfuraldehyde remediated by the aerobic microbial communities.

We are developing a process that will be used to remove some of the chemical species from wastewater. The next phase of this research is to perform electrochemical experiments to determine if these compounds can be degraded using electrical currents. Once these experiments are completed, the electrochemical method will be combined with the microbial degradation to determine if the remediation process can be improved. The treatment process can impact the gas and oil industry and hydraulic fracturing, as well as the semi-conductor, textile, and pharmaceutical industries and the way these businesses treat their wastewater for disposal. Data from these experiments will be used to write a proposal to be submitted to the National Science Foundation's Chemical, Bioengineering, Environmental, and Transport Systems (CBET) Division's Environmental Engineering Program.



Schematic of the processes investigated through this project for the breakdown of chemical species using microbial and electrochemical breakdown. These methods will be combined to determine if the processes can be optimized if performed in conjunction with each other.

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)

The objective of this project is to develop and test a methodology to periodically assess and optimize groundwater remediation systems at DoD sites contaminated with dense nonaqueous phase liquids (DNAPL). A computer program designated the Stochastic Cost Optimization Toolkit (SCOToolkit) that includes modules for (1) contaminant fate and transport in groundwater with multiple DNAPL sources, (2) cost-performance models for commonly used remediation technologies coupled with the transport model, (3) an inverse solution to calibrated model parameters from available site data, (4) a Monte Carlo model to compute the probability-weighted cost of a given remediation strategy, (5) an optimization algorithm to determine design variables that will minimize life cycle expected net present value cost to reach remediation objectives, and (6) a graphical user interface to simplify field applications.

The transport module employs a newly developed efficient 3-D semi-analytical solution for resident and flux concentrations that accounts for natural and engineered DNAPL source reduction and diffusion-limited mass transfer between high and low permeability zones. Remediation technologies that have been implemented include thermal source reduction, continuous and pulsed in situ chemical oxidation, electron donor enhanced reductive dechlorination, and plume containment. All functional modules have been tested on hypothetical problems and three demonstration sites have been selected for field testing. Efforts are in progress to develop a web-based user interface with on-line training modules.

An interesting finding from SCOToolkit optimization studies, that is contrary to current practice, is that decreasing monitoring frequency and/or number of samples per sampling event does not necessarily reduce expected life cycle. While less intensive monitoring reduces direct monitoring costs, fewer samples yield wider confidence limits which can increase the duration of long term monitoring to achive cleanup objectives with the same level of confidence.

Results from test problems and limited field site testing indicates that SCOToolkit can significantly increase the probability of meeting remediation objectives within a specified period and decrease expected cost based for one-time calibration and optimization analyses. The current program has been modified to allow periodic recalibration and optimization to take advantage of additional data collected since the prior calibration and optimization analysis. Preliminary results indicate this will substantially improve long-term site management and further decreases life-cycle costs. We anticipate average cost savings across all DoD sites of 10% to 30% or more, which can translate to hundreds of millions of dollars in cumulative savings to DoD, other public agencies, and private entities.Project completion is anticipated in mid-2017.

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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 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.

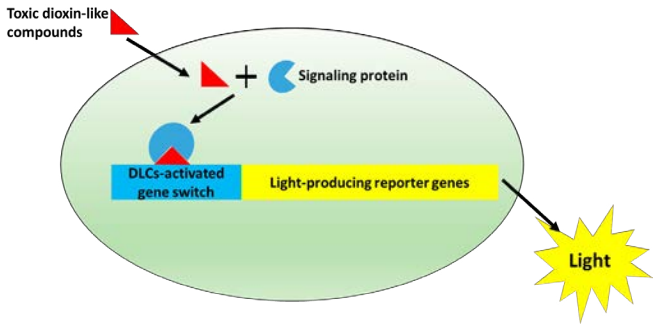


Diagram of the autonomous dioxin bioassay. The objective of this project is to develop a yeast-based bioassay for high-throughput, rapid, and cost-effective toxicity profiling of dioxin-like compounds (DLCs). The yeast cells will be engineered to express light-producing reporter genes under the regulation 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.

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

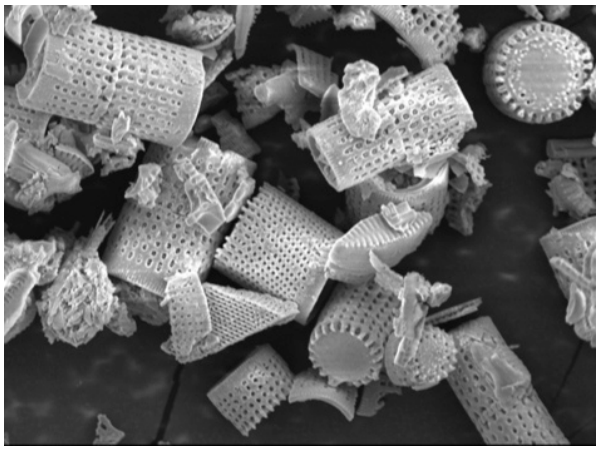
(Team: Angelica Palomino and Kimberly Carter; Civil and Environmental Engineering; Brian Long, Department of Chemistry)

Providing access to clean water is one of the National Academy of Engineering's Grand Challenges. However, the criteria for meeting this challenge are that the proposed water treatment technology should be environmentally sound, non-energy intensive, and economical for the removal of bacteria, suspended solids, and metal species. Metals such as arsenic and mercury are known

to be toxic to human health, harmful environmental pollutants, and difficult to remove from solution, especially at low concentrations. While reverse osmosis membranes and ion exchange resins have been used to remove salts and metal ions from solution, these technologies are generally expensive and energy intensive, especially in remote areas where little infrastructure for water treatment facilities are in place.

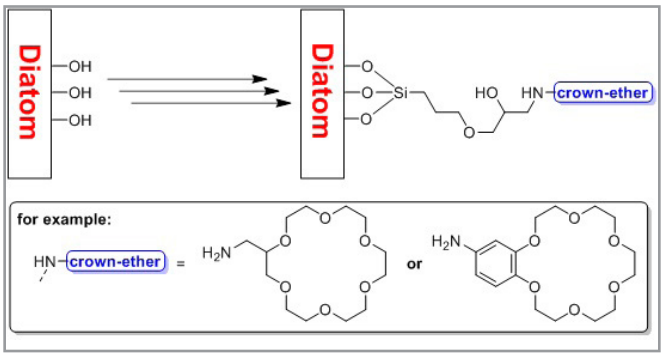
The purpose of this proof-of-concept study is to investigate the use of crown-ether modified diatoms for water treatment applications, in particular the removal of alkali metal ions (K+ and Na+), from aqueous solutions. If successful, the techniques and materials developed here will be further modified to address the removal of heavy metal species such as arsenic or mercury. The scope of this project is multidisciplinary, falling at the interface of water purification, geo-materials engineering, environmental engineering, chemistry, and material science that can impact society as a whole.

The two main components of the proposed system are crown ethers and diatoms. Crown ethers are cyclic polyethers that have found tremendous utility due to their remarkable ability to bind cationic metal salts. Previous studies have investigated their use when immobilized on silica surfaces to aid in the removal of various metals from solution. Diatoms are the skeletal remains of algae and plankton that are typically found in lakes, rivers, and other large bodies of natural waters. The skeletons are microscopic in size (~10-100 μm) and primarily composed of biogenic silica.



Diatoms as viewed through a scanning electron microscope

The advantages of using diatom surface immobilized crown ethers in environmental applications are many. First, the cost of the diatomaceous material is low. Second, silica-based materials, such as diatoms, are relatively chemically inert. Lastly, diatoms have a much higher surface area than traditional silica-based materials, which is extremely attractive as to maximize crown ether attachment and concentration. In sum, though previous studies have investigated attachment of crown ethers to silica-based surfaces for the removal of metal ions, the proposed work aims to provide proof-of-principle results that a simpler, more environmentally-friendly approach can be achieved by the use of surface immobilized crown-ethers on a less costly silica material, i.e. diatoms.



Example of crown-ether attachment to the surface of a diatom

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).

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Naturalistic behavior analysis involves the collection of "real-world" use data, with little to no intervention by the observer. The research team will develop instrumentation that will be widely deployable at a low cost, be minimally intrusive to the components of the subject e-bikes, and will passively (i.e., minimal to no input needed from user) collect data. A long-term goal of this study is to widely deploy instrumented bikes with the assistance of industry. The instrumentation kit (physical hardware and a mobile device application) will collect power usage, vehicle performance, and GPS location data. The collected data will then be used to better understand how sustainability metrics are affected by changes in e-bike usage and travel behavior. In addition, we will investigate the efficacy of assessing safety-critical behavior with mildly instrumented equipment. Finally, collected data will be used to explore technological advancements in e-bike connectivity and sophistication. This can include safety sensors and warnings to user, routing based on geoboundaries, and coordination of the power control systems depending on e-bike operation and the environment.

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)

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 as a significant source of methane emission has not received much attention, making it critical to systematically assess technologies and management practices for the reduction and recovery of methane from wastewater. Economic and technical feasibility typically represents the primary obstacles to the implementation of efficient wastewater treatment processes to reduce methane emission. With the ability to capture methane as renewable fuel instead of releasing methane as a greenhouse gas, anaerobic digestion is a sustainable technology with great potential in reducing the disposal costs for municipal waste sludge 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, the objective of the EPA-supported project is to evaluate the potential of anaerobic digestion and CHP technology for the recovery of methane from wastewater treatment plants. The joint U.S.-Chile team have completed the following tasks: 1) Evaluation of municipal waste sludge as significant methane resources in Chile; 2) Technical and economic evaluation of anaerobic digestion for methane recovery from municipal waste sludge; 3) Technical and economic evaluation of CHP technology for enhanced utilization of methane generated from anaerobic digestion; 4) Evaluation of the potential of anaerobic digestion and CHP for reducing methane and CO2 emission in Chile.

Results from this proposed project provide much needed guidance for selecting environmentally and economically sustainable technologies for reduced methane emission and improved methane recovery in Chile. The culminating outcome of this project is the "Simposio Internacional Emisiones de Metano, Medio Ambiente y Sustentabilidad" held at Santiago, Chile June 17-18, 2015. Project team lead, Dr. Qiang He, co-chaired this international symposium with team partner Dr. Christian Seal. The symposium was attended by researchers from the US and Chile as well as representatives from the Chilean government and US EPA. Dr. He represented the project team and gave a keynote presentation on findings from this project.

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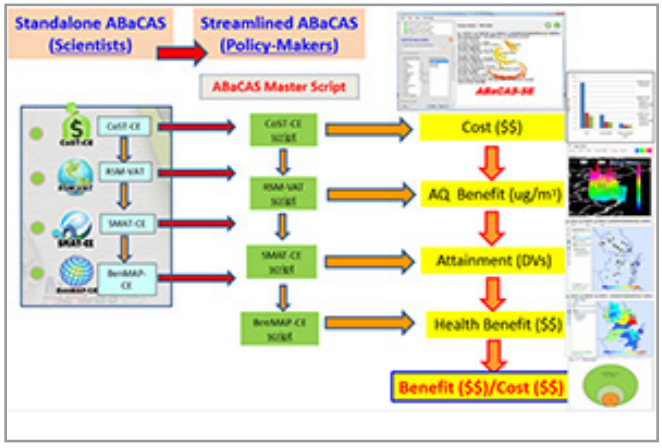
Results from this proposed project will provide much needed guidance for selecting environmentally and economically sustainable technologies for reducing methane emission and enhancing methane recovery as a renewable energy. The outcomes of this project include the reduction of methane emission as a potent greenhouse gas that will benefit the U.S. and other countries from the mitigation of climate change, and the promotion of U.S. technology and expertise for enhanced methane capture and use in Chile and the world clean energy market.

International Center for Air Pollution and Energy Studies (iCAPES)

(PI: Joshua Fu, Civil and Environmental Engineering)

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).

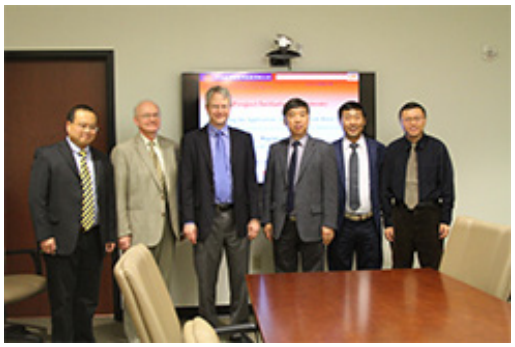


Developing Sustainable Technologies for the Beneficial Reuse of Bauxite Residue

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

The extraction of alumina, a necessary step in aluminum production, generates bauxite residue as a hazardous waste material. At an estimated production of 120 million tons per year, bauxite residue has caused severe soil and water pollution worldwide, particularly in China, now the largest producer of alumina.

Professors Baoshan Huang and Qiang He, both affiliated with ISSE, traveled to China in the summer of 2014 for site visits and met with stakeholders to explore potential solutions. In December 2014, the research team hosted a delegation from China Hebei Research Institute of Construction and Geotechnical Investigation (HBKC) led by Professor & Chief Engineer Qingke Nie and Chief Geotechnical Engineer Jianmin Hu. With the support of ISSE and CEE, HBKC agreed to sponsor an international collaborative research effort to develop sustainable technologies for the beneficial reuse of bauxite residue. This $400,001 project, initiated in January 2015, aims to develop innovative high-volume applications of bauxite residue as materials for civil infrastructures and the management of acidic waste streams. More importantly, this project seamlessly integrates research with education by actively engaging undergraduate students in laboratory studies at UT and pilot testing at HBKC in China.



Project Initiation Ceremony in December 2014. From left: Prof. Huang, Prof. Reed, Prof. Cox, Prof. Nie, Mr. Hu, Prof. He

CEE Undergraduate Student John Keyser conducting geopolymer research with Chinese engineers July 2015 at HBKC, Shijiazhuang, China

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Other Activities

The Center for Sustainable Business and Development (CSBD) is led by Dr. Rachel JC Chen. During 2014-2015, nine 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
- The Impacts of Transportation Contributions of TDOT Projects on Businesses, $109,250 funded by Department of Transportation, Tennessee, suspended
- Economic Impacts of Tennessee Aquarium in Hamilton County, Tennessee, $15,000 funded by Tennessee Aquarium, Tennessee, completed
- Center for Sustainable Business and Tourism–education, scholarship, and research efforts, $25,000 donation by Ruby Falls LLC., Chattanooga, Tennessee, in progress

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Dr. Sheila Webster, Research Director, and Rex Short, Senior Research Associate, facilitated training delivery to workers and subcontractors at DOE facilities across the country including Oak Ridge Operations, Savannah River Site, and Portsmouth Site. Trainees are workers, including 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. The training is funded by a grant from the National Institute of Environmental Health and Sciences (NIEHS) and administered by the Partnership for Environmental Technology Education (PETE).

In 2014-2015, ISSE trained approximately 2,300 DOE workers. To provide maximum convenience and accessibility, an online course, approved by NIEHS, is an alternative delivery option. Forty two workers completed the online course.

Training is updated and modified based on evaluation data and sponsor requirements. Data collection includes student performance, end of course evaluation by students and one year follow up of students and employers to collect data on the impact of training on the workplace and to assess how training has been used on the job. Assessments have indicated the course reduces work related illnesses and injury on the job. Training increases participants' awareness of ways to actively engage in improving the work health and safety conditions and establish methods for dialog and communication with other employees and employers to integrate safety awareness into the DOE culture.

ISSE hosted the DOE Advisory Board meeting in Knoxville on April 28, 2015. The Advisory Board is composed of representatives from DOE facilities and higher education institutions throughout the U.S. The committee reviewed activities and performance over the past five years and discussed plans for submitting a proposal for the next five-year grant cycle.

Presentors at the meeting included: Dr. Matt Murray, Baker Center Director, who shared the results of a study regarding the impact of DOE facilities on the East Tennessee area; Mark Smith, Director of Environmental Health and Safety at the University of Tennessee, who discussed new issues and operations of safety and waste management at UTK; and Bea Ross, Zero Waste Coordinator with UTK Facility Services, who talked about UT Recycling including the massive effort at Neyland Stadium during game day to ensure it is a zero waste event.

* * * * *

ISSE Research Director Catherine A. Wilt worked alongside other UTK researchers on the following projects:

Tennessee Advisory Committee on Intergovernmental Relations (with Drs. Bruce Tonn and Tim Ezzell, Department of Political Science, and graduate students, Kayla Stover and Guinevere Shaw) at the Howard H. Baker Jr. Center for Public Policy—provided an overview of new and innovative best practices being implemented in communities across the United States and Tennessee. The project identified innovations, best practices, tools, technologies and programs

that can assist Tennessee communities in overcoming challenges to their everyday constraints related to public financing, urban planning, energy constraints, etc. New technologies can be used to generate new revenue streams and reduce costs. Innovative financing approaches can be used to make implementation of these new technologies affordable to even the most economically distressed rural communities. Many of the innovations and new technologies can improve the self-sufficiency of communities (e.g., food, energy, manufacturing), thereby lessening somewhat their vulnerability to the volatile global economy. Communities throughout Tennessee and around the world are taking advantage of these opportunities to implement unique, thoughtful, and innovative programs. The final report is titled "What is Happening in the World? Reviews of Community-based Best Practices." This project was funded by the Tennessee Advisory Committee on Intergovernmental Relations through the Howard H. Baker Center for Public Policy. The full report is available at http://bakercenter.utk.edu/wp-content/uploads/sites/4/2015/08/TACIR-final_report-3-15.pdf.

Appalachian Community Research—Wilt served as Co-Principal Investigator on a project titled "Development of Best Practices Amongst Community Case Studies," to develop opportunities related to applied asset-based development research in Johnson County, Tennessee, Morgan County, Ohio; and Calhoun County, West Virginia. This project, funded by the Appalachian Regional Commission, was underway from January-December, 2015. These rural counties were identified through previous ISSE research as ones with both significant concerns related to local economic development, but also as having unique opportunities such as inspired local leadership, and valuable historic or environmental assets. For example, Calhoun County is one of the darkest counties east of the Mississippi River; UT researchers are working with the local community to plan for and identify resources for the development of a destination park for star gazing.

Distributed Generation (with UTK Political Science professor, Dr. Bruce Tonn)—This project was titled "Factors Influencing Decisions Related to Distributed Generation." The study was commissioned by the Howard H. Baker Jr. Center for Public Policy. Globally, the concern regarding climate change and the environment, rising energy costs, and decreasing costs for distributed generation (DG) technologies is solidifying interest in renewable energy. However, much of the research on the topic presumes that DG is a cost-neutral or cost-positive activity for utilities. While there may in fact be long-term benefits for utilities, in the short term, there may be costs and risks both to the utility and rate payers. It may be difficult through traditional rate design practices to recover the costs associated with DG programs from the DG customers; these factors can lead to increased rates for the non-DG customers, financial losses to the utilities, or both. The study, including significant interviews with key corporate, municipal and institutional leaders, yielded many valuable insights to better understand the factors influencing customer investment in distributed generation, particularly when price was not the primary factor.

Keep Knoxville Beautiful—Wilt served as Principal Investigator on a project titled "Survey of Recycling Attitudes and Behaviors for Keep Knoxville Beautiful." This project included a comprehensive waste recycling study for Knox County, Tennessee, with a focus on recycling attitudes and behaviors within the community. Various survey mechanisms were incorporated, including phone (cell and landline), electronic surveys and focus groups. ISSE staff worked with UT's Social Work Office of Research & Public Service to develop and implement a phone survey with nearly 1,000 completions of Knox County residents to better understand their knowledge base and preferences related to the local solid waste and recycling options. The resulting findings were provided to Keep Knoxville Beautiful to better inform the community about solid waste and recycling in Knox County.

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Research Accounts

Account #	Project Name	Project Title	PI	Start	End	Award Amt	FY15 Expenditures
R012531077	Racheff Environment Fund		Cox, Chris	5/31/1985	12/31/2047	NA	$ 926.71
R013601030	ISSE Support Fund		Cox, Chris	4/15/2007	12/31/2047	NA	$ 562.99
R013601121	DOE-DE-EE0001709	I-75 Green Corridor Project	Overly, Jonathan	10/1/2009	12/31/2014	818,091.00	$ 65,660.23
R013601136	NSF OCI-0963058	IRNC Pronet: Gloriad	Cole, Gregory	8/1/2010	4/30/2016	1,907,541.00	$ 114,895.40
R013601137	NSF OCI-0963058	IRNC Pronet: Gloriad	Cole, Gregory	8/1/2010	4/30/2016	40,000.00	$ 5,273.46
R013601139	Ruby Falls CSBT Fund	Unrestricted Research Support for Center for Sustainable Business and Tourism	Chen, Rachel	9/17/2010	12/31/2047	50,000.00	$ 1,718.67
R013601154	East TN Clean Fuels Coalition	Admin Support for East Tennesee Clean Fuels Coalition 2015	Cox, Chris	7/1/2011	9/30/2015	516,237.00	$ 140,661.38
R013601157	NSF OCI-0963058	IRNC Pronet: Gloriad	Cole, Gregory	8/1/2010	4/30/2016	3,568,710.00	$ 1,011,050.53
R013601165	NSF CBET-1220731	Self Protection of Organic Carbon in Soil Pores under Organic Agricultural Practices	Zhuang, Jie	6/1/2012	5/31/2015	90,844.00	$ 16,626.99
R013601172	MeadWestvaco	Air Quality Assessment to MeadWestvaco on potential VOC emission controls in Beijing, China	Fu, Joshua	8/1/2012	4/30/2016	218,304.00	$ 55,863.17
R013601173	USDA NIFA 2012-51130-2046	Renewal o Integrated Watershed Management in Oostanuala Creek Watershed, Tennessee	Schwartz, John	9/1/2012	8/31/2015	144,777.00	$ 54,844.11
R013601176	TDEC - 32701-01367	TN Permanent Stormwater Handbook	Gangaware, Timothy	11/1/2012	11/30/2014	77,432.00	$ 17,937.16
R013601184	EPA - XA-83539201	Assessment of Methane Resources from Municipal Wastewater in Chile	He, Qiang	1/1/2013	12/31/2015	99,748.00	$ 38,411.61
R013601185	UT-B 4000125754	Fusion roadmapping and Pilot Plant studies	Sheffield, John	10/1/2013	9/30/2014	10,002.00	$ 4,043.73
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	9/26/2013	9/25/2016	560,042.00	$ 187,072.06
R013601187	Natl Partnership (PETE) 10514	Worker Training at DOE Facilities	Webster, Sheila	9/1/2013	8/31/2014	107,500.00	$ 27,859.13
R013601189	Knox Co.Soil Conservation District	Stock Creek Watershed Restoration Project	Gangaware, Timothy	3/1/2013	2/28/2015	17,250.00	$ 5,605.25
R013601190	USDI-USGS-G11AP20107	WRRIP Application for TN Water Resources Center	Gangaware, Timothy	3/1/2014	2/29/2016	53,379.00	$ 41,313.01
R013601191	Tennessee Aquarium	Tennessee Aquarium	Chen, Rachel	3/31/2014	4/15/2015	15,000.00	$ 15,000.00
R013601193	Energy Foundation G-1403-20379	Air Quality Assessment in China	Fu, Joshua	4/1/2014	3/31/2015	45,000.00	$ 45,000.00

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Research Accounts

Account #	Project Name	Project Title	PI	Start	End	Award Amount	2015 Expenditures
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	6/18/2014	6/18/2019	180,000.00	$ 95,841.84
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	12/31/2015	192,418.00	$ 14,072.75
R013601196	Knox County 14-394 Work Order 1	Knox County MOU and Work Orders - Adopt-A-Watershed	Gangaware, Timothy	7/1/2014	6/30/2015	66,100.00	$ 66,100.00
R013601197	Knox County 14-395 Work Order 2	Knox County MOU and Work Orders - Adopt-A-Watershed	Gangaware, Timothy	7/1/2014	9/30/2014	10,000.00	$ 10,000.00
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	$ 26,877.57
R013601200	Natl Partnership (PETE) 10514	Worker Training at DOE Facilities	Webster, Sheila	9/1/2014	8/31/2015	116,152.00	$ 87,805.94
R013601201	Keep Knoxville Beautiful	Keep Knoxville Beautiful Waste Recyle	Wilt, Catherine	7/1/2014	6/30/2015	26,000.00	$ 25,929.22
R013601202	TN dept of Agric 32510-160-15	Urban Riparian Buffer Handbook	Gangaware, Timothy	11/1/2014	9/30/2015	22,200.00	$ 11,475.44
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	$ 7,340.05
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	$ 24,878.03
R013601205	Hebei Institute of Desulfurization	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	$ 12,092.00

ISSE Related Publications

(UT affiliated authors are **shown in bold**)

Bandeira, J., D. Carvalho, **A. Khattak,** N. Rouphail, P. Fernandes, T. Fontes, S. Pereira, and M. Coelho. 2015. Empirical assessment of route choice impact on emissions over different road types, traffic demands, and driving scenarios. *International Journal of Sustainable Transportation* (doi: 10.1080/15568318.2014.901447)

Buonocore, J. J., **X. Dong,** J. D. Spengler, **J. S. Fu,** and J. I. Levy. 2014. Using the Community Multiscale Air Quality (CMAQ) Model to Estimate Public Health Impacts of PM2.5 from Individual Power Plants. *Environment International* 68: 200-208 (http://dx.doi.org/10.1016/j.envint.2014.03.031) (SCI, IF=6.248)

Chen, R.J.C. and C. Barrows. 2015. Developing a Mystery Shopping Measure to Operate a Sustainable Restaurant Business: The Power of Integrating with Corporate Executive Members' Feedback. *Sustainability* 7(9): 2279-12294 (doi:10.3390/su70912279)

Chen, R.J.C. 2015. From sustainability to customer loyalty: A case of full service hotels' guests. *Journal of Retailing and Consumer Services* 22(1): 261-265 (http://dx.doi.org/10.1016/j.jretconser.2014.08.007)

Chen, R.J.C. 2015. Beyond Sustainability: from Sustainable Consumer Services to Sustainable Business. *Journal of Retailing and Consumer Services* 22(1): 223-224 (http://dx.doi.org/10.1016/j.jretconser.2014.08.002)

Chen, R.J.C. 2014. Integrated Sustainable Business and Development System: Thoughts and Opinions. *Sustainability* 6(10): 6862-6871 (http://www.mdpi.com/2071-1050/6/10/6862)

Chen, S. and **Q. He.** 2015. Distinctive non-methanogen archaeal populations in anaerobic digestion. *Applied Microbiology Biotechnolpgy*. In press (doi: 10.1007/s00253-015-6951-0)

Chen, S. and **Q. He.** 2015. Persistence of Methanosaeta populations in anaerobic digestion during process instability. *Journal of Industrial Microbiology and Biotechnology* 42(8): 1129-1137. DOI: 10.1007/s10295-015-1632-7

Chen, S. and **Q. He.** 2015. Enrichment and specific quantification of Methanocalculus in anaerobic digestion. *Journal of Bioscience and Bioengineering*. In press. DOI: 10.1016/j.jbiosc.2015.04.007

Chuang, M-T, **J. S. Fu,** N-H Lin, C-T Lee, Y. Gao, S-H Wang, G-R Sheu, T-C Hsiao, J-L Wang, M-C Yen, T-H Lin, N. Thongboonchoo, and W-C Chen. 2015. Simulating transport and chemical evolution of biomass burning pollutants originating from Southeast Asia during 7-SEAS/2010 Dongsha Experiment. *Atmospheric Environment* 112: 294-305 (doi:10.1016/j.atmosenv.2015.04.055 (SCI, IF=3.281)

Dong, X., M. Tschantz, and **J. S. Fu.** 2015. Estimating Evaporative Vapor Generation From Automobiles Based on Parking Activities. *Environmental Pollution* 202: 104–111 (doi:10.1016/j.envpol.2015.03.010) (SCI, IF=4.143)

Greene, D., C.Z. Liu, and S. 2014. Park, Public Policy and the Transition to Electric Drive Vehicles in the U.S.: The Role of the Zero Emission Vehicles Mandates. *Energy Strategy Reviews* 5: 66-77

Hathaway, J. M., R. Brown, **J. S. Fu,** and W. Hunt. 2014. Bioretention Function Under Climate Change Scenarios in North Carolina, USA. *Journal of Hydrology* 519(A): 503–511 (doi: 10.1016/j.jhydrol.2014.07.037) (SCI, IF=3.053)

Jones, J.R., **J.S. Schwartz, K.N. Ellis, J.M. Hathaway,** and C.M. Jawdy. 2015. Temporal variability of precipitation in the upper Tennessee Valley. *Journal of Hydrology–Regional Studies* 3: 125-138 (doi: 10.1016/j.ejrh.2014.10.006)

Keck, B.P., Z.H. Marion, D.J. Martin, J.C. Kaufman, **C.P. Harden, J.S. Schwartz,** and **R.J. Strange.** 2014. Fish functional traits correlated with environmental traits in a temperate biodiversity hot spot. *PLoS One* 9(3): e93237 (doi: 10.1371/journal.pone.0093237)

Lamphere, Jenna and **Jon Shefner**. 2015. Situating the Green Economy: Discourses, Cooptation, and States." *Current Perspectives in Social Theory* 32

Liu C. and **D.L. Greene.** 2015. Consumer Choice of E85: Price Sensitivity and Cost of Limited Fuel Availability. T*ransportation Research Record, Journal of the Transportation Research Board* 2454, 20-27

Liu J., **A. Khattak,** and **X. Wang**. 2015. The Role of Alternative Fuel Vehicles: Using Behavioral and Sensor Data to Model Hierarchies in Travel. *Transportation Research Part C: Emerging Technologies* 55: 379-392 (doi: 10.1016/j.trc.2015.01.028)

Njiojob, C. N., J. L. Rhinehart, **J. J. Bozell,** and **B. K. Long.** 2015. Synthesis of Enantiomerically Pure Lignin Dimer Models for Catalytic Selectivity Studies. *Journal of Organic Chemistry* 80: 1771.

Parsa, H.G., M. Segarra-Ona, S.C. Jang, **R.J.C. Chen,** and A.J. Singh. 2014. Special Issue on Sustainable and Eco-Innovative Practices in Hospitality and Tourism. *The Cornell Hospitality Quarterly* 55(1): 5

Ryu, S., **N. Labbe,** and **C. T. Trinh.** 2014. Simultaneous saccharification and fermentation of cellulose in ionic liquid for efficient production of alpha-ketoglu-

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taric acid. *Applied Microbiology and Biotechnology* 99: 4237-4244.

Shefner, Jon. 2015. How Community Collaboration Transformed the Research Question in a Study of Knoxville's Green Economy. In Martin Tolich (ed.) *Qualitative Research Ethics in Practice.* Left Coast Press.

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

Simmons, P.V., and **J.S. Schwartz.** 2015. A spatial analysis of streambank heterogeneity and its contribution to bank stability in East Tennessee, USA. *Geomorphology (*in review)

Sun, J., J. S. Fu, K. Huang, and Y. Gao. 2015. Estimation of future $PM_{2.5}$- and ozone-related mortality over the continental US in a changing climate: An application of high-resolution dynamical downscaling technique. *Journal of Air and Waste Management Association* 65(5): 611-623 (doi: 10.1080/10962247.2015.1033068) (SCI, IF=1.342)

Tran, L. 2015. An Interactive Method to Select a Set of Sustainable Urban Development Indicators. *Ecological Indicators* (in press)

Wang, H., Y. Zhu, C. Jang, C-J, Lin, S. Wang, **J.S. Fu,** J. Gao, S. Deng, J. Xie, D. Ding, X. Qiu, and S. Long. 2015. Design and demonstration of a next-generation air quality attainment assessment system for $PM_{2.5}$ and O_3. *Journal of Environmental Sciences* (doi: 10.1016/j.jes.2014.08.023) (SCI, IF=2.002)

Wang X., A. Khattak, J. Liu, G. Masghati-Amoli and S. Son. 2015. What is the Level of Volatility in Instantaneous Driving Decisions? *Transportation Research Part C: Emerging Technologies* 58: 413-427 (doi: 10.1016/j.trc.2014.12.014)

Wong, D. C., C. E. Yang, **J. S. Fu,** K. Wong, and Y. Gao. 2015. An Approach to Enhance pnetCDF Performance in Environmental Modeling Applications. *Geoscientific Model Development* 8: 1033–1046 (doi:10.5194/gmd-8-1033-2015) (SCI, IF=6.086)

Woockman, R.R., and **J.S. Schwartz.** 2015. Excess stream power management in small urban stream systems of the ridge and Valley province in Tennessee. Proceedings of the ASCE/EWRI Watershed Management Symposium; Reston, Virginia; August 5-7, 2015.

Xuezhen Qiu, Yun Zhu, Carey Jang, Che-Jen Lin, Shuxiao Wang, **Joshua S. Fu,** Junping Xie, Jiandong Wang, Dian Ding, and Shicheng Long. 2015. Development of an integrated policy making tool for assessing air quality and human health benefits of air pollution control. *Frontiers of Environmental Science & Engineering* (doi: 10.1007/s11783-015-0796-8) (SCI, IF=1.357)

Zhao, B., S.X. Wang, K. Fu, J. Xing, **J. S.Fu,** C. Jang, Y. Zhu, **X.Y. Dong,** Y. Gao, W.J. Wu, and J.M. Hao. 201). Assessing the nonlinear response of fine particles to precursor emissions: development and application of an Extended Response Surface Modeling technique (ERSM v1.0). *Geoscientific Model Development* 8: 115-128 (doi:10.5194/gmd-8-115-2015) (SCI, IF=6.086)

Zhu, Y., Y. Lao, C.J. Jang, C-J, Lin, J. Xing, S. Wang, **J. S. Fu,** S. Deng, J. Xie, and S. Long. 2015. Development and case study of a science-based software platform to support policy making on air quality. *Journal of Environmental Sciences* 27: 97-107 (doi:10.1016/j.jes.2014.08.016) (SCI, IF=2.002)

Summary of Faculty and Student Particpation

Faculty Actively Engaged in ISSE Research

Name	Affiliation
Joseph Bozell	Forestry, Wildlife and Fisheries
John Buchanan	Biosystems Engineering and Soil Science
Kimberly Carter	Civil and Environmental Engineering
Jiangang Chen	Public Health
Rachel Chen	Retail, Hospitality and Tourism Management
Christopher Cherry	Civil and Environmental Engineering
Daniel Costinett	Electrical Engineering & Computer Science
Chris Cox	Civil and Environmental Engineering
Jennifer DeBruyn	Biosystems Engineering and Soil Science
Mark Dean	Electrical Engineering & Computer Science
Kelsey Ellis	Geography
Timothy Ezzell	Political Science
Jennifer Franklin	Forestry, Wildlife and Fisheries
Paul Frymier	Chemical and Biomolecular Engineering
Joshua Fu	Civil and Environmental Engineering
David Greene	Economics
Carol Harden	Geography
Jon Hathaway	Civil and Environmental Engineering
Terry Hazen	Civil and Environmental Engineering; Earth and Planetary Sciences; Microbiology
Qiang He	Civil and Environmental Engineering
Baoshan Huang	Civil and Environmental Engineering
Bill Hunt	Biological & Agricultural Engineering, NC State
Benjamin Keck	Forestry, Wildlife and Fisheries
Asad Khattak	Civil and Environmental Engineering
Ungtae Kim	Civil and Environmental Engineering, Cleveland State
Nicole Labbe	Forestry, Wildlife and Fisheries
Brian Long	Chemistry
Lisa Reyes Mason	Social Work
Angelica Palomino	Civil and Environmental Engineering
Thanos Papanicolaou	Civil and Environmental Engineering
Jack Parker	Civil and Environmental Engineering
Mark Radosevich	Biosystems Engineering and Soil Science
Greg Reed	Civil and Environmental Engineering
Gary Sayler	Microbiology
John Schwartz	Civil and Environmental Engineering
Christian Seal	Civil Engineering, Universidad de Santiago de Chile
Sean Schaeffer	Biosystems Engineering and Soil Science
John Shefner	Sociology
Charles Sims	Economics
Richard Strange	Forestry, Wildlife and Fisheries
Bruce Tonn	Political Science
Liem Tran	Geography
William Sutton	Agricultural & Environmental Sciences, TN State University
Cong Trinh	Chemical and Biomolecular Engineering
Christopher Wilson	Civil and Environmental Engineering
DeEtra Young	Agricultural & Environmental Sciences, TN State University
Jie Zhuang	Biosystems Engineering and Soil Science

Post Docs and Graduate Students Involved in ISSE Research

Graduate Students	Department	Graduation Date
Aplin, Matthew	Civil and Environmental Engineering	
Arwood, Catherine	Social Work	Spring 2015
Budipradigdo, Maudy	Biosystems Engineering & Soil Science	
Cao, Liu	Civil and Environmental Engineering	
Chen, Si	Civil and Environmental Engineering	December 2014
Choi, Jinlyung	Civil and Environmental Engineering	
Christian, Jennifer	Social Work	Spring 2015
Dong, Xinyi	Civil and Environmental Engineering	Spring 2016
Epps, Thom	Civil and Environmental Engineering	
Gonzalez, Adrian	Civil and Environmental Engineering	
Harrison, Taylor	Social Work	Spring 2016
Hass, Alisa	Geography	Spring 2016
Howe, Drew	Civil and Environmental Engineering	Spring 2016
Hromadka, Michael	Business Administration	
Izquierdo, Jose	Geography	August 2014
Krivacsy, Kevin	Geography	
Lamphere, Jenna	Sociology	Summer 2015
Li, Yan	Geography	August 2014
Liu, Jun	Civil and Environmental Engineering	2015
Lynd, Jared	College of Law	
Manz, Katherine	Bredesen Center	May 2017
Mohler, Roderick	Civil and Environmental Engineering	
Murray, John	Electrical Engineering and Computer Science	Summer 2016
Rewcastle, Kenna	Ecology & Evolutionary Biology	
Simmons, William	Civil and Environmental Engineering	
Smith, Payton	Biosystems Engineering & Soil Science	
Sun, Jian	Civil and Environmental Engineering	2017
Tan, Jiani	Civil and Environmental Engineering	
Thompson, Jessica	Civil and Environmental Engineering	
Tirpak, Andrew	Civil and Environmental Engineering	
Tobin, Jacob	Electrical Engineering and Computer Science	Spring 2016
Torres, Tom	Sociology	
Veeneman, Andrew	Civil and Environmental Engineering	
Walton, Thomas	Civil and Environmental Engineering	
Woockman, Robert	Civil and Environmental Engineering	
Yang, Cheng-En	Civil and Environmental Engineering	
Yu, Ning	Center for Transportation Research	
Zhao, Ziliang	Geography	
Zhu, Xiufen	Civil and Environmental Engineering	2018
Post-Docs		
Njiojob, Costyl	Chemical Engineering	
Wang, Xin	Civil and Environmental Engineering	
Xu, Tingting	Center for Environmental Biotechnology	

Undergraduate Students Involved in ISSE Research

Undergraduate or Hourly	Department	Graduation Date
Bearden, Jordan	Retail, Hospitality, and Tourism	
Benton, Peggy	Retail, Hospitality, and Tourism	
Carnietto, Fabio	Civil and Environmental Engineering	
Cecil, Alisha	Center for Transportation Research	
Christian, Laurel	Civil and Environmental Engineering	Spring 2015
Hamm, Charles	Retail, Hospitality, and Tourism	
Kazmier, Isabella	Civil and Environmental Engineering	May 2015
Keyser, John	Civil and Environmental Engineering	
Lipman, Marcelle	Civil and Environmental Engineering	May 2015
Manka, Brandy	Civil and Environmental Engineering	Spring 2016
Myers, Kalie	Business Administration	
Roth, Mary	Civil and Environmental Engineering	
Szklarski, Colin	Civil and Environmental Engineering	May 2016
Todd, Blake	Center for Transportation Research	