sustainability science
FOR SOUND POLICY

institute for a secure and sustainable environment
A CENTER OF EXCELLENCE AT THE UNIVERSITY OF TENNESSEE




ISSE
INSTITUTE FOR A SECURE AND SUSTAINABLE ENVIRONMENT

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september 2009

THE UNIVERSITY of TENNESSEE

ISSE promotes development of policies, technologies, and educational programs that cut across multiple disciplines, engage the university's research faculty and staff, and grow in response to pressing environmental and security issues facing the state, the nation, and the globe.

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INSTITUTE FOR A SECURE AND SUSTAINABLE ENVIRONMENT

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sustainability science

FOR SOUND POLICY

ISSE, with its multidisciplinary staff, is uniquely situated at the crossroads of science and policy—realms that are, and always have been, inextricably linked. Indeed, scientific rigor and discovery guide and inform the formulation of effective public policy. ISSE's ever increasing depth in the sciences, in tandem with its continued emphasis on development of sustainable environmental policy, will greatly enhance the institute's ability to respond to environmental challenges currently confronting our state, nation, and globe.

sustainability science FOR SOUND POLICY

RANDALL GENTRY

Despite the global economic downturn and its impact on national and state budgets, ISSE has continued to develop, and even expand, its research portfolio, particularly in the growth areas of climate change, sustainable bioenergy production, enhanced carbon management, and hydrologic systems science.

Throughout the past year we have continued to bolster collaboration with colleagues at Oak Ridge National Laboratory (ORNL) and increase engagement of University of Tennessee (UT) researchers in climate modeling and assessment. We have also committed resources in support of the Department of Civil and Environmental Engineering's pursuit of a Governor's Chair in climate science and climate modeling.

ISSE's collaboration with scientists from the Chinese Academy of Sciences continues to evolve through the China-US Joint Research Center for Ecosystem and Environmental Change, which is housed at and administered by ISSE. In the process, we are sharing data and other resources with our Chinese colleagues, collaborating on international research proposals, and creating exchange programs that will allow scientists and students from the two nations to visit and contribute directly to the research efforts of the partnering organizations.

ISSE played a central role in organizing the second annual workshop of the China-US Joint Research Center, which convened in Beijing in fall 2008. The three-day workshop engaged more than 60 scientists and students from the two nations and welcomed several new partners from both the United States and China. You can access the 2008 workshop proceedings here: http://isse.utk.edu/jrceec/workshops/pdf/proceedings08.pdf

BY ISSE DIRECTOR
randall gentry

proposals and awards

ISSE's multidisciplinary staff continues to generate an increasing number of proposals in pursuit of funding opportunities, with increasing percentages garnering awards every year.

Faced with a generally flat funding environment created by the current global recession, ISSE has responded by focusing on larger interdisciplinary proposals.

Meanwhile, ISSE continues to support 22 students, representing hourly employees as well as graduate research assistants. Student involvement in ISSE projects also includes a substantial engagement of faculty across multiple UT departments and colleges.

ISSE has also welcomed two post-doctoral researchers, Shesh Raj Koirala and Ungtae Kim, who specialize in, among other areas, hydrologic modeling, contaminant transport, and impacts of climate change on water systems. They will contribute substantially to ISSE's established expertise in water-quality and water-quantity research.

return on investment

As in the past, ISSE has achieved a significant return on funds provided by the state of Tennessee. ISSE continues to use Center of Excellence funds strategically to expand its research enterprise in sustainability science for the betterment of citizens of Tennessee and the nation.

Indeed, our projects have, as the stories contained in this publication demonstrate, benefitted Tennessee citizens both directly and indirectly by improving efficiency of cleanup efforts on contaminated Department of Defense sites, assisting industry in creating cleaner consumer products, devising architectural models for next-generation sustainable homes, assisting citizen groups in restoring degraded urban waterways, helping the Southeast improve management of increasingly limited water resources, and developing new technologies that may one day improve the lives—and quality of life—for those suffering from diabetes and other endocrine disorders.

committed to sustainability, grounded in science

Many of ISSE's researchers have developed national reputations in environmental sustainability and have provided support for the development of energy and environmental policy in the state of Tennessee. ISSE researchers played key roles in drafting the Tennessee Solid Waste Management Act of 1991, which continues to guide Tennessee's solid-waste management policies, and Tennessee's Inter-basin Water Transfer Act of 2000, which requires new transfers of water from one river basin into another—particularly to out-of-state users—be approved by the Tennessee Department of Environment and Conservation.

Several of ISSE's specialized centers and subunits continue to shape and advance the policies and practices that contribute to improved air and water quality, energy conservation, community and economic development, environmental equity, historic preservation, increased adoption and availability of alternative fuels, sustainable production and end-of-life disposal of consumer products, and environmental education for the state's K-12 students.

While these policy efforts continue, science and technology have come to play an ever increasing role in ISSE's core research priorities, particularly among the institute's more recent initiatives. With this publication, we hope to tell that story through the presentation of a series of articles that showcases ISSE's expanding reliance on a range of sciences, including chemistry, hydrology, climatology, engineering, and modeling and other computational technologies.

ISSE, with its multidisciplinary staff, is uniquely situated at the crossroads of science and policy—realms that are, and always have been, inextricably linked. Indeed, scientific rigor and discovery guide and inform the formulation of effective public policy. We believe that ISSE's increasing depth in the sciences, in tandem with its continued emphasis on development of sustainable environmental policy, will greatly enhance the institute's ability to respond to environmental challenges currently confronting our state, nation, and globe.

Each article that follows presents an overview of a research project or projects as well as a discussion of the specific sciences and technologies that contribute to the project's execution.

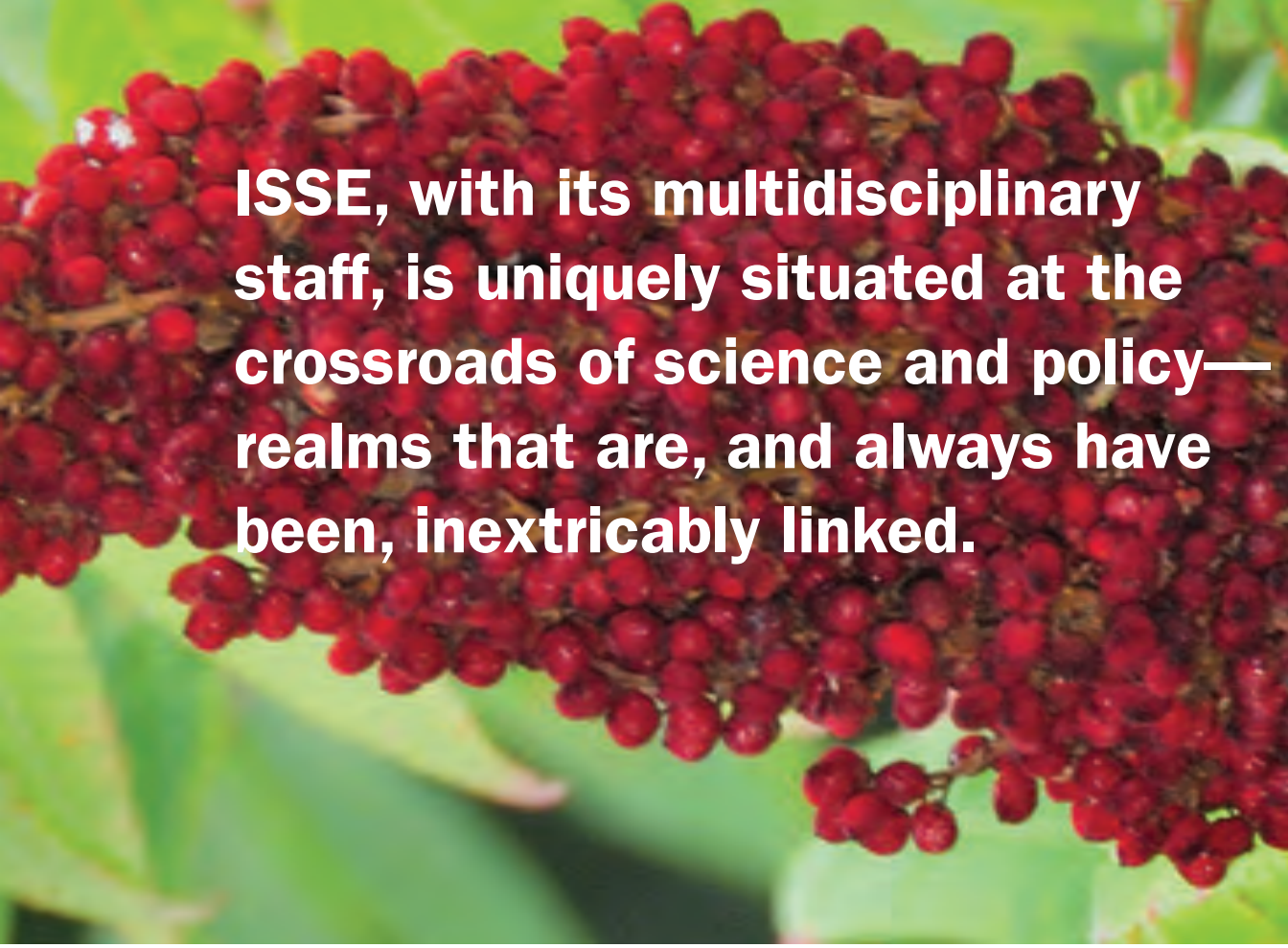
Beginning on page 11, "An Open Door to the Research Community" explores the wealth of technological resources that reside at ISSE's long-standing research partner, the Center for Environmental Biotechnology (CEB). "A Healthy Glow," which begins on page 17, takes a look at CEB's development of minute implantable biological-electronic systems that may one day maintain diabetics' glucose levels, monitor circulating thyroid hormones, destroy dangerous bacteria, and assess air quality aboard NASA's spacecraft.

Beginning on page 23, "Improving the Cost-Benefit Performance of Environmental Remediation Projects" examines an ISSE researcher's efforts to assess and enhance the efficiency and economy of various strategies to remediate decades-old contamination on US Department of Defense sites.

"The Story of Beaver Creek—from Ruin to Restoration" begins on page 29 and recounts the efforts of ISSE's Tennessee Water Resources Research Center and Center for Watershed Solutions to assist a group of engaged citizens in rescuing a suburban waterway from decades of neglect and abuse.

"The Gold Standard," beginning on page 37, examines ISSE's Center for Clean Products and its programs and projects that help government, corporations, and consumers identify more sustainable products and adopt greener purchasing patterns.

Beginning on page 45, "An International Response to Climate, Biofuels Challenges" explores the growing collaborative reach and focus of the China-US Joint Research Center for Ecosystem and Environmental Change. An accompanying photo essay, "A Journey Halfway around the World



ISSE, with its multidisciplinary staff, is uniquely situated at the crossroads of science and policy—realms that are, and always have been, inextricably linked.

Reveals Shared Concerns, Opportunities," presents images and reflections from a fall 2008 trip by ISSE researchers to the Chinese Academy of Sciences as well as to China's bustling urban centers and rural countryside.

"A New Spin on an Old Design Combines Preservation, Conservation," beginning on page 57, explores the Community Partnership Center's re-conceptualization of TVA's historic Norris House as the sustainable home for the 21st century. The accompanying story, "UT Team Claims Top Honors in EPA Sustainable Design Competition in DC," details student involvement in the project and the award of $75,000 from EPA to move the project from concept to actual construction.

"Underground Research," which begins on page 65, presents ISSE's efforts to study the fate and transport of colloids and contaminants such as pathogenic viruses and radionuclides in subsurface environments. The article also explores the value of ISSE's increasing scientific collaboration with Chinese scientists.

"A Regional Response to the Global Climate-change Challenge," which begins on page 71, addresses the role of ISSE and other partnering organizations at UT and ORNL in creating the Climate Change Initiative and shaping its research agenda. And "Sustaining the South's Overtaxed Water Resources," which starts on page 79, looks at my own research on the resilience of hydrologic systems and how that research can help us do a better job of managing and allocating limited water resources in our region. A related story, "From Clouds Come Rain—and Isotopes," which begins on page 83, traces two graduate students' study of the inter-relationship of rain and surface and groundwater in a Smoky Mountain stream.

Beginning on page 89, "Staff Citings" presents ISSE staff accomplishments for fiscal year 2008-09, including awards, appointments, presentations, and publications.

strategy for the future

Over the next several years ISSE will continue to nurture relationships with other UT academic departments and colleges and with ORNL, particularly in the areas of China-US collaboration, sustainable biofuels production, and computational climate modeling and science. The products of these research efforts will help spur economic growth, achieve increased national and international visibility for ISSE, and further reward Tennessee for its continuing investment in our research enterprise.

As always, I welcome comments and questions about our projects and programs and remain open to new opportunities for collaboration.

To learn more about ISSE, I invite you to visit our Web site: **isse.utk.edu**

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BY
elise leQuire

an open door
TO THE RESEARCH COMMUNITY

UT's Center for Environmental Biotechnology offers its interdisciplinary expertise and cutting-edge instrumentation across the campus, throughout the state, and around the world.

the project

In 1986, the US Department of Education provided $1 million in seed money for the University of Tennessee (UT) and Oak Ridge National Laboratory (ORNL) to establish a center where scientists could find new ways to use the emerging field of biotechnology to solve environmental problems. Since that original investment, UT's Center for Environmental Biotechnology (CEB) has garnered international attention as a leader in its field.

GARY SAYLER

"The idea behind CEB emerged from a perceived lag in how the advanced tools of molecular biology could be successfully applied to environmental research," says Gary Sayler, CEB's founding director and Beaman Distinguished Professor of Microbiology at UT. Since its inception, CEB has been closing that gap, attracting talented faculty and offering an array of sophisticated instrumentation to academic researchers from any department on campus.

For nearly two decades, CEB served as the technical arm of UT's Waste Management Research and Education Institute (WMREI). In 2006, WMREI was merged with other existing research organizations at UT to become the Institute for a Secure and Sustainable Environment (ISSE). CEB remains a primary ISSE research partner.

While CEB has a proven track record of securing funding from outside sources, the center uses its institutionally provided discretionary funds to initiate new research projects, provide support for faculty and students, and ensure continuity for long-term research projects.

JOHN SANSEVERINO

As an incentive to recruit top-flight scientists to affiliated academic departments, for example, CEB provides supplemental funds to new faculty start-up packages. "The salary is only part of the package necessary to attract and retain outstanding faculty," says John Sanseverino, CEB's managing director and a research associate professor director in UT's Department of Microbiology.

CEB also offers researchers relatively free access to a wide range of equipment that is not necessarily available in the academic departments. Moreover, through its institutional support, CEB finances the equipment's maintenance through vendor service contracts. "Service contracts to maintain equipment run to more than 10 percent of our budget each year," says Sanseverino, "and that takes institutional support."

CEB's facilities are also open to small startup companies moving basic research to real world applications. "The entrepreneurial spirit is strong in Tennessee, but there are very few places where someone can walk into a research facility and put their thoughts into development," says Sayler.

"CEB has branched out to be more than just a fundamental research organization, but also a technical core facility where entrepreneurs can spin their ideas into commercial applications."

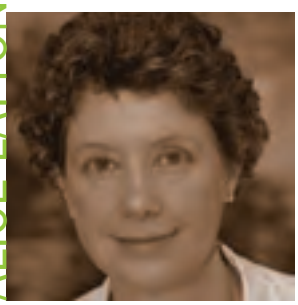
the science

Stock Creek flows into the Tennessee River near Knoxville. Designated by the US Environmental Protection Agency (EPA) as a 303(d) stream, it does not meet water quality standards for public uses such as recreation or drinking water because of bacterial contamination. Currently, EPA documents the presence of *E. coli* bacteria as an indication of fecal contamination.

Because of its genetic diversity and ability to propagate outside the digestive system, however, *E. coli* cannot be used to determine whether the contamination is from humans, livestock, or wildlife. Without a clear indication of the source, resource managers may have a difficult time controlling the contamination. Stock Creek is located in a rural environment where livestock drink from the creek, and there are also a number of failed or failing septic systems nearby.

Alice Layton, a research associate professor with CEB, has been performing a bit of high-tech sleuthing to pinpoint the origin of fecal contamination. She developed assays using real-time polymerase chain reaction (rt-PCR) to target Bacteroides, a genus of bacteria that is abundant in the digestive systems of all mammals and is host specific, so they can be used to "fingerprint" the animal of origin.

ALICE LAYTON



"This technique is superior because of the high concentration of Bacteroides and the ability to distinguish between human, bovine, and total Bacteroides to pinpoint the source: cattle in the creek, failing septic, or underground water sources," Layton says. "You can't do that with *E. coli*." The AllBac assay measures total Bacteroides present in humans, horses, and cattle, while BoBac is specific to cattle, and HuBac is specific to humans.

CEB has the equipment designed for measuring and working with DNA, particularly for Bacteroides assays. "This is not a piece of equipment most departments can afford or want to purchase," Layton says. It also requires a certain amount of training and experience to run the machinery and interpret the data. "Having this type of equipment allows us to interact with a lot of different groups."

Having developed the technique in the CEB laboratory, Layton and colleagues took the research to the field, or, rather, the creek. With support from the Tennessee Department of Environment and Conservation, Layton joined with an interdisciplinary team that included Larry McKay, Jones Professor of Hydrogeology in the Department of Earth and Planetary Sciences, and ISSE Director Randall Gentry, an associate professor in UT's Department of Civil and Environmental Engineering (CEE) whose research background is in hydrology.

Combining stream sampling in the field with groundwater hydrology and statistical modeling, and using Layton's assays, gives a clearer picture of the watershed and a better determination of whether fecal contamination is the result of failing septic systems, runoff phenomena, or from groundwater stored in the karstic aquifer.

"State regulators are excited to have this tool available for working in bacterially contaminated streams and coming up with a plan to delist them," says Gentry. Such plans might include implementing best management practices to exclude cattle from the creek or replacing failing septic tanks. In addition, the research has been cited as a useful scientific contribution to the field.

RANDALL GENTRY

"It has received numerous citations from top-tier journals," Gentry says. "Interdisciplinary research is exciting to people who do not stay highly focused within a myopic research area. These opportunities provide fertile ground for innovation, new ideas, and new science."

For more information, contact John Sanseverino at 865-974-8080, or email: jsansev@utk.edu.

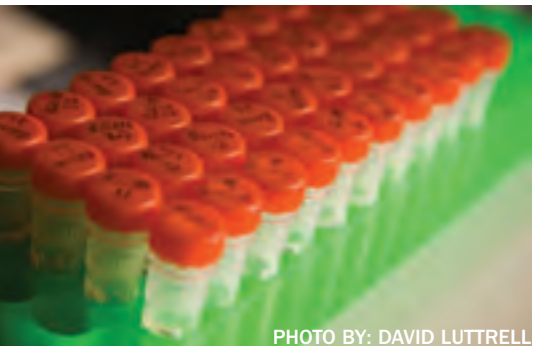


PHOTO BY: DAVID LUTTRELL

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PHOTO BY: DAVID LUTTRELL

from stock creek to bangladesh

LARRY MCKAY

Larry McKay, one of the collaborators on the Stock Creek project, embodies the multidisciplinary nature of research across the university. McKay, who is also the leader of ISSE's Water Resources Program, came to campus in 1993 with a background in hydrogeology. Specifically, McKay's research focused on how contaminants that are dissolved or suspended in a liquid travel through the fractured clay soils of glaciated terrain in Ontario.

McKay soon found that his expertise could be applied to the nonglaciated, fractured, clay-rich karst terrain of eastern Tennessee. "The soils are completely different in origin, but physically the fractured, clay-rich soils here behave similarly to those I was used to working in," says McKay.

The first application of his background expertise at UT was on contaminated sites at Oak Ridge National Laboratory. In the years since, his collaborations with CEB, ISSE, and CEE have guided research from contaminated watersheds in eastern Tennessee to a study, funded by the National Institutes of Health, of fecal contamination in wells in Bangladesh.

"In Bangladesh, we are studying fecal contamination in ponds, streams, and wells, using a variety of techniques we first developed for the Stock Creek project with Alice Layton, Randy Gentry, and CEE," says McKay. The Bangladesh project, which will end in 2010, is not just multidisciplinary, it's multi-institutional, with collaborators from Dhaka University in Bangladesh, Columbia University, Barnard College, and the University of North Carolina at Chapel Hill.

McKay's team also received a grant from the Department of Defense (DoD) to help devise a cleanup plan for a decommissioned Army ammunitions plant near the Tennessee River in Chattanooga. The Chattanooga-based Volunteer Army Ammunition Plant is the site of a new $1-billion Volkswagen plant scheduled to be completed in 2010 and to turn out its first car in 2011. The plant produced the explosive compound trinitrotoluene (TNT) during World War II.

Dinitrotoluene (DNT) is a precursor in the manufacturing process of TNT, and DNT turns out to be the bigger environmental hazard of the two. "TNT and DNT are both carcinogens, but because DNT is a liquid, it tends to penetrate deeper into the soil and can dissolve in groundwater," McKay says.

The goal of the project is to clean up the soil so that dissolved DNT doesn't contaminate wells or discharge into the river, which is about a mile away. "We are testing different types of chemical treatments to transform DNT and TNT into harmless compounds," McKay says. "One of the more promising treatments is the addition of sodium hydroxide (lye) to increase the pH of the soil."

At high pH, DNT and TNT are unstable and rapidly break down into harmless compounds. "What's tricky is that we are trying to do it in situ (in the ground), without excavating the soil, which is 20- to 50-feet thick and overlies highly permeable bedrock."

The Volunteer site project has also led to another large DoD contract through its environmental science and technology program. In collaboration with John Biggerstaff, a CEB research associate professor, and Melanie Mayes, a UT adjunct faculty member at ORNL, the research team is investigating processes that control movement of explosive residues in the soil. Developing a better understanding of these processes will aid in designing remediation plans for munitions testing ranges across the country.

The collaboration among different disciplines creates new opportunities for CEB staff and also for those in other departments. "I have dramatically expanded my work with CEB, ISSE, and CEE," says McKay. "Nowadays, if a project does not have a strong interdisciplinary focus, it is less likely to be funded."

Whether solving environmental problems close to home or working through international collaboration with scientists around the world, CEB has kept true to its original mission of training the next generation of environmental scientists and responding quickly to emerging environmental challenges.

BY
marshall brown

a healthy glow

CEB scientists are developing minute implantable biological-electronic systems that may one day maintain diabetics' glucose levels, monitor circulating thyroid hormones, destroy dangerous bacteria, and assess air quality aboard NASA's spacecraft.

the project

For diabetics, knowing the exact amount of glucose in the bloodstream is crucial. But the dreaded routine of drawing blood, testing glucose levels, and injecting insulin means the diabetic is tethered to a variety of intrusive devices. In addition to the discomfort and inconvenience caused by testing, maintenance of a stable blood glucose concentration is difficult to achieve by periodic insulin injections.

This means that for diabetics who inject insulin, blood glucose concentrations fluctuate between being too high or too low over the course of a day. After years of insulin therapy this variability in blood glucose may lead to further medical complications.

Steven Ripp and Jim Fleming, senior researchers at the University of Tennessee's (UT) Center for Environmental Biotechnology (CEB), hope to eliminate the need for needles and test kits by developing a small, implantable device that can detect glucose in the bloodstream and synthesize insulin only when needed by the body. CEB is a collaborative research partner of UT's Institute for a Secure and Sustainable Environment (ISSE).

Ripp and Fleming hope to eliminate the need for needles and test kits by developing a small, implantable device that can detect glucose in the bloodstream and synthesize insulin only when needed by the body.

the science

Ripp and Fleming's device combines biological and electronic components that sense the concentration of a target biomolecule in the bloodstream and then respond in a feedback-controlled fashion to regulate the concentration of that biomolecule. The sensor component is built around a living bioluminescent reporter, a genetically engineered human cell line that responds to the presence of a target substance—in this case, glucose—by emitting light.

These living cells will be attached to a tiny silicon chip that can be implanted in the bloodstream. The chip picks up the signal from the light-emitting organism and transmits the data to an onboard microprocessor, which will allow continuous, accurate monitoring of glucose levels.

For the device to function in the body, Ripp and Fleming have an important obstacle to overcome: while bioluminescent reporters made from bacteria are used to monitor a variety of environmental pollutants, the reporters, as they are now constructed, can't function in the human body.

higher order genes

"The bacteria survive, but the bioluminescent reaction doesn't function at body temperature," Ripp says. To surmount the hurdle, Ripp and Fleming hope to fuse bacterial genes with genes of a higher order found in plants, animals, and humans to produce a more robust organism that is also sensitive to the target substance. A two-year feasibility study is funded by the National Institutes of Health.

STEVE RIPP

Biosensors that respond to glucose by emitting light had been constructed previously, but they had to transmit the information to optical devices too large to implant in the human body. The new 5mm^2 biochip, developed by Michael Simpson at Oak Ridge National Laboratory, is about half the size of your little fingernail—small enough to be implanted in the body where it is in direct contact with the glucose in the bloodstream.

The device will be inexpensive to mass produce at around $10 apiece, and its demand for electricity is small, around 100 microwatts—about what it takes to power the light-emitting diode on your clock radio. If the first phase of the study is successful, a second phase will integrate circuitry of the biochip with an insulin-delivery system.

Miniaturization is only one challenge in creating an implantable device, however. Existing sensor technology uses genetically engineered mammalian cells containing a firefly protein, luciferase, and a separate chemical—luciferin—is added to the cells to promote luminescence.

"We're trying to get away from firefly luciferase because you have to add an additional chemical to get the desired response," Fleming says. That process entails extracting blood from the patient and adding an exogenous substrate that reacts to the presence of glucose, so the diabetic is still faced with needle pricks on a regular basis.

JAMES FLEMING

new light sources

Instead, the new bioluminescent reporter will create its own light-response reaction. The organism will be genetically altered in two steps to elicit this response. Dan Close, a graduate student funded by this project, will fuse the light genes—luxAB and luxCDE—from a highly luminescent, naturally occurring bacterium found in nematodes, *Photorhabdus luminescens*. These bacterial genes will then be spliced into a gene from eukaryotic cells, which are taken from higher organisms such as plants and animals.

The addition of the bacterial lux genes will theoretically allow the organism to respond to glucose by itself, without the need for destroying cells and adding an exogenous substance.

"It's a big jump from prokaryotic, or bacterial cells, to eukaryotic cells found in humans, animals, and plants because eukaryotic cells are more complicated," Fleming says. The modified organism also is coded to respond to the target, in this case glucose.

"These cells luminesce on their own. The more glucose, the more light," Ripp says.
This hybrid biosensor is also better adapted than previous reporters because it functions at 37 degrees C, normal human body temperature, while earlier versions can't survive above 30 degrees C. In addition, it will allow more accurate measurement of glucose than previous prototypes that used an enzyme in the bloodstream to detect glucose concentrations.

"That experimental approach worked perfectly in

research using dogs, which lack an enzyme inhibitor, but not with humans," Ripp says. Unlike earlier bacterial biosensors, this hybrid cell will be robust enough to survive in the human bloodstream and sensitive enough to respond to and report on the fluctuations of a living environment.

The applications for this new technology are not limited to glucose monitoring in diabetics. Ripp and Fleming submitted a proposal to the National Science Foundation in April to monitor and control thyroid hormone levels in the body.

"Imbalanced thyroid hormone contributes to a variety of physiological conditions, including metabolic changes, reduced cardiovascular fitness, bone density loss, and alterations in mental state," Fleming says.

An implantable device that could both monitor and control thyroid hormone concentrations would dramatically improve the lives of patients that suffer from this disorder. Beyond monitoring chemicals in the bloodstream, the CEB believes this technology can be applied to unwanted organic invaders.

"We are currently investigating the susceptibility of selected biological pathogens to bacteriophage infection," Ripp says.

Bacteriophage are naturally occurring viral organisms that feed entirely on bacteria. In nature, this process is invisible to the human eye. In the lab, however, CEB researchers are genetically engineering bacteriophage to emit light in the presence of targeted bacterial pathogens—in this case, *E. coli*.

The bioluminescent bioreporter, integrated into the bacteriophage, emits a light signal when the bacteriophage infects the target organism. The bacteriophage infection does more than trigger the light signal.

"Since the phage are infecting the pathogen, they're ultimately killing it as well," Ripp says. "So the phage itself could be sprayed onto an infected area to render the pathogens harmless."

from bloodstream to spaceship

There is also the possibility that NASA could use this bioreporter technology in long-term space missions "to monitor the air and water in the cabin so astronauts know if chemical contaminants are present and at what concentrations," Ripp says. "Astronauts could just toss them into air vents or water samples. The bioreporters thrive in an environment that ranges from room temperature, about 25 degrees C, to a hot summer day, about 40 degrees C. And you can freeze-dry them, and they last forever.

"Though this project is in its early stages, we have already successfully moved the lux gene from bacteria to the mammalian, or eukaryotic, cell lines," Ripp says. The project of integrating the biochip with a miniaturized, implantable insulin synthesis and delivery system is still several years away.

Nevertheless, the invention of a stand-alone sensor and transmitter in one unit opens the door to a variety of new applications that will move biosensor technology from the laboratory to the field.

For more information, contact Steven Ripp at 865-974-8080, or email: saripp@utk.edu.

BY
elise leQuire

improving the cost-benefit performance

OF ENVIRONMENTAL REMEDIATION PROJECTS

An ISSE researcher uses computer models to determine the most efficient and cheapest ways to clean up contaminated military sites.



the project

The Department of Defense (DoD) has identified more than 3,000 military sites where groundwater has been contaminated by dense non-aqueous phase liquids (DNAPL). These contaminants, primarily chlorinated solvents, have a higher specific gravity than water, are nearly insoluble, and can persist for very long periods in aquifers. Cleanup of these sites has proven problematic and expensive to achieve, with costs running into the tens of millions of dollars or more per site.

In 2008, DoD awarded a three-year, $1.3 million grant to Jack Parker, a research professor with the University of Tennessee's (UT) Institute for a Secure and Sustainable Environment (ISSE) and the Department of Civil and Environmental Engineering, and Peter Kitanidis, a professor with the Department of Civil and Environmental Engineering at Stanford University, to help guide cleanup decisions.


JACK PARKER

The researchers are developing and deploying computational methods to determine optimal management strategies for remediation and site characterization, taking into consideration uncertainty in predictions caused by limited data, complex site conditions, and model simplifications. "The core of the analysis involves a computer model to predict remediation performance given relevant physical, chemical, and microbiological properties of the site, design variables, and management decisions," Parker says. The prediction model is linked with computational tools that calibrate system properties to match all available quantitative and qualitative information from the site and, ultimately, that determine optimal management strategies that meet regulatory criteria with minimum possible cost.

Measurements of site properties, however, are expensive and yield relatively limited understanding of the system because of large spatial and temporal variability. The second phase of the project, field testing of the computer model, will be performed on contaminated sites at Hill Air Force Base (AFB) in Utah and Dover AFB in Delaware. The approach seeks to identify the least costly remediation plan that will meet regulatory cleanup criteria and base operational constraints. Because aquifer conditions are uncertain, predicted costs are uncertain.

“If Parker’s methodology achieves even modest cost reductions, cumulative savings to the federal government can run into the billions of dollars.”

“The optimal solution is taken to be the one that minimizes the probability-weighted cost of all possible simulated outcomes,” says Parker. “This approach should minimize total cleanup cost over the large portfolio of DoD sites.”

“If Parker’s methodology achieves even modest cost reductions, cumulative savings to the federal government can run into the billions of dollars,” says Randall Gentry, director of ISSE and associate professor in UT’s Department of Civil and Environmental Engineering.

Also involved in the project, which is funded through DoD’s Strategic Environmental Research and Development Program (SERDP), is Ungtae Kim, an ISSE research associate, Aleisa Bloom with the DoD Technical Support Group at Oak Ridge National Laboratory, and Kyle Gorden with the Hill AFB’s Environmental Restoration Branch.

the science

putting the model to the test

Since the 1940s, chlorinated solvents have leaked into groundwater at Dover and Hill AFBs. These solvents, which were primarily used for degreasing or stripping engines, are immiscible in water.

"If you put a chlorinated solvent in a glass of water, it sinks to the bottom," Parker says. If spilled into groundwater, this plume seeps down through the aquifer until it meets an impervious barrier. "It's spread all over the whole thickness of the aquifer." For that reason, it's nearly impossible to remediate using conventional pump-and-treat methods. Because of its low solubility in water, "you would be pumping water for hundreds of years," Parker says. At the other extreme is to let natural microbial organisms in the soil slowly decompose the solvents in the plume over time, a process termed natural attenuation. An alternative approach that the researchers are analyzing in the second phase of the project, enhanced attenuation, can speed that natural process along. Amendments such as emulsified vegetable oil are injected into the groundwater.

"These amendments modify the biogeochemistry of the environment below the surface," Parker says. In effect, the oil is a food source for the naturally occurring microbial population. The organisms don't directly utilize the chlorinated solvent but burn up oxygen, creating an anaerobic environment that indirectly facilitates decomposition of the solvents into less hazardous substances. "This is a relatively cheap technology proven to be effective at a lot of sites."

Another promising remedy the researchers are putting to the test with their computational tool is tackling contamination at its source by thermal treatment. Electrodes are thrust into the ground, electricity is pumped in to heat the soil to over 100 degrees C, and the chemicals are boiled off and captured in a vapor extraction system.

For more information, contact Jack Parker at 865-974-7718, or email jparker@utk.edu.

dealing with uncertainty in the field

Designing methodologies for remediation in the field, however, is fraught with unknowns: uncertainties about the actual distribution of the contaminants, the characteristics of the aquifer and the movement of the plume through it, and the cost of remediation efforts. In field trials, historical data from on-site sampling and other bits of information are fed into a fast-running field-scale model to produce a set of parameters that approximates true site conditions.

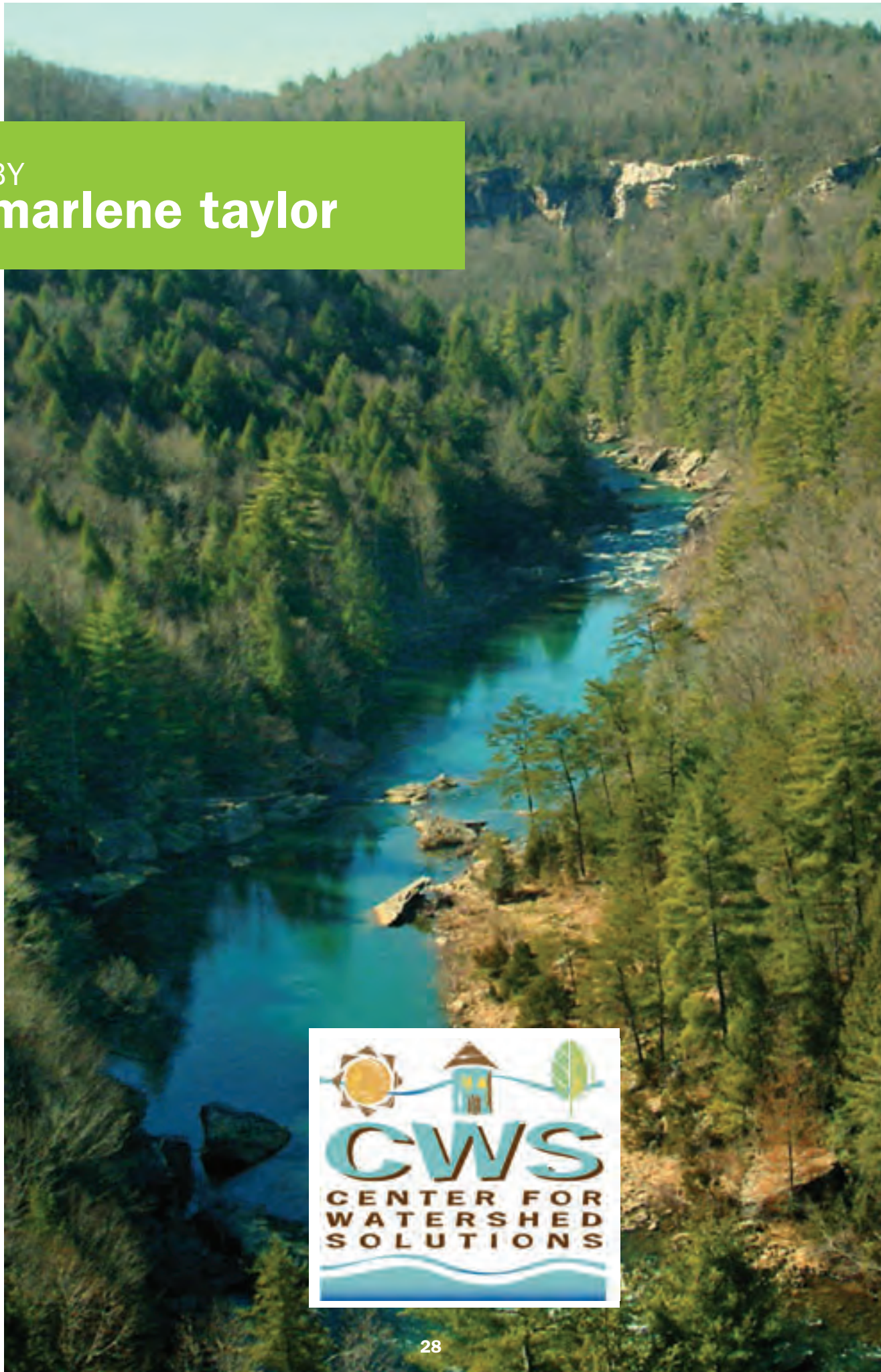
"Some of the parameters have small uncertainty, while others have huge uncertainties," Parker says. "We put in estimates and information and run the model repeatedly using an algorithm that compares predictions with current estimates."

This algorithm can be used to forecast the probability that any particular remediation design will meet the regulatory criteria while costing the least amount of money.

"If there is a remediation agreement with regulators to clean up at some compliance point below a certain value, we can quantify and predict the reliability of a certain procedure to succeed in achieving the cleanup goal," Parker says.

The comprehensive methodology and computational tools Parker and Kitanidis have developed are applicable to many other environmental and decision analysis problems, including Superfund sites identified by the Comprehensive Environmental Response, Compensation and Liability Act of 1980. "This approach can be used for any engineering or decision problem that can be quantified using standard methods for model calibration," Parker says.

BY
marlene taylor



the story of beaver creek

FROM RUIN TO RESTORATION

Citizens, with guidance from UT water resource specialists and other local, state, and federal agencies, have begun to reverse decades of abuse and neglect in restoring a degraded suburban stream.



the project

Good stories are meant to be shared. And the recently established Center for Watershed Solutions (CWS) is telling the story of the Beaver Creek watershed, which serves as a shining example for the rest of the state of how citizen-based efforts, assisted by University of Tennessee (UT) water resource specialists, can reverse decades of neglect.

It's about communities working together for a shared cause. It's about applying a range of technologies—everything from rain barrels to engineered devices for controlling erosion and restoring healthy stream banks. And ultimately, it's about tackling a problem that once seemed so large and complex that no one was quite sure where to begin.

Housed within the Tennessee Water Resources Research Center (TNWRRC), CWS is a partnership of UT's Institute for a Secure and Sustainable Environment (ISSE) and the Cumberland River Compact. CWS provides products, services, and support for organizations devoted to stream protection across Tennessee. More recently, CWS has begun to generate success stories from across the state.

The stories will be posted on the CWS Web site and distributed to regional media to provide guidance to other communities hoping to improve water quality in their rivers and streams. In selecting a story to begin the project, the CWS staff needed to look no further than their own backyards, where the Beaver Creek Task Force (BCTF) has, with the help of ISSE and other regional water-resource specialists, achieved tremendous strides in reversing years of neglect.

The 86-square-mile Beaver Creek watershed is home to 80,000 residents of the Knox County communities of Gibbs, Halls, Powell, Karns, and Solway. Drastically altered by rapid urbanization that occurred along the Emory Road corridor during the last several decades, the 44-mile-long Beaver Creek had been listed by the Tennessee Department of Environment and Conservation (TDEC) as "impaired."

From all directions, stormwater runoff carried sediment, fertilizers and, to a lesser degree, bacteria from agricultural waste—termed nonpoint source (NPS) pollutants—into Beaver Creek. Failing utility infrastructure allowed sewers to leak and overflow, which added the majority of bacteria—called point source pollutants. And what just 50 years earlier had been a home for migratory birds and a place of recreation for rural children was so severely degraded that the diversity of bird species dwindled and the creek was no long safe for play.

mutli-agency rescue plan

Facing the imminent death of the once-healthy waterway, in 1998, 20 local, state, and federal agencies—including the Knox County Stormwater Department, the US EPA, TDEC, the Tennessee Valley Authority (TVA), and TNWRRC—formed the Beaver Creek Task Force (BCTF). The task force sought to rescue the creek and its tributaries by educating developers as well as residents and implementing a range of restoration technologies. "We're telling the Beaver Creek story because the task force has years of effective work behind it," says Tim Gangaware, TNWRRC director and co-director of CWS. "The organizations have achieved amazing results in involving citizens, businesses, and others in their efforts."

But a project this size can't happen overnight. Unsound environmental practices can destroy a stream's viability in just a few years, while rehabilitating it can take decades. With that in mind, BCTF, with funding from the Tennessee Department of Agriculture Nonpoint Source Program, released the Watershed Action Plan in 2006 and the following year began work on the Restoration Implementation Plan. Roy Arthur, TNWRRC research associate and Knox County Watershed Coordinator, guided the effort. According to Arthur, the plan was crucial for developing a roadmap to guide restoration of the creek.

"We began looking at retrofits to improve failed or inadequate stormwater management systems on public and private property, securing easements on and donations of floodplain property, restoring wetlands, and stabilizing the stream bank," says Arthur, who manages the restoration project. "We also implemented simpler techniques, such as putting up fencing to keep cattle out."

The organizations quickly identified a welter of behaviors that were contributing to the creek's decline. Indeed, conventional construction methods can cause a rapid decline in water quality because the land, stripped of vegetation, is vulnerable to frequent flooding and easily erodes and is carried away by stormwater. As a result, sediment blankets the streambed and clouds the water, choking aquatic life and impairing the vision of fish trying to feed or mate.

Homes and commercial buildings landscaped with acres of nonnative grasses bring more problems for the stream in the form of fertilizers and other chemicals applied to keep lawns green. Rich in phosphates and nitrogen, fertilizers are washed into the stream, causing algae to grow aggressively. Decomposition of the algae depletes oxygen levels in the waterway.

The impacts to the stream are greatly compounded through the establishment of countless square miles of impervious surfaces like roofs, roads, and parking lots, which, with each rainfall, allow thousands of gallons of water to cascade off these surfaces and to carry whatever contaminants they contain into the stormwater systems.

the technologies

BCTF is a partnership of national, state, and regional agencies and organizations that uses a variety of disciplines, skills, and technologies to plan and carry out restorative efforts on impaired streams. The team of participating organizations provided plenty of guidance and help in addressing problems affecting Beaver Creek.

Between 1998 and 2000, Knox County reviewed and updated a flood study for Beaver Creek that had been performed by the Federal Emergency Management Agency in response to increasing development pressure and flooding. The follow-up Beaver Creek Watershed Stormwater Master Plan explored regulatory tools that could address future flooding and other environmental impacts. TVA joined BCTF in creating the Tennessee Growth Readiness Initiative, which educates the public, local officials, and other decision makers about NPS pollution and the impacts of land-use decisions on water quality. And TDEC, EPA, and the US Department of Agriculture all awarded funds to the restoration efforts.

The UT School of Architecture and Design worked with the task force to prepare a Green Infrastructure Plan, which identifies areas in the Beaver Creek watershed best suited for preservation and lands best suited for development.

a new way to build

Rapid development and nonsustainable construction practices have contributed to declining water quality in streams across the state, including Beaver Creek. In response, TNWRRC Director Tim Gangaware, ISSE Senior Research Associate Bruce Tschantz, and John Buchanan, an associate professor in UT's Department of Biosystems Engineering and Environmental Science, have worked with TDEC to develop training programs on erosion prevention and sediment control for the construction industry.

Tennessee Erosion Prevention and Sediment Control (TNEPSC) Level 1 is the fundamental course geared at on-site inspectors who are responsible for inspecting the silt fences used to control sediment runoff and maintaining the on-the-ground best management practices (BMPs).

The workers on each site must be sufficiently trained to keep their construction area in compliance with that site's Stormwater Pollution Prevention Plan.

"In the course, we're telling students what's expected of them, how to properly install and

sustainable yards

Because the behavior of watershed residents—including the landscaping schemes they implement—affects water quality, TNWRRC, BCTF, TVA, and UT Extension created the Tennessee Yards & Neighborhoods (TYN) program to educate homeowners on sustainable ways to plant and maintain their yards.

American homeowners have long aspired to lush, green yards, but verdant lawns—particularly those sown with nonnative grasses—require periodic fertilization, frequent irrigation, occasional herbicide application, and seemingly endless mowing. TYN offers them a range of sustainable alternatives.

"Through the TYN program, we provide alternative landscaping options to residents in an urban setting and arm them with the information and know-how they need to change the old patterns," says TNWRRC Senior Research Associate Ruth Anne Hanahan. "Once people understand that they can help stop water pollution while enjoying a yard designed for their needs and one that requires less work, they're all for it."

TYN encourages cultivation of native, deep-rooted garden plants that need less water and allow rainwater to filter slowly down into the water table. The program encourages the use of rain barrels that collect run-off from roofs, which is then used for irrigating ornamental and vegetable gardens. These low-tech but effective devices cut water bills and reduce runoff that can total many thousands of gallons for an average Knox County roof—water that would otherwise enter stormwater systems.

Strategically placed rain gardens that catch runoff before it hits the streets and storm drains also achieve significant reductions in stormwater runoff while enhancing a home's curb appeal.

After an initial investment of labor and money, these environmentally sustainable landscaping practices reap savings in maintenance time as well as expenditures on water for irrigation, gasoline for mowers, and fertilizers and herbicides required to keep traditional lawns green and growing.

maintain sediment controls, and what to do if those controls don't work," Gangaware says.

Topics covered include the impact of erosion on Tennessee's natural resources, the role of state agencies and local officials involved with erosion and sediment control and how they interact, the erosion process and hydrologic cycle, and the most effective vegetative and structural erosion and sediment controls.

BMPs run the gamut from silt fences to buffer strips to mattings to sediment ponds.

"No one BMP will address all problems," Gangaware says. "The course preaches that multiple BMPs in the right places are necessary to keep eroded material from leaving the site."

The Level 1 course, launched across the state in 2002, is obligatory for anyone inspecting construction sites.

The TNEPSC Level 2 course, launched in 2003, is intended for the engineers who design Stormwater Pollution Prevention Plans. According to Gangaware, those enrolled in the Level 2 course are essentially "taking a 16-week graduate course in stormwater hydrology in two days."

telltale aquatic species

Ask any angler which stream characteristic makes for the best fishing and the answer most likely will be "clean water." Aquatic biologists would no doubt agree. Fish rely on certain families of insects that are sensitive to pollutants; if the insects can't survive, neither can the fish.

State biologists have been relying on insect populations for more than 20 years to assess a stream's water quality. Termed benthic studies, this science looks at those insects and other invertebrates that inhabit the benthic, or bottom, layer of a stream. Caddisflies, mayflies, stoneflies and dobson flies—all of which spend their larval stages in the water—are just a few examples of the myriad aquatic invertebrates that create a healthy stream ecosystem by consuming organic materials and serving as prime food for fish. "Biology is the canary in the stream," says Ganagware. "It really tells us the quality of a stream as accurately as any other method of monitoring."

Carefully lifting up stone after stone to find bland-colored, flattened creatures no more than a half-inch long may not be everybody's idea of a good time, but, for an aquatic biologist, it can be a treasure hunt. The increasing presence, diversity, and quantity of these tiny indicators—found in abundance in unpolluted water with plenty of oxygen—confirm that a stream is returning to health.

As important to stream health as a thriving population of aquatic species is a stable stream bank. To enhance stream bank stabilization along Beaver Creek, TNWRRC and affiliate organizations rely on a combination of Mother Nature's healing processes and tried-and-true soil bioengineering techniques. In other cases, it has been necessary to apply techniques that use plant materials that are engineered to withstand the water's erosive forces until the root systems of installed live plants have had time to take hold.

One such technique uses rolls of coconut fibers—20 feet wide and 12 to 20 inches long—that are stacked in a stair-step fashion from the edge of the streambed to the top of the bank. Willow and dogwood branches, which root easily, are then tucked between the rolls to provide new growth along the water's edge.

Brush mattressing involves wiring together dogwood and willow branches and staking them to a bank in mat-like fashion to stop erosion. Revetments anchor together cedar trees laid trunk to treetop along the edge of a streambank. New vegetation grows as the cedars drop seeds.

For fascines, branches are bundled, laid in a trench at the edge of a streambed, and covered with soil. Fascines protect banks from washout and seepage, and the branches eventually sprout. Live stakes are

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made out of live branches and usually are two to three inches in diameter. They can be hammered directly into a streambed or bank to stop erosion and provide new growth.

In his work on Beaver Creek, UT hydrologist and civil engineer John Schwartz relies on innovative—and cost effective—tools to modify sections of the streambank and alter the water's flow. By putting an uprooted tree into the creek, Schwartz creates a makeshift "root wall" against the bank. The tree's roots create riffles and pools that provide diverse habitats for aquatic life. At the same time, these natural devices can catch and hold sediment, providing a foothold for aquatic plants like sedge and rush.

Storm water retrofitting is another engineering approach that addresses antiquated, poorly-functioning stormwater-management systems. Many of the subdivisions in the Beaver Creek watershed were built before today's stricter guidelines that require 80 percent of the sediment in runoff be removed from stormwater before it's released into the system.

"In the past, stormwater was managed for quantity, not quality, to reduce flooding," Gangaware says. "It would just be captured in retention ponds and released 24 hours later, but that wasn't addressing the water-quality issue. We're looking at a new approach that retrofits some of those facilities to get that 80-percent removal efficiency."

Most of the existing retention pools that hold stormwater were not installed properly or they are completely filled with sediment. In some cases, total redesign of the retention ponds may be required. In other cases, yard-by-yard techniques such as those encouraged through Tennessee Yards & Neighborhoods are also effective and much less expensive than installing new engineered solutions.

senior research associate
BRUCE TSCHANTZ

To learn more about the Tennessee Water Resources Research Center, contact Tim Gangaware at 865-974-4777 or email: gangwrrc@utk.edu.

To learn more about the Center for Watershed Solutions, contact co-directors, Tim Gangaware (gangwrrc@utk.edu) and Margo Farnsworth (screendoor@bigfoot.com).

Visit the Tennessee Yards & Neighborhoods Web site: tnyardsandneighborhoods.tennessee.edu/.

BY
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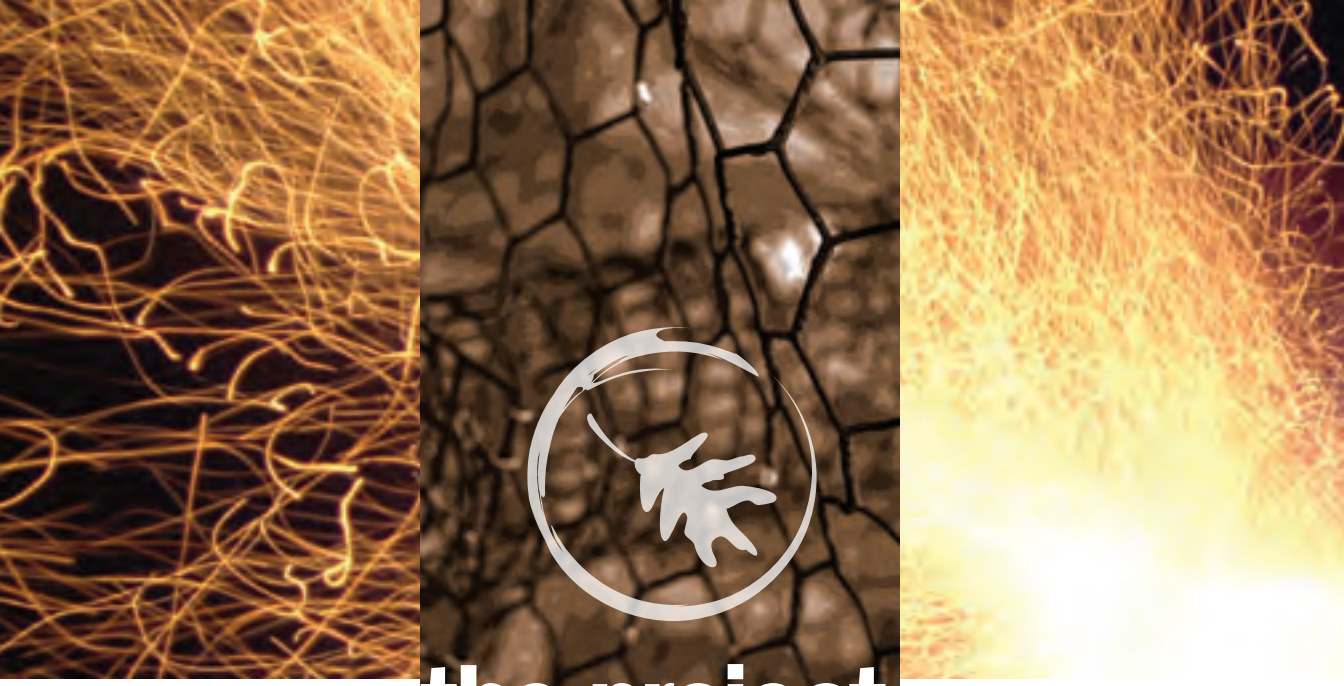
the gold standard

ISSE's Center for Clean Products helps government, corporations, and consumers raise the bar for environmental leadership.



the project

The Institute for a Secure and Sustainable Environment's Center for Clean Products (CCP) continues to live up to its name, working hand in hand with governmental and corporate partners to quantify the terms green and clean. It's not an easy task. A simple life-cycle analysis of any particular item involves computing dozens or hundreds of pieces of data, from the initial process of creating or mining the materials that go into a product, to its final disassembly and disposal.

Since CCP first began analyzing data in 1992 with an aim toward guiding consumer choices, government and private corporations have gradually come to embrace the greening of the marketplace. "Our research opportunities have really been booming lately," says Catherine A. Wilt, CCP's director of policy. "The business and regulatory climate have finally caught up with our original mission and vision for our research."

The Electronics Environmental Benefits Calculator (EEBC) is a good example. Under a cooperative agreement with the US Environmental Protection Agency (EPA) and support from environmental and technical consultants Abt Associates and Dillon Environmental Associates, CCP has led the development of this calculator, available online in Excel format, to assist institutional purchasers in assessing the environmental and economic benefits of electronic equipment. Using metrics such as reductions in toxic materials and air emissions and savings in energy and water usage, the tool gives purchasers meaningful information about the tradeoffs involved in their choices. (You can download the calculator from the CCP Web site: http://isse.utk.edu/ccp/projects/benefitscalculator/elecbenecalc.html).

EEBC also helps federal agencies, which spend nearly $70 billion annually on information technology products and services, meet the Federal Electronics Challenge (FEC) program's goal of reducing the environmental impact of these purchases. The US Federal Acquisition Regulation, for example, requires that 95 percent of the computers, televisions, and mobile phones purchased by federal agencies be EPEAT-registered. EPEAT, the Electronic Product Environmental Assessment Tool, rates electronics on their overall environmental impact and is aimed primarily at large-volume purchasers such as corporations and federal agencies. CCP is managing the development process of four new environmental standards for EPEAT.

Information from EPEAT and the EEBC tool can help purchasers meet increasingly rigorous federal environmental standards.

"CCP looks for ways to emphasize strong policy and regulatory guidance within the technical analyses we perform," says Wilt. "Environmental benefits are stronger when research and policy work hand in

hand as opposed to being in reaction to each other." In the first phase of the EPEAT project, gold, silver, and bronze ratings were assigned to desktop and notebook computers based on a number of environmental and economic criteria, including energy usage, the presence of toxic materials, and the ease of breaking down and recycling components at the end of the product's life. CCP is currently expanding EPEAT's scope to include additional electronic products such as televisions and imaging devices.

CCP also has a robust history of helping to develop environmental and human health standards, working with organizations such as EcoLogo and Green Seal. Most recently, CCP embarked on a new project to create clear criteria for children's toys that must be met before the products can be marketed as being green or environmentally improved. (See "It's Not Child's Play" below.)

"Without the scientific rigor underlying the environmental criteria developed for a standard, you don't wind up with a strong environmental leadership standard," says Wilt, who has been recognized nationally by *Waste & Recycling News* as one of "25 Influential Women in Environmental Management" who have worked to eliminate gender barriers in their field. The March 9, 2009, issue cited Wilt's contributions in coordinating the National Electronic Product Stewardship Initiative and the industry-government Carpet America Recovery Effort. Wilt was also recognized at the UT Chancellor's Honor's Banquet for Extraordinary Community Service in April 2009.

"Environmental standards work within the current marketplace for a variety of products," says Wilt, "whether it's environmentally preferable electronics, green cleaning services, or improved toys."

it's not child's play
ENVIRONMENTAL STANDARDS FOR TOYS

In 2009, the Center for Clean Products was invited by EcoLogo to lead the development of a national green product standard for toys. EcoLogo is a North American, multi-stakeholder, third-party ecolabeling program that provides certification of environmentally preferable products.

"Retailers with large markets for toys, including Wal-Mart, Target, and FAO Schwartz, are participating in the effort to develop clear criteria for children's toys that must be met before they can claim to be 'green' or environmentally improved," says Wilt, who leads the project.

Establishing green product standards for toys will allow purchasers to consider the environmental and human health impacts of the toys they buy for their children and grandchildren, and not just the electronic gadgets they buy for themselves. (For information on the EcoLogo program, visit the Web site: http://www.terrachoice-certified.com/en/index.asp.)

~ elise lequire

the technologies

back to the future

In the 1930s, Tennessee Valley Authority (TVA) chairman Arthur Morgan had a dream, one that was truly visionary for a time when the term "sustainable design" had yet to be coined. TVA was building housing for workers constructing the Norris Dam on the Cinch River. For Morgan, this was more than a construction project. His vision included homes that were designed and built to be energy efficient at a time when electrification had yet to reach many rural areas of the South. The design concept also created walkable communities and used local building materials that blended in with the natural surroundings.

On the occasion of the 75th anniversary of historic Norris, Tennessee, a team of UT students and faculty has revived the dream. Undergraduate and graduate students in planning and architecture recently garnered top honors in a national competition sponsored by EPA with their concept, The New Norris House: A Sustainable Home for the 21st Century.

"The idea was to create a 21st century green Norris house suitable for infill in a historic community," says Wilt, who assisted students in the basics of green building materials and community design. Tim Ezzell, director of ISSE's Community Partnership Center and the principal investigator on the project, and Tricia Stuth, assistant professor in UT's College of Architecture and Design, served as faculty mentors to the students.

The team won the first leg of the competition, sponsored by EPA's People, Prosperity and the Planet (P-3) Student Design Competition, earning $10,000 to create an abstract scale model of the house. TVA provided additional support. In April 2009, the students and faculty won a $75,000 grant to build the house on a site in the historic Norris community.

The design, which incorporates natural ventilation, a solar-powered hot-water heater, a high-efficiency heat pump, and a system for collecting and storing rainwater, meets the standards of the US Green Building Council's Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND). The demonstration home, which will serve as an educational and research tool for architects and planners, will sustain the original vision of the historic Norris community well into the 21st century.

(For more information on the New Norris House, see "A New Spin on an Old Design Combines Preservation, Conservation" on page 57.)

"PVC is cheap, but the regional impact is huge," says Geibig. "Vinyl is manufactured in a segment of Louisiana that has been dubbed 'Cancer Alley'."

building for the future:
GULF COAST RESTORATION

CCP is currently applying its expertise in environmental assessment to reconstruction of the Gulf Coast after Hurricane Katrina. With a three-year, nearly $300,000 grant from EPA, CCP is working with the Healthy Building Network and modular home manufacturers Clayton Homes and Unity Homes Modular to test sustainable building materials and practices in the fabrication of modular housing and to construct a model home in the Gulf Coast region.

The first step was to compile a set of materials used in traditional modular home building and to generate a list of environmentally preferable materials.

"Clayton Homes provided us information on the base materials with which modular homes are built," says Jack R. Geibig, CCP's director. The second phase is to develop and publish a methodology for evaluating the information and making it transferable to other home builders and industries. The methodology is based on the Pharos Project model, the leading consumer-oriented materials evaluation tool. "There is another wrinkle in this project," says Geibig, a team member of the Pharos Project. Modular homes are considered affordable, and many environmentally preferable materials are more expensive. (For more information on the Pharos Project, see "Build it Green" on page 43.) "We factored in the cost of the materials to expand the dynamics of the Pharos tool," says Geibig, who hopes to gain EPA support to perform long-term monitoring of indoor air quality in comparison to that of traditional modular homes.

Aside from the materials themselves, other factors include the environmental and occupational health impacts during the construction process. Modular homes are by definition created in a manufacturing environment, where exposure to toxic materials may be more concentrated than in construction of houses on site. Furthermore, when comparing the use of a cheap, long-lasting material such as polyvinyl chloride (PVC) to traditional materials such as wood, impacts from the production of a material may be an important factor.

"PVC is cheap, but the regional impact is huge," says Geibig. "Vinyl is manufactured in a segment of Louisiana that has been dubbed 'Cancer Alley'."

Unity Homes, which built the model home in Gulfport, Mississippi, on the Gulf Coast, is also constructing a manufacturing facility to produce "healthy, high-quality, energy-efficient, and affordable homes while stimulating local and regional economic growth in the hurricane-ravaged Gulf of Mexico through long-term job training and employment opportunities," according to the company's Web site.

This project is one of several in which CCP has taken its research from the drawing board to the real world. "Someone is living in the model home right now," Geibig says.

how does natural stone stack up?

The Natural Stone Council (NSC) is a group of trade associations and corporations in the natural stone industry that was formed to address issues common to all industry members and ultimately promote the use of natural stone. Since 2007, the NSC Sustainability Committee has partnered with CCP to explore the environmental impacts of natural stone products.

"The NSC wanted to bring stone into the green building arena but wasn't sure how to accomplish that. That's where we came in," says Amanda Pike, a CCP research associate.

In summer 2007, CCP researchers visited nearly 15 facilities across the country that quarry and process a variety of natural stone, particularly granite, limestone, marble, and sandstone. Using the information gleaned from these visits and from consultations with industry leaders, the team created a data-collection tool that was sent to quarries and processing facilities across North America. The information has helped identify industry best practices and develop stone fact sheets and is now being used in a life-cycle assessment of stone cladding.

"Life-cycle assessment (LCA) is a telling analysis when used appropriately," says Pike. "The methodology takes a holistic approach to evaluating environmental impacts by including all stages in a product's lifetime, from raw material extraction to the end of its useful life." The study also includes LCAs of alternate cladding products such as brick, aluminum, and precast concrete.

"Comparing the environmental profile of stone veneer to those of its competitors will determine natural stone's status as a green building material in cladding applications," says Pike.

CCP is also taking the message about the proper use of LCA on the road, using the stone industry work as a prime example. In April 2009, Geibig presented an educational seminar at the American Institute of Architects' national convention in San Francisco titled "The Use of Life-cycle Inventory Data in Materials Selection: A Case Study of the Natural Stone Industry." Geibig and Pike will offer a similar presentation in November 2009 at the GreenBuild International Expo, the world's premier green-building conference.

Best practices and case studies, in addition to life-cycle inventories and fact sheets for granite, limestone, sandstone, and slate, are being posted on CCP's Web site as they are produced and also are accessible on the Natural Stone Council's Web site. This collaborative effort of NSC and CCP to characterize and compare the environmental profile of stone is the most comprehensive study to date of the natural stone industry.

For more information, contact Catherine Wilt, 865-974-1915, or email: catwilt@utk.edu; or Jack Geibig, 865-974-6513, or email: jgeibig@utk.edu. Visit the CCP Web site: http://isse.utk.edu/ccp/.

center for clean products

director JACK GEIBIG

policy director CATHERINE WILT

research associate AMANDA PIKE

build it green

To assist consumers, building contractors, and purchasing agents in their decision making, the Center for Clean Products (CCP) joined an international partnership to improve the selection process for sustainable construction and building materials.

Announced in November 2006, Pharos is an evaluation tool that assesses building materials for their life-cycle environmental and human-health impacts. The tool further evaluates the social and economic impacts associated with raw material sourcing, manufacture, and delivery of construction materials.

Pharos product evaluations communicate to consumers the key human-health and environmental sustainability indicators associated with a product's manufacture, such as use of renewable materials, embodied energy, or toxic content. Other categories rank corporate practices, occupational and consumer safety, stakeholder equality, and other socio-economic criteria, all of which, says CCP Director Jack R. Geibig, "will change how consumers think about materials."

For retail consumers, evaluations are printed on a label that's attached to finished products, similar to nutritional labels on foods. For purchasing agents and contractors, the Pharos evaluation is included along with marketing literature and product information. These data are also accessible from the searchable Pharos Web site (http://www.pharoslens.net/).

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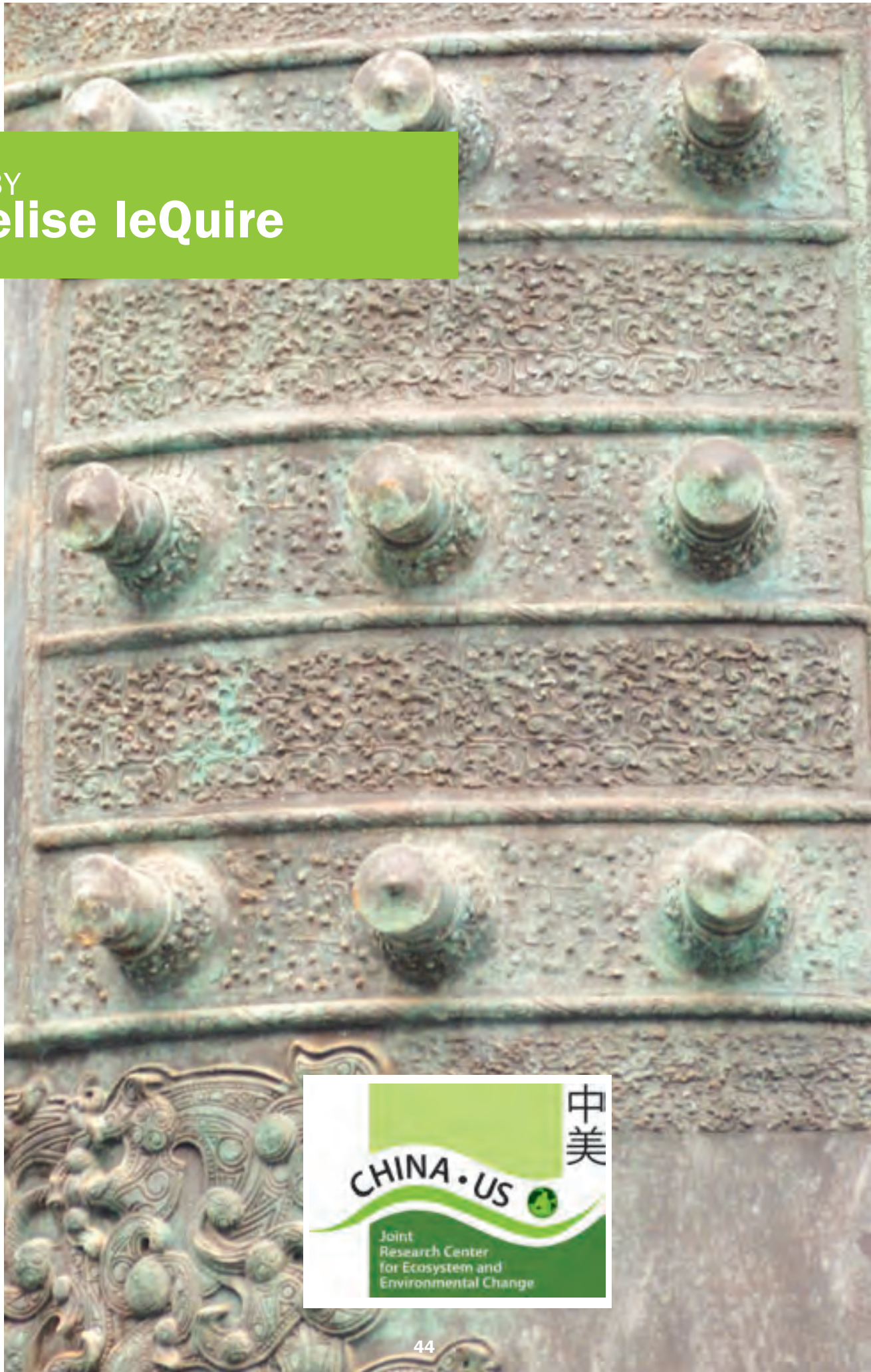


an international response to climate, BIOFUELS CHALLENGES

Chinese and US scientists continue to build on an established collaborative framework for addressing two of the more pressing issues facing the globe: climate change and sustainable production of biofuels.

The China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC) was launched in July 2006 by scientists from the University of Tennessee (UT) and Oak Ridge National Laboratory (ORNL) and researchers from the Chinese Academy of Sciences (CAS).

The center, which is housed and administered by UT's Institute for a Secure and Sustainable Environment (ISSE) and occupies research facilities at UT/ORNL and CAS, addresses the combined effects of climate change and human activities on regional and global ecosystems and explores technologies for restoration of degraded environments.

The center organizes annual workshops, held reciprocally in China and the United States. The first workshop was held September 11-13, 2007, at UT Knoxville. The 2008 workshop, Bioenergy Consequences for Global Environmental Change, was held October 15-17 in Beijing and was hosted by CAS.

This second annual workshop further cemented the ongoing collaboration between Chinese and American colleagues. The third annual workshop will be held in Oak Ridge, Tennessee, November 11-13, 2009, to address the "Climate-Energy Nexus" and to explore international collaboration under the sponsorship of the US Department of Energy and the National Science Foundation.

shared emphasis on climate

On July 29, 2009, the governments of China and the United States signed a Memorandum of Understanding (MOU) to Enhance Cooperation on Climate Change, Energy, and Environment. One of the stated goals of the MOU is to promote "joint research, development, deployment, and transfer…of climate friendly technologies."

"This MOU will help solidify a number of China-US cooperative agreements, including international efforts such as the China-US Joint Research Center," says Jie (Joe) Zhuang, coordinator of the joint center and an ISSE research director.

JOE ZHUANG

THE CENTER'S PARTNERS:

- UT/ORNL Joint Institute for Biological Sciences
- ISSE, UT
- Institute of Geographic Science and Natural Resources Research, CAS
- Research Center for Eco-Environmental Sciences, CAS
- Center for the Environment, Purdue University
- University of Science and Technology of China.
- Center for Environmental Biotechnology, UT



the project

On a global scale, China and the United States are considered the world's greatest energy users, consuming more of the Earth's natural resources than other countries and producing the lion's share of carbon emissions.

"We are looking at bioenergy technologies as a way to break the input from fossil (carbon) energy systems and move towards a strategy of recycling carbon dioxide directly from the atmosphere for production of biofuels," said Gary Sayler, director of the UT-ORNL Joint Institute for Biological Sciences and UT's Center for Environmental Biotechnology. "Bioenergy and biofuels alone cannot solve all our problems, but they may give us more time to solve other problems with new technologies to capture and store carbon or usher in other renewable energy sources so that we can move forward in the future."


GARY SAYLER

Sayler was a keynote speaker at the second annual China-US Joint Research Center workshop, which was supported by the US National Science Foundation, the Bureau of International Cooperation (CAS), the National Natural Science Foundation of China, and the Institute of Geographic Sciences and Natural Resources Research (CAS).

"Together, all our partners are setting an example for international collaboration to solve some of the world's most pressing energy issues, and to do so based on a firm foundation of sound science and in a spirit of cooperation and friendship," says Sayler. More than 80 participants attended the workshop, which featured six keynote and 20 contributing speakers and included 26 scientists and program leaders from the United States.

The workshop had five objectives: to evaluate the potential for carbon sequestration through bioenergy production, to address the role of biomass management in protecting eco-environmental systems, to explore bioenergy strategies for incorporating social and economic issues into natural resources management, to develop a framework for large-scale China-US joint research on the sustainability and security of bioenergy production, and to establish a mechanism to engage students and young scientists in bioenergy-based eco-environmental and engineering research. "This next generation of scientists is crucial to the long-term success of the China-US research collaboration on renewable energy and climate," says Zhuang.

the science

Researchers in China and the United States alike agree on one basic issue: grain-based biomass sources such as corn for ethanol are not a long-term, sustainable replacement for the finite fossil fuels that have driven economic development in the past. China, for example, with limited agricultural lands per capita, must first feed its people. "In 2008 a decision was made to shut down ethanol production facilities and encourage only non-grain based ethanol production," says Jinghua Cao, deputy director general of the CAS Bureau of International Cooperation and a keynote speaker at the workshop. "In the United States, ethanol plants now produce about as much ethanol as they ever will from corn and other grains," says Sayler. Instead, the world will need to turn to bioenergy from biomass, particularly cellulosic biomass, for renewable fuels.

switchgrass

A major hurdle to creating energy from biofuels feedstock is the recalcitrance of the cell walls to processing. Efforts are underway at the US Department of Energy's BioEnergy Science Center (BESC), managed by UT and ORNL, to genetically improve switchgrass, a wild perennial grass native to North America, to make it less resistant to extraction of sugars from which fuels and other bioproducts are produced.

"The genomics revolution is taking over switchgrass, and we are now having its genome sequenced," says C. Neal Stewart, Jr., a professor and Racheff Chair of Excellence in Plant Molecular Genetics in UT's Department of Plant Sciences. Genomics research will also lead to improvements in crop yield per acre and the plant's ability to produce roots that can store more carbon underground. "Many genes have been identified to enable carbon sequestration," Stewart says.

The state of Tennessee is already moving forward with a complete vision for rural economic development that couples agricultural production of energy biomass crops to regionally and locally located processing facilities, Sayler says. It remains to be seen, however, whether farmers will readily make the transition from agricultural production of conventional food and feed crops.

"When we think about whether farmers will embrace producing switchgrass or other energy crops, an understanding of economics is important," says ISSE Research Leader Mary English, "but social and psychological factors must be taken into account as well."

the carbon cycle

Accelerated climate change driven by greenhouse gas accumulation in the atmosphere is the result of an imbalance between anthropogenic emissions of carbon and the natural cycling of carbon through ecosystems.

"If we continue to explore the use of bioenergy as a means to mitigate or replace fossil-fuel derived carbon-dioxide emissions, we will benefit by emphasizing the use of labile biomass components while leaving carbon destined for soil sequestration in an undisturbed condition," says Paul J. Hanson, a distinguished scientist with the Environmental Sciences Division at ORNL.

Hanson and colleagues in the Ecosystem Science Group are using isotopic tracers to study the fate and accumulation of carbon within organic and mineral soils of eastern deciduous forests of the United States.

"Fundamental information on the carbon cycles of both natural and managed ecosystems is needed to determine the fraction of the Earth's carbon cycle that might be sequestered within global ecosystems for the management of anthropogenic emissions," Hanson says.

water: a limiting factor

A critical limitation on the production of any crop, whether for biofuels feedstock or food, is water, another finite resource that is increasingly strained on a global basis. In areas where natural rainfall or surface water is scarce, irrigation can take a toll on groundwater resources.

RANDALL GENTRY

"As we begin to change the vegetative patterns in a particular basin, we affect natural recharge and replenishment to the surface water tables and also the deeper aquifers," says Randall Gentry, director of ISSE and an associate professor in UT's Department of Civil and Environmental Engineering.

Gentry has used isotopic tracers to understand hydrologic behavior and sustainability at a fundamental scale in the Ramsey Prong Basin in Great Smoky Mountains National Park.

"This work is just one example of how hydrologic tracers and geochemistry can be used to assess surface water and groundwater interactions to understand ecosystem sustainability," Gentry says. "The long-term sustainability issue is to ensure the availability of drinking water resources."

For more information on the China-US Joint Research Center, contact Jie (Joe) Zhuang, 865-974-1325, or email: jzhuang@utk.edu.

a journey halfway around the world REVEALS SHARED CONCERNS, OPPORTUNITIES

ARTICLE BY
randall gentry

PHOTOS BY
david brill

In October 2008, I was among a group of US scientists who traveled to China to participate in the conference "Bioenergy Consequences for Global Environmental Change," which was hosted by the Chinese Academy of Sciences in Beijing.

Among our US contingent were researchers from UT, Oak Ridge National Laboratory, Purdue University's Center for the Environment, and the US Environmental Protection Agency.

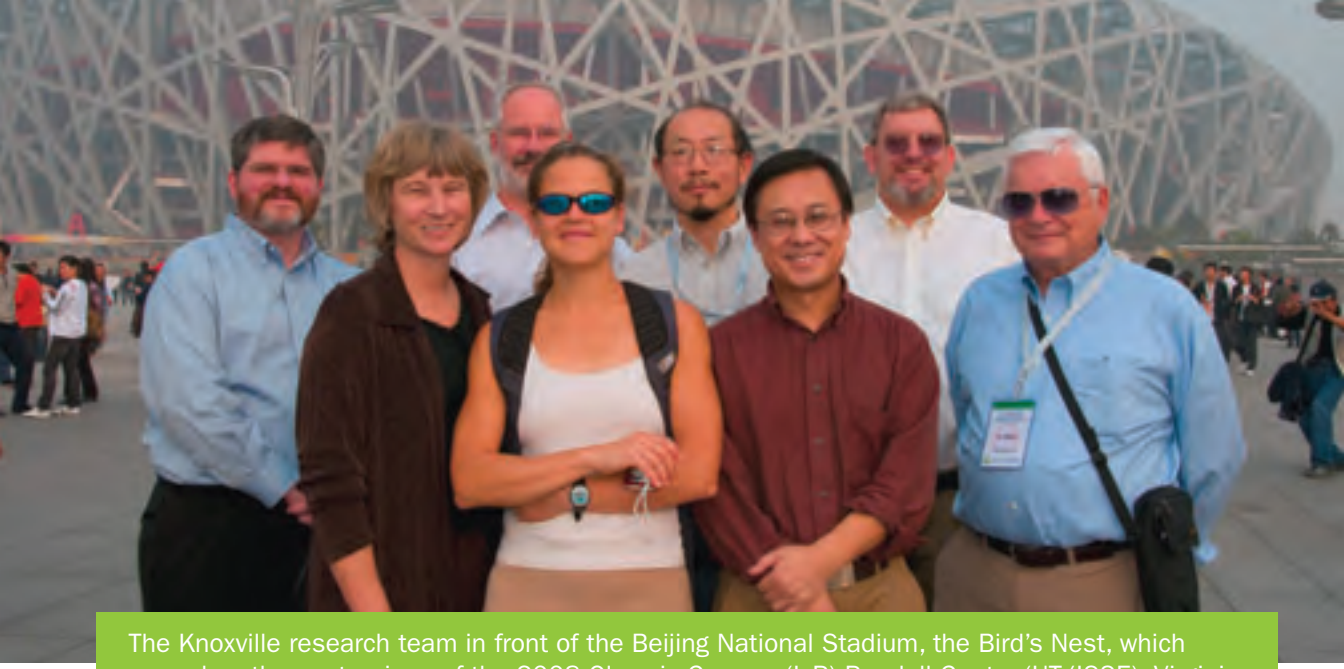
For three days, more than 60 scientists from the two participating nations gathered and shared perspectives rooted in fields ranging from plant genetics to sociology, from ecosystem dynamics to land-use policy. Through the presentations and the discussions they inspired, the Sino-American research team explored opportunities in the field of sustainable bioenergy production and common concerns regarding climate change and the carbon cycle. (For details on the conference, see "An International Response to Climate, Biofuels Challenges" on page 71.)

In the process, we further nurtured a collaborative relationship we at ISSE began with our Chinese colleagues in 2006, through the establishment of the China-US Joint Research Center for Ecosystem and Environmental Change. (For information on the center, visit the ISSE Web site: http://isse.utk.edu/jrceec/.)

Although scientific interaction was the principal purpose of our trip, our visit to China provided an important secondary benefit by greatly enhancing our understanding of the Chinese people, their culture, and their customs. I believe that this understanding will prove essential to future collaboration between two nations situated at opposite points on the globe and marked by very different political, economic, and social systems.

Though vastly different, our two cultures share much in common, including a devotion to family and friends, an abiding concern for the environment, and an eagerness to engage fellow scientists from across the globe in purposeful

ISSE's Randall Gentry and ORNL's Virginia Dale pause while climbing part of the 138-foot tower at the Qianyanzhou Agricultural Experimental Station. The tower is part of the China-FLUX system of 20 monitoring sites across the nation. The tower, situated in a conifer forest, features air monitors placed at various heights to study the exchanges of carbon dioxide, water vapor, and energy between terrestrial ecosystems (whose plants absorb carbon dioxide and release oxygen) and the atmosphere. The AmeriFLUX network conducts similar studies in the United States.



The Knoxville research team in front of the Beijing National Stadium, the Bird's Nest, which served as the centerpiece of the 2008 Olympic Games: (L-R) Randall Gentry (UT/ISSE), Virginia Dale (ORNL), Neal Stewart (UT), Kathleen Daumer Cusick (UT), Max Cheng (UT), Jie (Joe) Zhuang (UT/ISSE), Paul Hanson (ORNL), and Lee Shugart (L.R. Shugart & Associates, Inc.).

discussion and research. The remarkable warmth and hospitality demonstrated by our Chinese friends amply bore this out.

It has been my experience that, in the context of these shared values, our differences are dwarfed by our commitment to improving conditions for all citizens of the world, and I fully expect that our recent visit to China will mark the early stages of a research venture that will unite Chinese and US scientists well into the future.

Presented here and on the pages that follow are images captured during our trip, which included visits to the urban centers of Beijing and Shanghai and a journey to the Qianyanzhou Experimental Station in rural, subtropical southeastern China. The images and extended captions tell a very small part of the story of a vast and culturally diverse nation that is closely linked, both economically and environmentally, with our own.

I invite you to contact me to learn more about the China-US Joint Research Center for Ecosystem and Environmental Change, ISSE's role in the partnership, or emerging opportunities for collaborative research.

Randall Gentry directs UT's Institute for a Secure and Sustainable Environment and serves as associate professor in UT's Department of Civil and Environmental Engineering. Contact him at 865-974-4251, or email rgentry@utk.edu.

the old and the new
IN CHINA'S LARGEST CITY

Shanghai's imposing modern skyline occupies the east bank of the Huangpu River.

On the opposite bank, the stalwart structures of the historic Bund, which once contained European and American banks, trading houses, and consulates, date back to the late 1900s. Shanghai, China's largest city, has an official population of 14 million, though some estimates that include nonregistered residents exceed 21 million.

rolling stock

China's urban roadways are crowded with vehicles of every description, including innovative gas-powered cars, carts, and motorcycles as well as bicycles bearing enormous loads.

rice:
A LIFECYCLE PERSPECTIVE

Rice is the staple crop in China's rural southeast, occupying nearly every hectare of arable land. The mature plant droops under the weight of ripened seed before being harvested—almost entirely by hand—and then run through a hand-cranked thresher to separate seed from straw. The rice straw is formed into mounds that will later provide fodder for livestock (in rural China, most cattle are draft animals, not sources of food and milk) and fuel for cooking and heating. Farmers spread the "paddy" (rice grain still encased in the hull) on roads and other paved surfaces to dry before being bagged and sent to mills that remove the hull and, in the case of white rice, the bran.

qianyanzhou agricultural experimental station

ISSE Director Randall Gentry, ORNL's Paul Hanson, ISSE Research Director Jie (Joe) Zhuang, and ORNL's Virginia Dale and Keith Kline make an entry in the Qianyanzhou Agricultural Experimental Station's official guest book, expressing gratitude for the hospitality and a commitment to continued collaboration with their Chinese hosts.

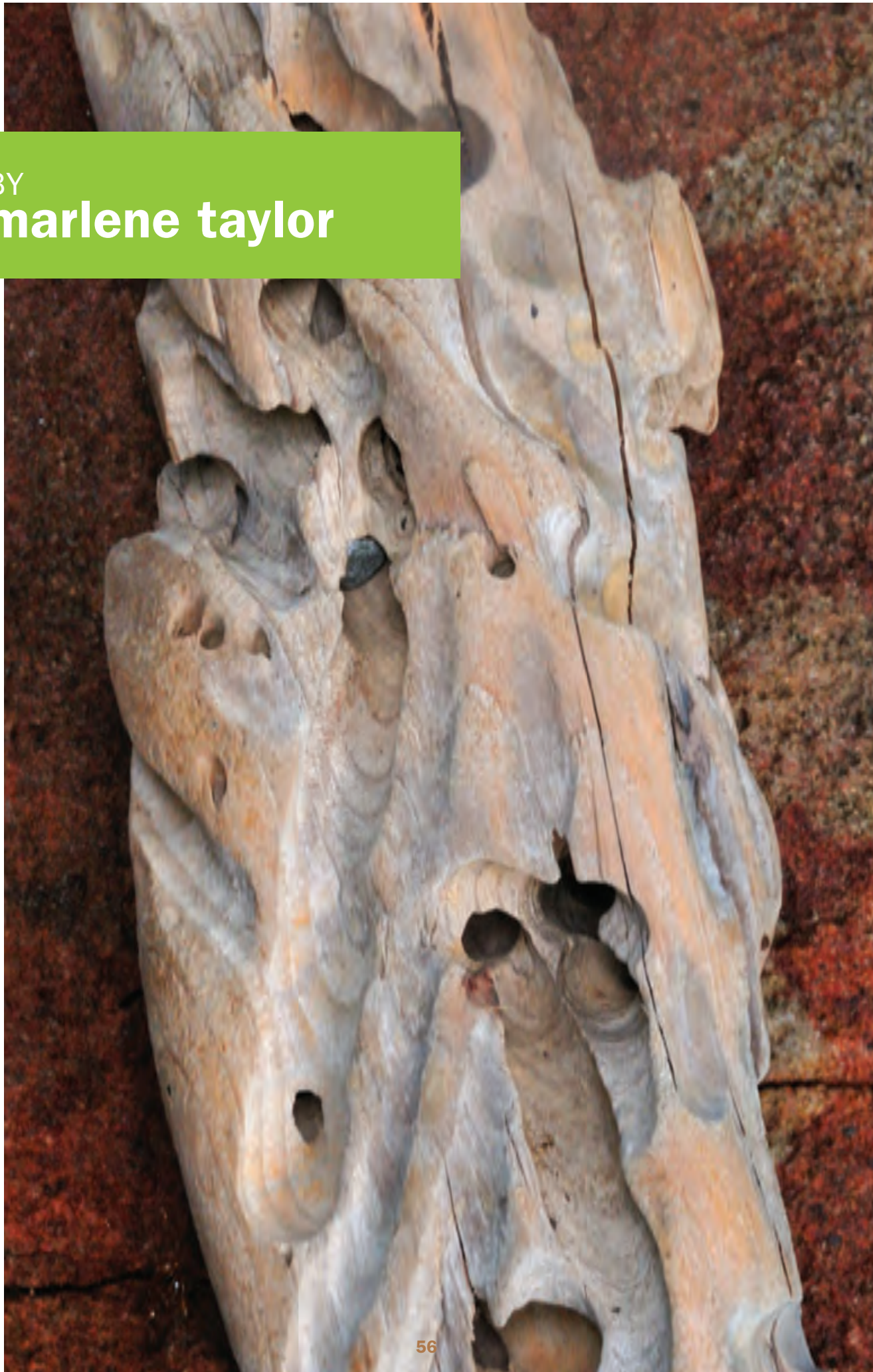
After long days devoted to science, the Chinese delegation hosted lavish banquets featuring 20 or more dishes. All are presented on the lazy susans that serve as the centerpieces of traditional Chinese banquet tables.

A shopkeeper in rural Taihe County in southeastern China offers basic items like duck eggs, cooking supplies, and medicinal products, as well as homemade rice wine.

Tea oil seeds, shown here, are grown at the Qianyanzhou Agricultural Experimental Station. The seeds provide oil for cooking, soaps, and cosmetics but may soon also be used as a feedstock for the production of biodiesel.

In 1982, the Chinese Academy of Sciences established Qianyanzhou Agricultural Experimental Station in rural Taihe County, Jiangxi Province, in southeastern China. Over previous decades, area farmers, seeking firewood for cooking and heating, had stripped timber from all but 1 percent of the once-forested hilly terrain. Researchers and the local government have restored forest cover to 35 percent of the area. Pine represents the majority of the forest, but local farmers also cultivate orange groves.

BY
marlene taylor



a new spin on an old design

COMBINES PRESERVATION, CONSERVATION

An ISSE-led student team travels to a national design competition in Washington, DC, and returns home with a $75,000 prize and confirmation that the past can—and should—guide our path into the future.

the project

More than 75 years ago an experimental concept in community development materialized in the small Tennessee Valley Authority (TVA)-built town of Norris, Tennessee.

Patterned after the Garden City Movement of the 1890s, the quaint hamlet was nestled within the natural features of the area and built with local lumber and stone, with plans to incorporate agricultural and industrial production to maintain self-sustainability. The small homes were contemporary for the times—fully electrified through power generated by TVA's first dam, Norris, on the Clinch River.

Besides the town's immediate purpose, to house the dam builders and their families, Norris also was meant to demonstrate cooperative living. A series of pathways led from the homes to a centralized commercial center where residents might meet and converse along the way. Houses face each other in a friendly, open manner, and each has a porch that puts neighbors in sight of one another.
All these carefully thought-out components encourage a close-knit, integrated community. Compare this congenial layout with today's developments, and is it any wonder few people know their neighbors?

Convinced that what worked for Norris in its early days can work again, ISSE's Community Partnership Center (CPC) and the University of Tennessee (UT) College of Architecture and Design are re-examining the century-old idea with an eye to the future. With both preservation of the Norris community and sustainable housing in mind, CPC Director Tim Ezzell, who serves as the principal investigator on the project, advised a group of planning and design students as they conceptualized the New Norris House.

Among its deliverables, the project led to the creation of a prototype for the new, energy-efficient home of the 21st century.

technical and cultural challenges

Co-mentored by Ezzell and architectural design professor Tricia Stuth, the team consisted of designing students Levi Hooten, Daniel Luster, Joan Monaco, and Samuel Mortimer and planning graduate students Bethany Wild, Ramune Matuliauskaite-Morales, and Thomas Herbert. "The students addressed both technical and cultural challenges in developing their interpretation of a 21st century house in the Norris community," says Stuth of the interdisciplinary team. "Taking into account the town's history and planning, they proposed a concept for how they would develop a small house on one lot, with shared amenities and an intersecting path system."

In April, the students exhibited the prototype at the National Sustainable Design Expo on the National Mall in Washington, DC, and won top honors, including a $75,000 grant from the EPA's P3 project (people, prosperity, and the planet), a public-private partnership aimed at achieving economic prosperity and a high quality of life while protecting the natural systems of the planet. (See "UT Team Claims Top Honors in EPA Sustainable Design Competition in DC" on page 62.) The award will help finance construction of the actual home, which will begin this fall.

Because the students held frequent meetings in Norris and maintained a Web site to encourage comments, the townspeople of Norris also had the opportunity to contribute to the project. The exchange of ideas and feedback helped shape the prototype design.

the sustainability of small

"We're starting to see a trend among the National Association of Homebuilders to build smaller homes," Stuth says. "The building of smaller homes has been increasing steadily for the last number of years, and the increase is directly related to energy use, material use, and land use. People are starting to look at quality over quantity."

But can anyone live in 450 square feet of space? To begin with, the New Norris Home is designed to accommodate two add-ons, if needed, to reach a maximum size of 1,000 square feet. To further reduce space and increase efficiency—not to mention neighborly interaction—the concept creates facilities shared among adjacent homes, including a work shop, a guest room, office space, and a play room.

the technologies

The Norris Project is a shining example of combining the know-how and innovation of the 1930s with the technology of the 21st century.

With the advent of sealed homes and a seemingly endless stream of artificially cooled and heated air, we may have forgotten the old principles that guided where and how people built their homes in the past. Homes were often sited and constructed to take advantage of natural heating and cooling systems. "The Norris house prototype incorporates an active and passive response to the environment," says Stuth. "For instance, we oriented the house to take advantage of useful solar gain, like warmth in the winter and breezes for natural ventilation in the summer."

The students utilized a range of design software in developing the New Norris House concept and designing the model: AutoCAD, Adobe Creative, Adobe Photoshop, Adobe Illustrator and Design, form-Z (a program for 3-D rendering), and Ecotect (a software system that helps situate a home and surrounding trees to capitalize on natural heating and cooling).

The team designed the house's envelope to deflect or capture solar heat through use of overhangs and roof lines. A system of louvers allows sunlight to penetrate in winter months but limits light in the summer months when the sun is high. Strategically placed deciduous trees block the summer sun. A cistern will collect rainwater for use in watering lawns and vegetable and flower gardens.

The plan calls for construction of three houses situated proximate to one another, which will create shared space.

"Each home will be a work in progress," says Stuth. "Then we'll share this concept and technology with the rest of the nation."

the greening art of homebuilding

Green technology is on the fast-track for development and not a moment too soon, if you ask CPC's Ezzell.

"The Norris prototype incorporates every kind of green technology feasible for the area and the design of the home," says Ezzell.

Ezzell's colleagues, Catherine Wilt and Jack Geibig of ISSE's Center for Clean Products (CCP), assisted the project in its evaluation and selection of green building materials and technologies. (For more on CCP's expertise in green building, see "The Gold Standard" on page 37.)

Green technology encompasses everything from fluorescent light bulbs to low-VOC (volatile organic compound) paints, carpet, and building materials to formaldehyde-free insulation. It involves ways to treat gray water (from sinks, tubs, and showers) so it can be used to water gardens. The New Norris House project is even evaluating ways to treat and use black water (from toilets).

When the model is completed, the occupant (perhaps a graduate student) will conduct both quantitative and qualitative testing to evaluate the design's effectiveness. Quantitative measures might include monitoring the stability of indoor temperature, calculating the number of days requiring supplemental heating and cooling, or monitoring need for artificial lighting.

Qualitative assessment would explore how residents adjust to living in a relatively small space, their sense of privacy with houses situated nearby, and their attitudes about shared outdoor spaces and facilities.

Only by accurately monitoring the conditions within the home and assessing quality-of-life issues can the Norris House project prove its ultimate sustainability.

For more information contact Tim Ezzell at 865-974-9036, or email: tezzell@utk.edu.

community partnership center

director
TIM EZZELL

program coordinator
ERIC OGLE

ut team claims top honors in epa sustainable design competition in dc

ARTICLE BY
amy blakely

A team from the University of Tennessee, Knoxville, won top honors at the P3 Award Competition during the Environmental Protection Agency's (EPA) National Sustainable Design Expo held in Washington, DC, in April.

The team of students and faculty from the College of Architecture and Design and UT's Institute for a Secure and Sustainable Environment (ISSE) presented "The New Norris House: A Sustainable Home for the 21st Century." The project was a contemporary interpretation of a historic home design featured in the Norris, Tennessee, community in the early 1930s.

As its prize, the winning team has been awarded a grant of $75,000 from the EPA. The team will use the money to construct an actual house based on the design in Norris.

The EPA competition focused on benefiting people, promoting prosperity, and protecting the planet (P3). About 40 teams competed. UT's teams were among the six teams winning top awards and the 11 receiving honorable mentions.

UT's winning team consisted of undergraduate architecture students Levi Hooten, Daniel Luster, Joan Monaco, and Samuel Mortimer, who developed the high-efficiency design for the New Norris House, and planning graduate students Bethany Wild, Ramune Morales, and Thomas Herbert.

Tim Ezzell, project principal investigator and director of the Community Partnership Center, a division of ISSE, and Tricia Stuth, assistant professor in the College of Architecture and Design, served as faculty mentors on the project. Catherine Wilt, policy director for ISSE's Center for Clean Products, advised the project on green building materials and other sustainable design elements.

Stuth said the winning team "did an amazing job—representing the very best our college and profession are capable of envisioning, creating and relating—and the college can be extremely proud of their representation of us and their commitment to design excellence."

Ezzell noted the team's unique approach: "We often tend to look to the future in developing efficient and affordable design concepts. But in the case of the Norris House, the lessons come from our region's past. The UT students did a great job of adapting the original design in creating a sustainable concept that will carry us forward over the next 75 years."

Mortimer called the competition "empowering."

"We were confident from the get-go that we had the idea and we thought our idea was the perfect match for the competition," he said.

For more about the competition and the winners, see http://www.epa.gov/ncer/p3/project_websites/2009/2009awardwinners.html.

the norris house

The Norris project was a model community constructed by the Tennessee Valley Authority in 1933 as part of the Norris Dam construction. The centerpiece of the community was the Norris House, an innovative, affordable home that featured new technologies, locally produced materials, and efficient vernacular design.

The community was considered one of the nation's first planned sustainable communities, featuring innovative, affordable homes with new technologies and efficient designs.

"The original Norris House represented the sustainable home of the 1930s and survives as a symbol of innovation," Ezzell said. "The student team created a design for the next 75 years."

The New Norris House is designed to take advantage of natural ventilation and winter sunlight and summer shade. The house features a solar-powered hot-water heater, a high-efficiency heat pump, a system for collecting and storing rainwater, and an on-site system for treating gray water.

The house is designed, where possible, to be constructed of locally produced green building materials and complies with the US Green Building Council's Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) standards.

As with the original Norris House, the new design integrates the home into the surrounding community via pedestrian paths linking homes to community service nodes that provide for shopping, recreation, public gatherings, and performances.

TVA helped finance the project and provided transportation of the team's model to the national competition.

The architecture students' interpretation of the historic home also won top honors in the 2009 Exhibition of Undergraduate Research and Creative Achievement (EURēCA) at UT Knoxville.

~amy blakely

BY
elise leQuire

underground research

An ISSE researcher takes soil science from the lab to the field while also fostering Chinese-US joint research efforts.



the project

Jie (Joe) Zhuang knows how to multitask. Since 2007, he has served as a research director of the University of Tennessee's (UT) Institute for a Secure and Sustainable Environment (ISSE) and a research associate professor in UT's Department of Biosystems Engineering and Soil Science (BESS). In addition, Zhuang brings tireless energy to his role as coordinator of the China-US Joint Research Center for Ecosystem and Environmental Change. (For more information on the China-US Joint Research Center, see "An International Response to Climate Challenges, Biofuels Production" on page 45.)

"Joe Zhuang is extremely capable on the policy side, helping us coordinate with our Chinese colleagues through the China-US Joint Research Center, but he's equally skilled as a soil scientist," says Randall Gentry, ISSE's director.

This year marks the third annual workshop of the China-US Joint Research Center. Titled "Climate-Energy Nexus," the meeting will be held in November at Oak Ridge National Laboratory with sponsorship from the US Department of Energy (DOE) and the US National Science Foundation.

Since the past two workshops, held in Knoxville in 2007 and in Beijing in 2008, participation and interest among US and Chinese scientists and students in the China-US Joint Research Center has risen sharply.

"We intend to use the joint center to explore new collaborative research and expand study sites in China and the United States, improve research facilities, promote student education, and increase the number of joint publications, books, and reports," says Zhuang. "US-Chinese collaboration on energy and climate can create new economic opportunities through technology transfer that meet the goals of clean and sustainable development established by our two governments in recent years."

JOE ZHUANG

Zhuang's own research, which focuses on soil physics and transport of colloids—small suspended particles that can transport contaminants in soils and in subsurface water systems—has taken him to experimental sites in Japan, the United States, and China, where he started his career at Shenyang Agricultural University.

At UT, Zhuang has collaborated with John F. McCarthy, a world recognized research professor with the Department of Earth and Planetary Sciences (EPS) and UT's Center for Environmental Biotechnology (CEB), to develop experimental designs that can be used to study colloid transport

under transient unsaturated flow conditions. "Rainfall, irrigation, flooding, and snowmelt are all transient water flow conditions," says Zhuang. "Researchers like to use steady-state conditions in the lab, which are easy to control. It is more difficult to explore natural processes."

Together with McCarthy and other researchers at EPS, BESS, CEB, and UT's Department of Microbiology, and with colleagues at other research facilities, Zhuang is working to overcome experimental challenges in the observation of the invisible underground natural environment.

the science

A major focus of Zhuang's research is to gain understanding of the fate and transport of colloids and contaminants such as pathogenic viruses and radionuclides in subsurface environments. His research in this area led him to the Hanford Site in Washington State.

As part of the Manhattan Project, Hanford was one of three major facilities devoted to the production of nuclear weapons. Since World War II, the site has been contaminated with weapons-grade plutonium that was buried in tanks on the site. Nearly 70 percent of these tanks are leaking, and the radioactive material seeps downward through the soil into the groundwater and eventually into the Columbia River.

"Scientists don't understand why the movement is so fast," says Zhuang. "DOE spends more than a billion dollars a year to remediate subsurface nuclear contamination."

Through their collaborative research, Zhuang and colleagues have helped elucidate how these contaminants move through subsurface soils. Radioactive isotopes are absorbed on tiny clay, or colloidal, particles, which carry these radionuclides through deep soils. This flow can be increased by transient hydrological pulses from precipitation or fluctuating groundwater tables.

In addition, the team found that textural layering and/or mineralogical heterogeneity also influence

the transport of radionuclides and that the forces that control the movement include capillary, electrostatic, hydrodynamic, and hydrophobic forces.

The study, supported by DOE and published in *Environmental Science and Technology*, may help guide remediation efforts at the Hanford site and other sites plagued with nuclear contamination.

In other studies, Zhuang has tracked how bacteriophages—viruses that live in bacteria—move through an aquifer in the natural environment. Seepage from wastewater systems and septic tanks can release viruses and bacteria into the ground, where they eventually wind up in groundwater and ultimately in drinking water, endangering human health.

While it is possible to filter out bacteria in water-treatment systems, viruses are more problematic. "Most viruses are much smaller than bacteria, about 1/100th the size of bacteria, or 1/1000th of the thickness of a human hair, and most treatment systems don't work well at removing viruses from water."

Using surrogate viruses that do not pose risks to human health—harmless bacteriophages with similar size and chemistry as infectious agents—Zhuang has followed the transport of the viruses in porous, sandy, and silted soils in the natural aquifer. He found that iron oxides and tiny, nano-aluminum oxides can prevent the transport of viruses through porous media, while dissolved organic acids facilitate transport and survival. These findings have been applied by industry to provide a way for NASA to recycle astronauts' urine for drinking water.

Zhuang is also exploring cycles of carbon, water, and nitrogen in the environment. "These areas are related to agriculture, land use, water quality, bioenergy production, and global climate change," he says.

From a perspective of soil physics, Zhuang, together with his colleagues, found that high water retention in soil microstructure can increase filling of soil micropores by organic matter, providing physical protection of organic matter and eventually retarding decomposition of soil organic carbon. The result is an increase in soil productivity and mitigation of greenhouse gas emission from lands.

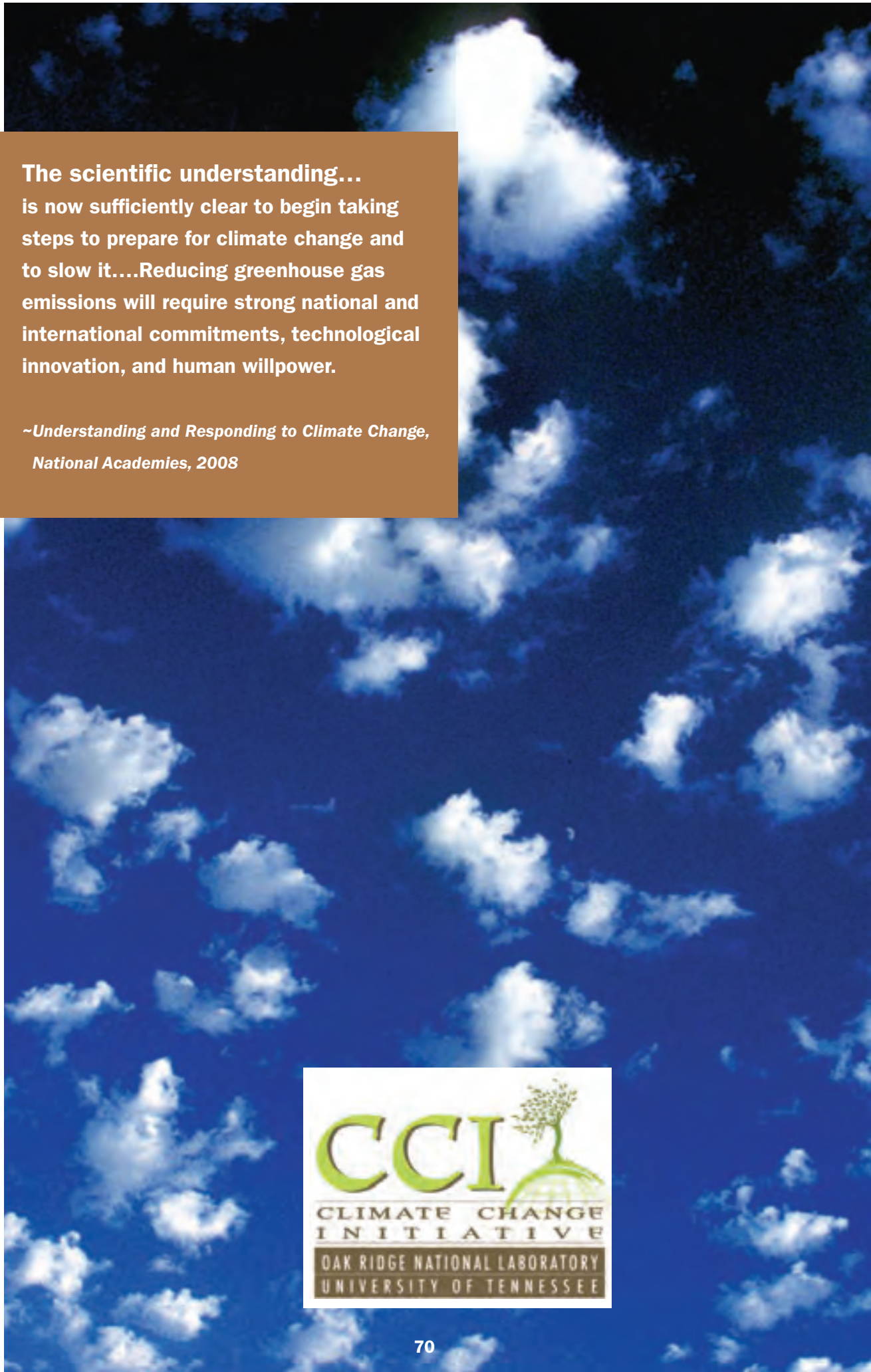
The study, supported by the US Department of Agriculture and published in *Soil Science Society of America* journal, may help clarify how much organic carbon can be retained in soils of various types and facilitate optimization of land restoration strategies for maximizing the capacity for long-term carbon storage underground.

In his own soil-science based research, through interdisciplinary cooperation with researchers across and outside the university and in collaborative work through the China-US Joint Research Center, Zhuang and colleagues are advancing the forefronts of knowledge that can benefit water-quality protection, environmental sustainability, and economic and environmental security.

For more information, contact Jie (Joe) Zhuang at 974-1325, or email jzhuang@utk.edu.

For more information on the China-US Joint Research Center, visit the Web site: http://isse.utk.edu/jrceec/.

“Most viruses are about 1/100th the size of bacteria, or 1/1,000th of the thickness of a human hair, and most treatment systems don’t work well at removing viruses from water.”



The scientific understanding…
is now sufficiently clear to begin taking steps to prepare for climate change and to slow it.…Reducing greenhouse gas emissions will require strong national and international commitments, technological innovation, and human willpower.

~Understanding and Responding to Climate Change, National Academies, 2008

CCI
CLIMATE CHANGE INITIATIVE
OAK RIDGE NATIONAL LABORATORY
UNIVERSITY OF TENNESSEE

a regional response

TO THE GLOBAL CLIMATE-CHANGE CHALLENGE

East Tennessee is home to some of the nation's leading research organizations. Together, they are shaping a collaborative and multidisciplinary team to study the science of global climate change. ISSE is helping to coordinate the effort.

The challenge of addressing climate change will engage the world's top scientists and policymakers for many years to come, and the urgency attending this issue argues for collaboration that spans the disciplines.

In that regard, our region boasts a complement of technological capabilities and scientific resources that are unique to the nation and the globe, and together they form a promising foundation for the study of the dynamic and multidimensional aspects of climate science.

the partners

OAK RIDGE NATIONAL LABORATORY

Oak Ridge National Laboratory (ORNL) is the Department of Energy's largest science and energy laboratory and is situated a half-hour's drive from Knoxville. Managed since April 2000 by a partnership of the University of Tennessee (UT) and Battelle, ORNL was established in 1943 as a part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. During the 1950s and 1960s, ORNL became an international center for the study of nuclear energy and related research in the physical and life sciences. With the creation of the Department of Energy (DOE) in the 1970s, ORNL's mission broadened to include a variety of energy technologies and strategies.

In the late-1950s ORNL researchers completed their first briefing to the US Atomic Energy Commission (AEC) on the need to understand the global carbon cycle at a time when global climate change remained an unknown threat to the world's environment. ORNL/DOE remains a dominant participant in the US Global Change Research Program, a nearly $2-billion enterprise encompassing 12 US agencies examining the full range of global change challenges.

THE UNIVERSITY OF TENNESSEE

Established in 1794, the University of Tennessee (UT) system of higher education enrolls 42,000 students and includes the University of Tennessee-Knoxville; University of Tennessee Health Science Center; University of Tennessee at Chattanooga; University of Tennessee at Martin; University of Tennessee Institute of Agriculture; University of Tennessee Institute for Public Service; and University of Tennessee Space Institute. UT-Knoxville is a Carnegie I research institution that conducts $160 million annually in

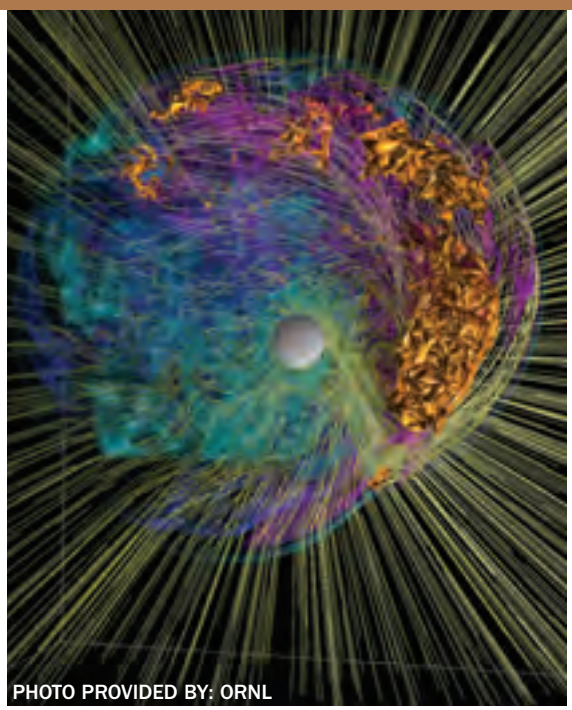


PHOTO PROVIDED BY: ORNL

externally funded research, including more than $20 million annually in joint research with ORNL. UT's Institute for a Secure and Sustainable Environment (ISSE) will house the UT-ORNL Center for Climate Change and Environment. ISSE, a multidisciplinary research center, focuses on the convergence of the carbon cycle and carbon sequestration, climate and natural systems response, and renewable bioenergy. While these foci establish ISSE's overarching research strategy, the institute's specialized centers address a range of other issues that fall under the broad rubric of sustainability.

The academic home of the UT-ORNL Center for Climate Change and Environment is UT's Department of Civil and Environmental Engineering. Through its graduate degree programs in environmental engineering, the department has a long history of training students on the environmental impacts of human activity and the mitigation of those impacts. New course offerings, including "Three-dimensional Climate Modeling," "Climate Impacts on Water Resources," "Air Pollution Climatology," and "Climate and Environmental Informatics," extend this training

to allow students to project the impacts of climate change in such areas as air quality, flood and drought forecasting, water supply, and built infrastructure.

Under the direction of UT and ORNL researchers, graduate students may have opportunities to immediately apply the concepts and tools developed in these courses to federally funded projects related to the formation of national and international climate policy. The emphasis on predicting the impacts of climate change will supplement and build upon existing faculty expertise in such areas as air pollution (Professors Sandeep Agnihotri, Joshua Fu, and Terry Miller), water resources (Professors Randall Gentry, Jack Parker, John Schwartz, and Glenn Tootle), and water quality and bioenergy production (Professors Chris Cox, Qiang He, and Kevin Robinson).

TECHNOLOGICAL RESOURCES

UT, through its partnership with Battelle and with substantial support from the state, manages ORNL and $3 billion in research facilities, equipment, and expertise in East Tennessee. Because of the proximity of UT's flagship campus to the national laboratory, the research and academic linkages are strong. In fact, the partnership has more than $6 million in funding for the 35 faculty with joint appointments to UT and ORNL.

the partnership's unique resources

THE $1.4-BILLION SPALLATION NEUTRON SOURCE is an accelerator-based neutron source. When at full power, this one-of-a-kind facility will provide the most intense pulsed neutron beams in the world for scientific research and industrial development.

THE CRAY XT4 JAGUAR SUPERCOMPUTER is the world's most powerful system for open science and is ranked among the fastest in the world.

The National Science Foundation awarded $65 million to UT to build and operate the supercomputer and lead a nationwide partnership to put it to use. The National Institute for Computational Sciences, based at ORNL, facilitates the use of the new supercomputer. The computer will boost climate scientists' efforts to predict extreme weather events such as hurricanes and tornadoes as well as long-term climate change and the effects of pollution. Backed by $72.6 million in state funding, scientists at the UT Institute for Agriculture and ORNL are exploring ways to improve production of ethanol from switchgrass, a crop that can be grown anywhere in Tennessee. State funding includes construction of a pilot biomass ethanol plant capable of producing 5 million gallons per year.

PHOTO PROVIDED BY: ORNL

joint institutes

The UT-ORNL partnership is home to four new joint institutes.

- The Joint Institute for Computational Sciences (JICS), the first state-owned facility ever built on a national laboratory campus, houses the National Institute for Computational Sciences and the Cray XT4 Jaguar Supercomputer.
- The Joint Institute for Advanced Materials (JIAM), a $45-million facility, will be built on UT's new Cherokee campus.
- The Joint Institute for Biological Sciences (JIBS), an $11.8-million facility on the ORNL campus, will be home to the Department of Energy's new Bioenergy Science Center, a $125-million research endeavor between ORNL, UT, and other partners.
- The Joint Institute for Neutron Sciences (JINS) is being built adjacent to the Spallation Neutron Source at ORNL.

PHOTO PROVIDED BY: ORNL

key participants

Though the UT-ORNL partnership engages more than 100 scholars, researcher affiliates, and scientists from both organizations, several key individuals guide and administer the collaboration.

THOMAS ZACHARIA, ORNL's Deputy for Science and Technology, manages ORNL's $1.4-billion research and development portfolio and formerly led the laboratory's agenda in advanced high-performance computing in priority areas such as climate change, fusion energy, nanotechnology, and biotechnology. Zacharia joined ORNL in 1987 as a postdoctoral researcher in the Metals and Ceramics Division. He formed the Materials Modeling and Simulation Group and served as group leader until he accepted the position of division director of the Computer Science and Mathematics Division in 1998. He served as Deputy Associate Laboratory Director for High Performance Computing from 2000 to 2001. He was named Associate Laboratory Director for the newly formed Computing and Computational Sciences Directorate in 2001.

JAMES J. HACK has been director of the National Center for Computational Sciences at ORNL since late 2007. An atmospheric scientist, Hack also leads ORNL's Climate Change Initiative. After receiving a PhD in atmospheric dynamics from Colorado State University in 1980, Hack became a research staff member at the IBM Thomas J. Watson Research Center, where he worked on the design and evaluation of high-performance computing architectures. In 1984 Hack moved to the National Center for Atmospheric Research, a National Science Foundation-sponsored center, where, as one of the principal developers of the NCAR global climate model, his roles included senior scientist, head of the Climate Modeling Section, and deputy director of the Climate and Global Dynamics Division.

JOHN DRAKE is leader of the Computational Earth Sciences Group in the Computer Sciences and Mathematics Division at ORNL. He received his PhD in mathematics from UT in 1991, having previously joined the mathematics group at ORNL in 1984. His research interests include numerical methods and parallel algorithms for climate modeling, fluid dynamics modeling, and the numerical approximation of conservation laws. Drake has worked on two DOE Scientific Discovery through Advanced Computing (SciDAC) Program projects: Collaborative Design and Development of the Community Climate System Model for Terascale Computers and a Scalable and Extensible Earth System Model for Climate Change Science. Drake is an adjunct professor in UT's Department of Civil and Environmental Engineering.

DAVID ERICKSON has been a senior research staff member in the Computational Earth Sciences Group of the Computer Science and Mathematics Division at ORNL since 2000. He is also an adjunct professor in UT's Department of Civil and Environmental Engineering and the Division of Earth and Ocean Sciences of the Nicholas School of the Environment and Earth Sciences at Duke University. Erickson received his PhD in atmospheric chemistry/chemical oceanography/marine chemistry from the Graduate School of Oceanography at the University of Rhode Island in 1987. He completed post-doctoral work in climate modeling, marine and atmospheric chemistry, and geophysical fluid dynamics at the Scripps Institution of Oceanography at the University of California. Erickson served as staff scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado from 1990-1999. At NCAR and ORNL, Erickson developed several numerical models of global-scale biogeochemistry, CO_2 modeling within global climate model frameworks, atmospheric chemistry, and a variety of climate simulations investigating the impacts of aerosols, biomass burning, and soil moisture anomalies on climate. Erickson's research interests also include global and regional climate modeling, numerical modeling of the carbon cycle, and modeling the global air-sea exchange of energy, momentum, trace gases, and particles. Recent activities have addressed evaluating climate-related extreme event frequencies with implications for policy decisions, national security, and detailed energy/policy models.

AUROOP R. GANGULY, a research scientist with the Geographic Information Science and Technology Group of ORNL's Computational Sciences and Engineering Division, has broad research interests spanning predictive modeling of climate extremes and regional climate change; climate change impacts on natural, engineered, and human systems; hydrology and hydro-meteorology; knowledge discovery from sensor data; business systems; and social processes related to national and homeland security. Ganguly's interests in the computational data sciences include data mining and nonlinear modeling as well as applied time series and spatial statistics. Ganguly's research has been published in journals like *Geophysical Research Letters*, *Proceedings of the National Academy of Sciences*, *Journal of Hydrometeorology, Physical Review E*, *Journal of the Operational Research Society*, and *IEEE Transactions on Intelligent Transportation Systems*. Ganguly has been invited to workshops and panels sponsored by the NSF and DOE and has led research projects funded by DoD, including DARPA, and DHS. Ganguly currently is an associate editor of the *ASCE Journal of Computing in Civil Engineering*, is a member of the invited reader panel for the journal Nature, and holds adjunct professor appointments with UT's Department of Industrial and Information Engineering as well as Civil and Environmental Engineering.

RANDALL GENTRY directs UT's Institute for a Secure and Sustainable Environment, is president of the UT Research Foundation, and serves as an associate professor in UT's Department of Civil and Environmental Engineering. Gentry, who earned his PhD in civil engineering from the University of Memphis, also directs the Southeastern Water Resources Institute, a multidisciplinary, multi-institutional research entity devoted to the study of science, technology, and public policy issues related to surface and ground water. Gentry's research focuses on the evaluation of groundwater hydrologic interfaces of highly localized systems as well as broad-scale watershed processes. Under Gentry's direction, ISSE's multidisciplinary research team is exploring the convergence of the carbon cycle and carbon sequestration, climate and natural systems response, and renewable bioenergy.

PHOTO PROVIDED

JOSHUA FU is research associate professor in the UT Department of Civil and Environmental Engineering. He received his PhD in environmental system analysis at North Carolina State University after working in the EPA's supercomputing center. One focus of his research is the consequences of global climate change on air quality and water resources, including the application of a large-scale global climate and air-quality modeling assessment with greenhouse gases, ozone, and aerosol emissions; development of downscaling techniques for the linkage of global- and regional-scale climate and atmospheric models; international air-quality modeling assessment; and development of cost-effective control strategies and alternative standards for managing global and regional climate and tropospheric ozone and particulate matter. Fu leads the research effort to link global and regional models for the Hemispheric Transport of Air Pollution task force of the UN Economic Commission for Europe and participates in the EPA-funded Global Climate and Air Pollution research group, along with collaborators from Harvard University, the California Institute of Technology, Argonne National Laboratory, and NASA's Goddard Institute for Space Studies.

GLENN TOOTLE is an assistant professor in the UT Department of Civil and Environmental Engineering. He earned his PhD in civil engineering from the University of Nevada, Las Vegas. Tootle's research focuses on hydroclimatology and paleohydrology, specifically on climate variability (and change) impacts on water resources. Current research projects include glacier recession impacts on water supply, stream flow reconstruction using tree rings, improved stream flow forecasting, and sea surface temperature variability impacts on water resources.

MARCIA BRANSTETTER joined the Computational Earth Sciences Group of ORNL's Computer Sciences and Mathematics Division after serving as a postdoctoral research scientist at the laboratory. She received her PhD in geological sciences (specializing in hydrology) from the Jackson School of Geosciences at the University of Texas at Austin in 2001. At the University of Texas, Branstetter served as a graduate fellow in the Department of Geological Sciences and as a graduate research assistant in the Department of Mathematics. Branstetter's research involves the use of climate system modeling to study the effects of continental runoff on the earth's climate system, the possible impacts of biofuel energy deployment on climate and hydrology, and analysis of the scenario simulation results of the Intergovernmental Panel on Climate Change. Branstetter has worked on two DOE SciDAC projects.

technology rich region

In addition to UT and ORNL, the area defined by the Southeast Technology Corridor stretches from the Research Triangle of North Carolina to Huntsville, Alabama, and embraces a number of other prominent US research organizations. Among them, moving from east to west, are Duke University, North Carolina State University, University of North Carolina at Chapel Hill, Western Carolina University, the Tennessee Valley Authority, Tennessee Tech University, University of Alabama at Huntsville, and NASA's Marshall Space Flight Center. The Southeast Technology Corridor also comprises hundreds of highly specialized consulting firms that support the R&D efforts of these major institutions.

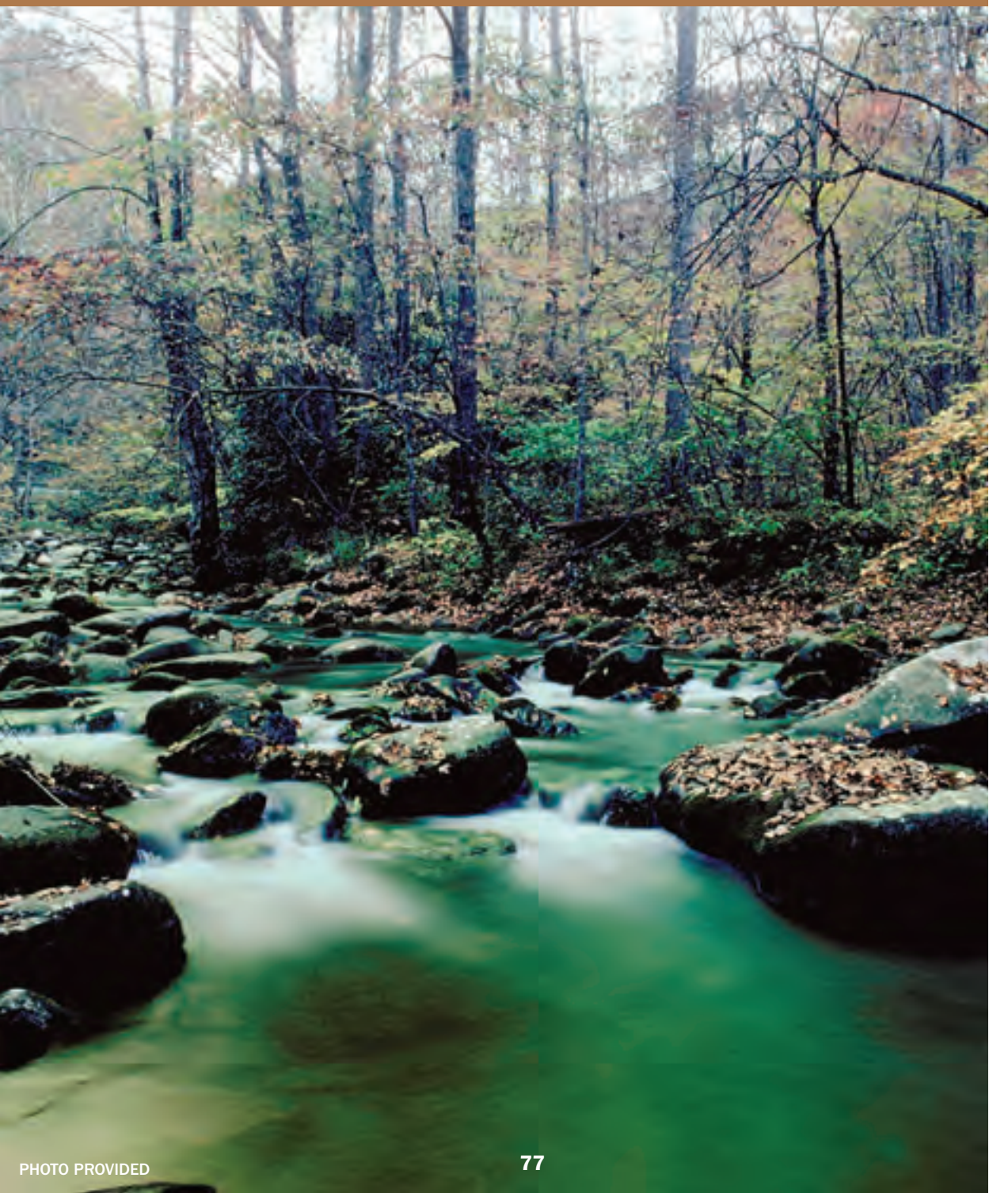


PHOTO PROVIDED

BY
elise leQuire

sustaining the south's overtaxed water resources

The availability of clean freshwater resources underlies the stability and security of any population. The water-rich Southeast is no exception.

the project

In the Southeast, with its rapid population growth, what was once considered an abundant resource is now a bone of contention at the interstate and even the intrastate level. A federal judge ruled in July 2009, for example, that the city of Atlanta has three years to cease withdrawing water from Lake Lanier, the sprawling city's primary water resource. Water thirsty Georgia has even gone so far as to attempt to correct a surveyor error from the early 19th century in order to lay claim to a portion of the Tennessee River.

In the South, water law is based on the riparian doctrine derived from English common law. "If the water flows through or over or beneath the land, that water belongs to the landowner," says Randall Gentry, director of the University of Tennessee's (UT) Institute for a Secure and Sustainable Environment (ISSE). Though that sounds simple, because of the complex interplay among surface water, groundwater, and soils, understanding the ability of a watershed to remain healthy poses an interdisciplinary scientific challenge.

"We need to define what requirements are necessary to sustain ecosystem health and habitat," says Gentry, who is also an associate professor in UT's Department of Civil and Environmental Engineering. Gentry and other ISSE researchers have teamed up with scientists across many interrelated disciplines, including hydrogeology, earth sciences, environmental engineering, and biochemistry, to gain a better understanding of watersheds, water availability, and water quality in the region. Sustainability of water resources, however, can be hard to define. "Some researchers focus on the scarcity or abundance of water," says Gentry. "I prefer the idea of resilience of a hydrologic system. Knowing where resilient systems are will be important for management of limited water resources."

RANDALL GENTRY

With a background in hydrologic modeling, Gentry takes a forensic approach to the science. "My colleagues and I are gaining a better understanding of how hydrologic systems behave and what unique tell-tale signs or signatures occur at the mixing zone of surface water and groundwater in an aquifer and what role these interactions play along major transects in a watershed."

Current plans for ISSE include beefing up the science side of its mission. "We at ISSE have begun to organize and coordinate the research efforts carried out by our multiple centers and institutes devoted entirely or in part to water-related issues," says Gentry. This work, based on unbiased, analytical science, will allow ISSE and its partner research institutions to find new ways of regarding the region's water resources and contribute substantially to solving challenges to the region's water resources.

"The future I see is in bringing physical scientists and social scientists together, working in the area of sustainability," says Gentry.

the science

Recently, Gentry's research has been increasingly case-study specific, as he takes his expertise in modeling hydrologic systems to the field to validate models within a defined system, whether a specific watershed or on a larger scale.

The Little River rises from a pristine stream in Great Smoky Mountains National Park and empties 60 miles downstream into the Tennessee River near Knoxville. In its lower reaches the river has been classified by the state as threatened because of bacterial contamination from a number of sources: failing septic systems, agricultural and industrial practices, and urban runoff.

Gentry and colleagues from UT's Departments of Civil and Environmental Engineering and Earth and Planetary Sciences and the Center for Environmental Biotechnology (CEB) have explored variations over time in the presence of total coliform bacteria in water samples collected daily for five years at the intake of a water processing plant on the river. Not surprisingly, they found concentrations varied seasonally, with higher levels in the warmer, drier months, and lower levels in the cooler, rainier months.

Coliform bacteria, however, are persistent in soil and in the river bed. The researchers also collected hydrological data, comparing it to total coliform data. Their results suggest that during high flow events such as floods, coliforms can be resuspended in surface water, leading to higher concentrations during these transient events. Understanding the fate and transport of bacteria in impaired waters is key to assisting regulatory efforts to improve water quality.

In further refinement of this line of research, Gentry has teamed up with Alice Layton, a CEB research associate professor, to pinpoint not just the presence, but the origin, of *E. coli* bacteria in stream water. One of their study sites is in Stock Creek, which flows into the Tennessee River near Knoxville. The creek is located in a rural environment where livestock drink from the creek, and a number of failed or failing septic systems are also nearby. Layton has developed assays using real-time polymerase chain reaction (rt-PCR) to target Bacteroides, a genus of bacteria that is abundant in the digestive systems of all mammals and is host specific, so it can be used to "fingerprint" the animal of origin. The AllBac assay measures total Bacteroides present in humans, horses, and cattle, while BoBac is specific to cattle, and HuBac is specific to humans.

Combining stream sampling in the field with groundwater hydrology and statistical modeling gives a clearer picture of the watershed and a better determination of whether fecal contamination is the result of failing septic systems, runoff phenomena, or from groundwater stored in the karstic aquifer. "Interdisciplinary research is exciting to people who do not stay highly focused within a myopic research area," says Gentry. "These opportunities provide fertile ground for innovation, new ideas, and new science."

For more information, contact Randall Gentry at 865-974-1843, or email rgentry@utk.edu.

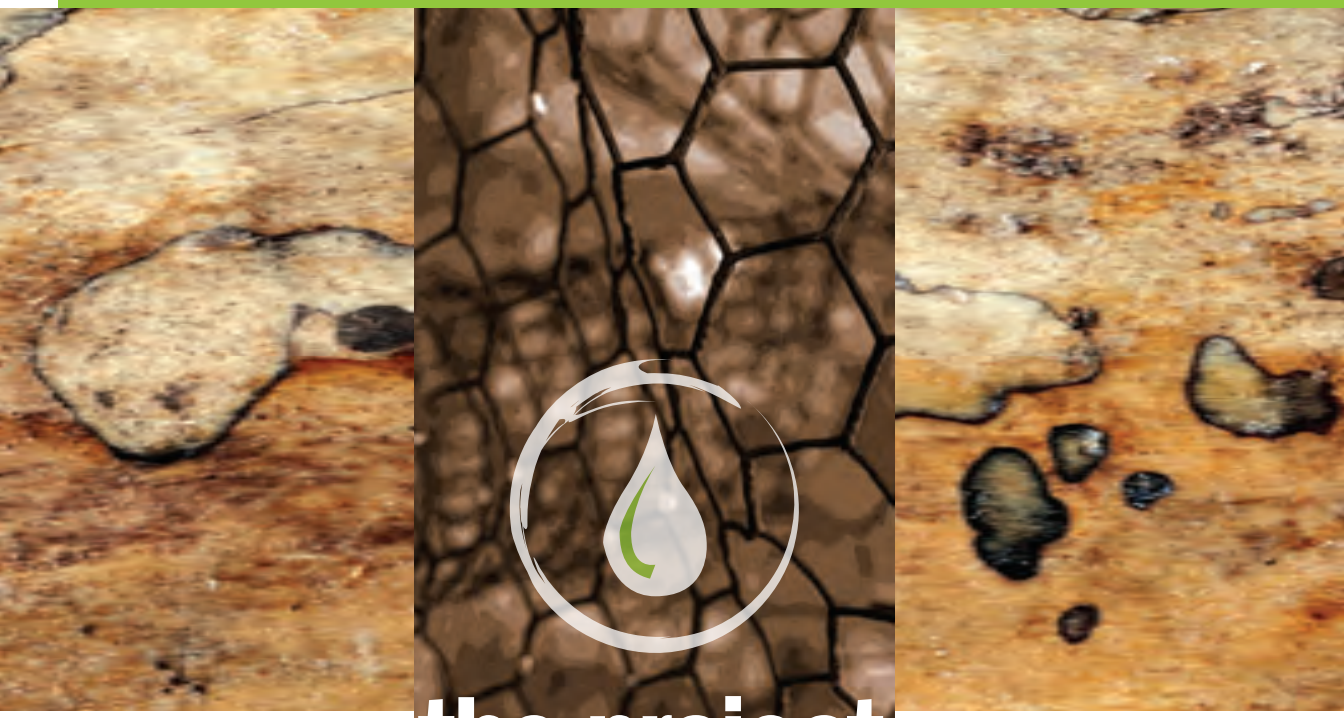
BY
randall gentry

from clouds come rain—and isotopes

The clouds wafting through the Great Smokies impart a mood of mystery and mist—not to mention an unhealthy dose of acid rain. Guided by telltale ions and isotopes, UT graduate students explore the relationship among rain, the water coursing along the mountains' surface, and pockets residing underground.

A glimpse of East Tennessee's Great Smoky Mountains shrouded in low-slung clouds is an archetypical image and one that prompted the Cherokee Indians to term the region "the place of blue smoke."

But while the daydreamers among us are inclined to study the cloud formations drifting across the sky overhead, the region's scientists—UT researchers among them—are more interested in what's happening on, and under, the ground. The cloud formations above and the moving water below are, in fact, closely linked.



the project

Over a period of five months in the spring and summer of 2007, Amanda McKenna Pike and Candice Owen, former graduate students in UT's College of Engineering, tested the waters in a remote Smoky Mountain stream to explore the interaction between the cascades, seeps, and plunge pools on the surface and the catchments of water held within the earth.

The students were particularly attentive to the stream's chemistry, including the water's acidity as calculated on the pH scale. pH is the measure of the concentration of hydrogen ions in a solution, ranging from highly acidic (low pH) to highly basic (high pH).

The students' research was funded by the UT Natural Resource Policy Center through a grant from the US Environmental Protection Agency. The grant also included research being performed by John Schwartz in UT's Department of Civil and Environmental Engineering.

Schwartz, along with Steve Moore, supervisory fisheries biologist of Great Smoky Mountain National Park (GSMNP), were studying the relationship between episodes of high acidity in the park's higher-elevation waterways and the disappearance of native brook trout in six headwater streams.

the science

The clouds cloaking the Smokies' higher peaks and the waters gurgling many feet beneath the mountains' surface are, in fact, phases of the same system.

The hydrologic system is a continuing cycle through which evaporative water from oceans, rivers, and lakes, along with water vapors given off by plants and animals, enters the atmosphere and eventually forms clouds. Once airborne, this water returns to earth through rain and the columns of mist that drape the Great Smoky Mountains.

The Great Smokies, among the oldest mountains on earth, are known for their abundant rainfall, with some of the region's peaks receiving 85 inches of rain each year. Some of the Smokies' water is stored underground in aquifers that recharge the mountains' surface streams and provide flow during dry periods between storms.

We know that the surface water cascading down the Smokies' slopes is fed by tributaries and springs and interacts with the water stored underground, but exactly how these waters interact and the chemical changes that result from this interaction are not well understood.

With that challenge in mind, Pike and Owen sampled the waters of Ramsey Prong, a small headwater stream and part of the Little Pigeon watershed in GSMNP. The stream is accessible only by a steep foot trail.

Their research focused on water quality and flow, based in part on the study of ions and isotopes contained in the water at various monitoring points. Ions are atoms or molecules that have lost or gained electrons, and isotopes are differing forms of elements marked by varying numbers of neutrons. Both are reliable indicators of the chemical exchanges taking place in a water system.

AMANDA PIKE

On their forays into the park, the students were equipped with various tools for analyzing stream flow and the chemical composition of the water, along with a scholarly quest. Says Pike: "We set out to study the hydrology of a remote mountain area and to learn more about groundwater's role in neutralizing acids entering the streams."

it fell from the sky

For the connection between acid and the Smokies' seemingly pristine streams, we return to the clouds. The Smoky Mountains' remoteness and relatively unaltered state makes them ideal for studying the interaction between surface and ground waters. Rivers and streams in other, more developed, areas are influenced extensively by activities that occur around them, including agriculture, construction, and pollutants entering storm drains from paved surfaces.

By contrast, the streams of the Smokies are largely protected from these impacts by their elevation and remoteness.

But they are not protected from airborne pollutants—chiefly the acids carried by the Smokies' familiar cloud formations. Created through the combustion of fossil fuels, including coal and petroleum products, sulfates and nitrates enter the atmosphere and return to earth in the form of acidic rain and the moisture in clouds that is transferred as the clouds make contact with the ground.

"Acid deposition from precipitation and fog or clouds has long been associated with low pH (high acidity), low acid neutralizing capacity, and heightened levels of sulfates and nitrates in the waters of GSMNP," says Owen.

In fact, GSMNP experiences some of the highest acid rain levels in the nation, and nearly half of the total nitrogen in the park comes from dripping cloud water, reported Jim Renfro, chief of GSMNP Air Quality Branch, at a 2005 conference on air quality hosted by UT.

Acid also comes from underground, as water moves through fractured rock—particularly highly acidic Anakeesta formations—disturbed through natural processes or mining.

acid test results

The highest—and steepest—monitoring site in the watershed, as expected, displayed more prominent effects of acid deposition than the lower sites. The upper reaches of the stream are marked by poor soil cover, steep slopes, and a less-permeable rock under layer, which means less interaction between groundwater and surface water. By contrast, the lower, more-moderately pitched sections of the stream were more likely to interact with groundwater, which dilutes and neutralizes some of the waterborne acids.

"The sensitivity of Ramsay Prong to acid deposition has notable ecological implications," says Pike. "Less-hardy fish species, such as native brook trout, may be eradicated from the stream, particularly in the high elevation reaches. Only the very bottom of the basin may prove suitable for these sensitive creatures."

Pike and Owen's research contributed to our understanding of how the surface streams of the Great Smoky Mountains interact with water stored underground and the chemical changes that result. They also demonstrated that limited sampling can be a useful tool in understanding the hydrology of sensitive and protected areas, like GSMNP, where more conventional field techniques would not be permitted.

The more clearly we understand the intermixing of surface and ground water—as well as the complex constituents of the Smoky Mountains' seemingly benign clouds—the better equipped we'll be to protect our region's valuable resources.

“The more clearly we understand the intermixing of surface and ground water the better equipped we’ll be to protect our region’s valuable resources.”

Randall Gentry is director of UT’s Institute for a Secure and Sustainable Environment and an associate professor in UT’s Department of Civil and Environmental Engineering.

Contact him at 865-974-4251, or email rgentry@utk.edu.

COMPILED AND WRITTEN BY
sherry redus

staff citings
2008-2009

ROY ARTHUR

Awards, Appointments, and Other Honors:

Roy Arthur was recognized by USEPA, Region 4, Water Protection Division for outstanding work done in the Beaver Creek Watershed community.

MARY ENGLISH

Awards, Appointments, and Other Honors:

Mary English was reappointed for a third term as a member of the Tennessee Air Pollution Control Board. She was also appointed to a study committee of the National Research Council: the Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption.

WILLIAM FULKERSON

Presentations:

Fulkerson, W. A framework for managing climate change. School of Engineering, Vanderbilt University, March 16, 2009; Howard Baker Center for Public Policy, University of Tennessee, September 26, 2008.

Fulkerson, W. Biocoal. Oak Ridge National Laboratory, February 6, 2009.

JACK GEIBIG

Presentations:

Geibig, J. Use of life cycle inventory data in materials selection: A case study of the natural stone industry. American Institute of Architects' National Convention, San Francisco, California, April 30, 2009.

RANDALL W. GENTRY

In the media:

Randall Gentry was quoted in a March 13, 2009 *BusinessGreen.com* story, "Californian groups clash over geothermal water use."

Randall Gentry was quoted in the Jan/Feb 2009 issue of *Business TN Magazine* in the story, "Water down theory: Georgia continues its push for a sip of Tennessee."

Randall Gentry was interviewed by radio station WKNO-FM in Memphis for a December 2, 2009 story, "The Memphis-Mississippi water fight resumes."

Randall Gentry was quoted in a June 10, 2009 article in the *Chattanooga Times Free Press*, "Tennessee: Turning methane into power."

Randall Gentry wrote an article on graduate research done by ISSE's Amanda McKenna for the summer 2008 issue of UT's *Tennessee Alumnus Magazine*, "From clouds come rain—and more."

Awards, Appointments, and Other Honors:

Randy Gentry was invited to become an Honorary Scientist of the Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources.

The paper, "Temporal variation and persistence of bacteria in streams," by Shesh R. Koirala, Randall W. Gentry, Edmund Perfect, John S. Schwartz, and Gary S. Sayler, in the July-August 2008 issue of *The Journal of Environmental Quality*, was selected for inclusion in the Research Highlights program by the American Society of Agronomy/ Crop Science Society of America/ Soil Science Society of America (ASA/CSSA/SSSA). It was also featured on Science Daily.

UNGTAE KIM

International Research Reports:

Kim, U., J. J. Kaluarachchi, and V. U. Smakhtin. 2008. Climate change impacts on hydrology and water resources of the Upper Blue Nile River Basin, Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI) Research Report 126. 27 p. ISBN 978-92-9090-696-4.

Presentations:

Kim, U. and J. J. Kaluarachchi. Applicability of partially observed runoff data in parameter calibration. Fall Meeting, American Geophysical Union, San Francisco, California, December 17, 2008.

Parker, J., U. Kim, M. Widdowson, and F. Chappel. A practical modeling approach for NAPL dissolution kinetics, microbially-mediated Redox reaction and aquifer-aquitard diffusion to assess remedial options. Fall Meeting, American Geophysical Union, San Francisco, California, December 17, 2008.

Kim, U. and J. J. Kaluarachchi. Analysis of hydrology and water resources of the upper Blue Nile River Basin under climate change. Nile Regional Workshop, Addis Ababa, Ethiopia, June 16-19, 2008.

SHESH KOIRALA

Awards, Appointments, and Other Honors:

The paper, "Temporal variation and persistence of bacteria in streams," by Shesh R. Koirala, Randall W. Gentry, Edmund Perfect, John S. Schwartz, and Gary S. Sayler, in the July-August 2008 issue of *The Journal of Environmental Quality*, was selected for inclusion in the Research Highlights program by the American Society of Agronomy/ Crop Science Society of America/ Soil Science Society of America(ASA/CSSA/SSSA). It was also featured on Science Daily.

Shesh Koirala was appointed an Associate Editor of the *Journal of Hydrologic Engineering*.

ALICE LAYTON

Presentations:

Eldridge, M. L., D. E. Williams, J. Sanseverino, A. C. Layton, J. P. Easter, and G. S. Sayler. Fecal and hormonally-active compound inputs into an East Tennessee watershed. 108th General Meeting of the American Society for Microbiology, Boston, Massachusetts, June 1–5, 2009.

Knappett, P., L. D. McKay, A. Layton, et al. Ultrafiltration performance as determined by recovery of in situ bacteria and viruses. First International Conference on Microbial Transport and Survival in Porous Media, Niagara on the Lake, Ontario, May 10-13, 2009.

DiClaudio, M. L., D. E. Williams, J. Sanseverino, A. C. Layton, J. P. Easter, and G. S. Sayler. Fecal and hormonally active compound inputs into an East Tennessee watershed. Nineteenth Tennessee Water Resources Symposium, Montgomery Bell State Park, Burns, Tennessee, April 15-17, 2009.

Layton, A. C. Endocrine disrupting chemicals: Potential problems in surface waters in Tennessee? Trace Pharmaceuticals in Drinking Water: Analysis, Effect and Removal or Treatment Seminar, Tennessee Division of Water Supply, November 12, 2008.

Knappett, P. S., L. D. McKay, A. Layton, et al. Investigating fecal contamination pathways to an unconfined sandy aquifer in Bangladesh. GSA/ ASA Joint Annual Meeting, Houston, Texas, Oct 5-9, 2008.

McKay, L. D., P. Knappett, and A. Layton. Efficiency of hollow-fiber filtration methods for microbial sampling in groundwater. Canadian Water Network Pathogens Consortium Meeting, Calgary, Alberta, Canada, Sept. 4-5, 2008.

LARRY MCKAY

In the media:

Larry McKay appeared in newspaper articles or television interviews for the Prince George Citizen newspaper and local television concerning his Birdsall-Dreiss Lecture tour.

Larry McKay appeared on the WVLT television show "Inside Tennessee" on January 18 & February 1st, 2009 to discuss environmental impacts of the fly ash spill at the TVA Kingston Fossil Plant.

Larry McKay's research and lecture tour were prominently featured in UT publications from the Alumni Affairs office and the *ISSE Indicator* magazine.

Presentations:

McKay, L. D. Germs and geology. Southeastern center for emerging biologic threats, Conference on factors influencing emerging infectious diseases in the southeast. Emory University, Atlanta, Georgia, June 23-24, 2009.

McKay, L. D., J. Zhuang,and E. Perfect. Colloid transport with advancing wetting fronts in sand: Effects of solution ionic strength and surface tension. First International Conference on Microbial Transport and Survival in Porous Media, Niagara on the Lake, Ontario, May 10-13, 2009.

Knappett, P., L. D. McKay, A. Layton, et al. Ultrafiltration performance as determined by recovery of in situ bacteria and viruses. First International Conference on Microbial Transport and Survival in Porous Media, Niagara on the Lake, Ontario, May 10-13, 2009.

Brown, T., L. D. McKay, and J. McCarthy. Fluorescence characterization of carbonate aquifers in East Tennessee. AGU Chapman Conference, Birmingham, UK, Oct 20-23, 2008.

Knappett, P. S., L. D. McKay, A. Layton, et al. Investigating fecal contamination pathways to an unconfined sandy aquifer in Bangladesh. GSA/ASA Joint Annual Meeting, Houston, Texas, Oct 5-9, 2008.

Donat, R., E. Perfect, R. Gentry, L. D. McKay, and E. van den Berg. Modeling the scale-dependent relationship between effective and slug test-determined saturated hydraulic conductivities. GSA/ASA Joint Annual Meeting, Houston, Texas, Oct 5-9, 2008.

McKay, L. D., P. Knappett, and A. Layton. Efficiency of hollow-fiber filtration methods for microbial sampling in groundwater. Canadian Water Network Pathogens Consortium Meeting, Calgary, Alberta, Canada, Sept. 4-5, 2008.

Continued the GSA Birdsall Dreiss lecture tour with presentations at Northern Illinois University, Iowa State University, University of Northern B.C., University of B.C., University of Ottawa, Queen's University, Laval University, University of Montana–Missoula, GSA Annual Meeting, Grand Valley State University, Michigan State University, Flinders University, University of New South Wales, Australian Nuclear Science & Technology Organization,and the International Association of Hydrogeologists-Australian Division's Annual Conference.

Awards, Appointments, and Other Honors:

Appointed Fellow of the Geological Society of America.

McKay has been appointed Head of the UT Department of Earth and Planetary Sciences

McKay's PhD student, Keshia Koehn, received an NSF Graduate Fellowship in June 2009. The award is for 3 years and the total value (stipend, tuition & travel funds) is approximately $120,000.

ERIC OGLE

Appointments:

Selected to evaluate American Recovery and Reinvestment Act (ARRA) proposals to the Department of Commerce National Telecommunications and Information Administration (NTIA) and the US Department of Agriculture Rural Utilities Service (RUS). The federal government received more than 2,200 applications asking for $28 billion in stimulus funding for new broadband projects across the USA, which is aimed at driving deployment of high-speed Internet access in rural and underserved areas.

JACK PARKER

Presentations:

Liu, X., M. Cardiff, J. Parker, and P. Kitanidis. NAPL remediation cost optimization under uncertainty using a semi-analytic model. American Geophysical Union, Fall Meeting, San Francisco, California, December 17, 2008.

Parker, J. C, U. Kim, M. Widdowson, and F. Chappel. A practical modeling approach for NAPL dissolution kinetics, microbially-mediated redox reactions and aquifer-aquitard diffusion to assess remedial options. American Geophysical Union, Fall Meeting, San Francisco, California, December 17, 2008.

Parker, J., P. Kitanidis, X. Liu , M. Cardiff, U. Kim, D. Becker, A. Bloom, and K. Gorder. Practical cost-optimization of characterization and remediation decisions at DNAPL sites with consideration of prediction uncertainty. SERDP Environmental Symposium, Washington, D.C., December 2008.

Awards, Appointments, and Other Honors:

Journal of Hydrologic Engineering—Groundwater Section Editor.

MILTON RUSSELL

Presentations:

Russell, Milton. The elusive search for consensus. Resources for the Future conference, Energy Policy Challenges: Is the Past Prologue, October 29, 2008.

Awards, Appointments, and Other Honors:

The "Clean Water Act Brief" submission on a case now before the Supreme Court, coauthored by Milton Russell and other economists, was listed on the SSRN Top Ten Download List for both the Public Policy Centers Research Papers category and the Industrial Organization & Regulation Journals category for two months.

JOHN SANSEVERINO

Presentations:

Eldridge, M. L., D. E. Williams, J. Sanseverino, A. C. Layton, J. P. Easter, and G. S. Sayler. Fecal and hormonally-active compound inputs into an East Tennessee Watershed. 108th General Meeting of the American Society for Microbiology, Boston, Massachusetts, June 1–5, 2008.

GARY SAYLER

In the media:

The paper, "Temporal variation and persistence of bacteria in streams," by Shesh R. Koirala, Randall W. Gentry, Edmund Perfect, John S. Schwartz, and Gary S. Sayler, in the July-August 2008 issue of *The Journal of Environmental Quality*, was selected for inclusion in the Research Highlights program by the American Society of Agronomy/ Crop Science Society of America/ Soil Science Society of America (ASA/CSSA/SSSA). It was also featured on Science Daily.

Presentations:

Sayler G. S. and J. M. DeBruyn. Molecular diagnostics: Examples and implications for PAH natural attenuation and bioremediation. Croucher Advanced Study Institute, Innovative Technologies for Soil Remediation Workshop, Hong Kong Baptist University, Hong Kong, PRC, December 2008.

MAGGIE STEVENS

Awards, Appointments, and Other Honors:

Received 2009-2010 Rotary Ambassadorial Scholarship, Outbound Scholar to Brazil.

BRUCE TONN

Research Reports:

Ternes, M., M. Schweitzer, B. Tonn, R. Schmoyer, and J. Eisenberg. 2007. National evaluation of the Department of Energy's Weatherization Assistance Program (WAP): Program year 2006 experimental plan. ORNL/CON-498, Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Tonn, B., L. Dawson, C. Haddad, D. Gray, J. Joice, and C. Oelgoetz. 2008. The next big thing in environmental protection. ISSE Working Paper 2008-01, Knoxville, Tennessee: Institute for a Secure and Sustainable Environment, University of Tennessee, Knoxville.

Tonn, B. and J. Peretz. 2008. Barriers to reducing energy consumption at home and on the road. ISSE Working Paper 2008-02, Knoxville, Tennessee: Institute for a Secure and Sustainable Environment, University of Tennessee, Knoxville.

Presentations:

Tonn, B. An equity-first, risk-based framework for managing global climate change. Conference on Renewable Energy and Green Economy, Shanghai University, October 19-20, 2008.

Healy, K. C. and B. Tonn. Future U.S. energy portfolios: Gain power from new perspectives. Deloitte Touche d-Brief Webinar, October 15, 2008.

Tonn, B. and K. C. Healy. Power from perspective: Potential future United States energy portfolios. Howard Baker Center for Public Policy, University of Tennessee, Knoxville, Sept. 12, 2008.

Tonn, B. The oil shock challenge. Invited presentation to the Tennessee Advisory Committee on Intergovernmental Relations, June 12, 2008.

Tonn, B. Trends, scenarios, and transportation: 2050. Invited presentation to the World Transport Conference, Berkeley, California, July 28, 2007.

In the media:

Bruce Tonn was quoted in a January 2009 article in the *The Earth Times*, More americans focusing on personal energy use to save money in current economic downturn. A White Paper titled "Barriers to reducing energy consumption at home and on the road," co-authored by Tonn and ISSE researcher Jean Peretz, is also mentioned in the article.

BRUCE TSCHANTZ

Presentations:

Tschantz, Bruce A. What about (public) safety at dams? WaterPower XVI Conference, Spokane, Washington, July 2009.

McCubbin-Cain, Sarah and Bruce A. Tschantz. Romancing the profession: Promoting careers in dam engineering and dam safety. WaterPower XVI Conference, Spokane, Washington, July 2009.

In the media:

History Channel Special on June 21, 2009: The crumbling of America. Dr. Tschantz was interviewed by Actuality Productions, Inc. on the December 2008 TVA Kingston Fossil Plant ash spill disaster.

Citizen's Voice, *Knoxville News Sentinel*, June 27, 2009. No reason for secrecy of ash sites. Dr. Tschantz argues for the Federal Government to allow public disclosure of 44 potentially hazardous coal ash storage sites classified by EPA as being potentially hazardous to property and lives because of potential structural instability.

Awards, Appointments, and Other Honors:

Bruce A. Tschantz was appointed in January 2009 by the Commissioner of the Tennessee Department of Environment and Conservation (TDEC) to the Governor's Advisory Oversight Committee on the December 2008 TVA Kingston Fossil Plant ash spill.

CHRISTIAN VOSSLER

Presentations:

Vossler, Christian. Dynamic pollution taxes under regulatory uncertainty. European Association of Environmental and Resource Economists, Amsterdam, The Netherlands, June 24-27, 2009.

Vossler, Christian. Panel participant in session "Environmental Law and Policy." Writing Green: An Environmental Journalism Conference, Knoxville, Tennessee, March 27, 2009.

Vossler, Christian. Dynamic pollution taxes under regulatory uncertainty. Southern Economic Association, Washington, D.C., November 21-23, 2008.

Vossler, Christian. External validity in ambient-based pollution control experiments: A comparison of student subjects to agricultural decision makers. University of Tennessee, Department of Economics, Knoxville, Tennessee, October 2008.

Vossler, Christian. Bridging the gap between the field and the lab: Environmental goods, policy maker input, and consequentiality. European Association of Environmental and Resource Economists, Gothenburg, Sweden, June 25-28, 2008.

Awards, Appointments, and Other Honors:

Promoted to Associate Professor with tenure effective Aug. 1, 2009

CATHERINE WILT

Presentations:

Wilt, C. The green building movement: Opportunities for the Tennessee recycling industry. Keynote speech, 20th Annual Tennessee Recycling Coalition conference, Franklin, Tennessee, February 5, 2009.

In the media:

Cat Wilt was dubbed a "green goddess" and "Environmental Friend" in the August 2008 Knoxville edition of *Skirt Magazine*.

Awards, Appointments, and Other Honors:

Catherine Wilt was recognized for "Extraordinary Community Service by the University of Tennessee at the UT Chancellor's Honors Banquet on April 6, 2009.

Catherine Wilt was named by *Waste & Recycling News* to a list of "25 Influential Women in Environmental Management" who have worked to eliminate gender barriers in their field. The article was published on March 30, 2009.

JIE (JOE) ZHUANG

Presentations:

Zhuang, Jie. Colloid and colloid-facilitated transport of radionuclides in natural sediments. Invited seminar at the Institute of Soil and Water Conservation, Chinese Academy of Sciences, Yangling, Shaanxi, China, July 1, 2009.

Zhuang, Jie, Larry McKay, and Ed Perfect. Colloid transport with advancing wetting fronts in sand: Effects of solution ionic strength and surface tension. First International Conference on Microbial Transport and Survival in Porous Media, Niagara on the Lake, Ontario, May 10-13, 2009.

Awards, Appointments, and Other Honors:

Appointed, Board Member, *Environmental Management and Ecotoxicology*.

Invited to be Overseas Member of Chinese Academy of Sciences International Partnership Project "Watershed Processes and Modeling."

Invited to become an Honorary Professor of Liaoning Academy of Agricultural Sciences, China.

publications

JENNIFER DEBRUYN

DeBruyn, Jennifer M., Thomas J. Mead, Steven W. Wilhelm, and Gary S. Sayler. 2009. PAH biodegradative genotypes in lake erie sediments: Evidence for broad geographical distribution of pyrene-degrading mycobacteria. *Environmental Science & Technology* 43(10): 3467–3473.

Debruyn, Jennifer and Gary Sayler. 2009. Microbial community structure and biodegradation activity of particle-associated bacteria in a coal tar contaminated creek. *Environmental Science and Technology* 43(9): 3047–3053 (doi: 10.1021/es803373y).

WILLIAM FULKERSON

Fulkerson, W. and T. J. Wilbanks. 2008. Adaptation: a natural strategy. In the proceedings of the International Seminar on Nuclear War and Planetary Emergencies, 38th Session, Erice, Italy, August 19-24, 2007.

RANDALL GENTRY:

Bell, A., A. Layton, L. D. McKay, D. Williams, R. W. Gentry, and G. S. Sayler. 2009. Factors influencing the persistence of fecal bacteroides in stream water. *Journal of Environmental Quality* 38:1224-1232 (doi:10.2134/jeq2008.0258).

Franklin, S. B., J. A. Kupfer, S. R. Pezeshki, R. W. Gentry, and R. D. Smith. 2009. Complex effects of channelization and levee construction on western Tennessee floodplain forest function. *Wetlands* 29(2): 451-464.

Franklin, S. B., J. A. Kupfer, S. R. Pezeshki, R. W. Gentry, and R. D. Smith. 2009. Efficacy of the Hydrogeomorphic Model (HGM): A case study from Western Tennessee. *Ecological Indicators* 9(2): 267-283 (doi:10.1016/j.ecolind.2008.05.004).

Ivey, S. S., R. W. Gentry, D. Larsen, and J. L. Anderson. 2008. Case study of the Sheahan Wellfield using 3-H/3-He field data to determine localized leakage areas. *Journal of Hydrologic Engineering* 13(11): 1011-1020.

Ivey, S. S., R. W. Gentry, D. Larsen, and J. L. Anderson. 2008. Inverse application of age-distribution modeling using environmental tracers 3-H/3-He. *Journal of Hydrologic Engineering* 13(11): 1002-1010.

UNGTAE KIM:

Kim, U. and J. J. Kaluarachchi. In press. Hydrologic model calibration using incomplete data: An example from the upper Blue Nile River Basin of Ethiopia. *Hydrological Processes*.

Kim, U. and J. J. Kaluarachchi. In press. Assessment of climate change impacts on water resources of the upper Blue Nile River Basin, Ethiopia. *Journal of American Water Resources Association*.

Kim, U. and J. J. Kaluarachchi. 2008. Application of parameter estimation and regionalization methodologies to ungauged basins of the upper Blue Nile River Basin, Ethiopia. *Journal of Hydrology* 362(1-2): 39-56 (doi: 10.1016/j.jhydrol.2008.08.016).

Kim, U., J. J. Kaluarachchi, and V. U. Smakhtin. 2008. Generation of monthly precipitation under climate change for the upper Blue Nile River Basin, Ethiopia. *Journal of American Water Resources Association* 44(5): 1231-1247 (doi: 10.1111/j.1752-1688.2008.00220.x).

ALICE LAYTON

Bell, A., A. Layton, L. D. McKay, D. Williams, R. W. Gentry, and G. S. Sayler. 2009. Factors influencing the persistence of fecal bacteroides in stream water. *Journal of Environmental Quality* 38:1224-1232 (doi:10.2134/jeq2008.0258).

Hawkins, S. A., A. C. Layton, S. Ripp, D. Williams, and G. S. Sayler. 2008. Genome sequence of the Bacteroides fragilis phage ATCC 51477-B1. *Virology Journal* 5: 97-101.

Henry, T. B., J. T. McPherson, E. D. Rogers, T. P. Heah, S. A. Hawkins, A. C. Layton, and G. S. Sayler. 2009. Changes in the relative expression pattern of multiple vitellogenin genes in adult male and larval zebrafish exposed to exogenous estrogens. *Comparative Biochemistry and Physiology, Part A: Molecular & Integrative Physiology* 154: 119-126.

Sanseverino, J. M. Eldridge, A. Layton, J. Yarbrough, J. Easter, T. W. Schultz, and G. S. Sayler. 2008. Screening of potentially hormonally active chemicals using bioluminescent yeast bioreporters. *Toxicological Sciences* (doi: 10.1093/toxsci/kfn229).

LARRY MCKAY:

Bell, A., A. Layton, L. D. McKay, D. Williams, R. Gentry, and G. Sayler. 2009. Factors influencing the persistence of fecal Bacteroides in stream water. *Journal of Environmental Quality* 38: 1224-1232.

Driese, S. G., Z. Li, and L. D. McKay. 2008. Evidence for high-frequency mid-Holocene climate changes recorded in alluvial floodplain catena, southeastern Tennessee, USA. *Journal of Quaternary Research* 69: 276-291.

Knappett, P., M. B. Emelko, J. Zhuang, and L. D. McKay. 2008. Transport and retention of MS-2 bacteriophage and microspheres in saturated porous media: Impact of ionic strength and grain size. *Water Research* (doi:10.1016/j.watres.2008.07.041)

Mayes, M. A., G. Tang, P. M. Jardine, L. D. McKay, X. L. Yin, M. N. Pace, J. C. Parker, F. Zhang, T. L. Melhorn, and R. Dansby-Sparks. 2009. Influence of sedimentary bedding on reactive transport parameters under unsaturated conditions. *Soil Science Society of America Journal*. In press.

JACK PARKER:

Mayes, M. A., G. Tang, P. M. Jardine, L. D. McKay, X. L. Yin, M. N. Pace, J. C. Parker, F. Zhang, T. L. Melhorn, and R. Dansby-Sparks. In press. Influence of sedimentary bedding on reactive transport parameters under unsaturated conditions. *Soil Science Society of America Journal*.

Park, E. and J. C. Parker. 2008. Effects of mass reduction, flow reduction and enhanced biodecay of DNAPL source zones. *Transport in Porous Media* 73: 95-108.

Parker, J. C., E. Park, and G. Tang. 2008. Dissolved plume attenuation with DNAPL source remediation, aqueous decay and volatilization–Analytical solution, model calibration and prediction uncertainty. *Journal of Contaminant Hydrology* 102: 61-71.

Parker, J. C. and R. W. Falta. 2008. Comparison of alternative upscaled model formulations for simulating DNAPL source dissolution and biodecay. *Advances in Water Resources* 31: 1325-1332.

Tang, G., M. A. Mayes, J. C. Parker, X. L. Yin, D. B. Watson, and P. M. Jardine. In press. Improving parameter estimation for column experiments by multi-model evaluation and comparison. *Journal of Hydrology*.

Tang, G., E. Perfect, E. H. van den Berg, M. A. Mayes, and J. C. Parker. 2008. Estimating effective hydraulic parameters of unsaturated layered sediments using a Cantor bar composite medium model. *Vadose Zone Journal* 7(2): 493-499.

Yan, X., E. Radwan, F. Zhang, and J. C. Parker. 2008. Evaluation of dynamic passing sight distance problem using a finite element model. *Journal of Transportation Engineering* 134: 225-235.

Zhang, F., W. Luo, J. C. Parker, B. P. Spalding, S. C. Brooks, D. B. Watson, P. M. Jardine, and B. Gu. 2008. Geochemical reactions affecting aqueous-solid partitioning metals during titration of uranium contaminated soil. *Environmental Science and Technology* 42: 8007-8013.

Zhang, F., W. Luo, D. B. Watson, J. C. Parker, B. Gu, B. P. Spalding, and P. M. Jardine. 2008. A reactive transport model to simulate uranium immobilization through pH manipulation. *Geochimica et Cosmochimica Acta* 72(12): A1080-A1080.

Zhang, F., G. T. Yeh, J. C. Parker, and P. M. Jardine. 2008. A reaction-based river/stream water quality model: Model development and numerical schemes. *Journal of Hydrology* 348: 496-509.

Zhang, F., L. Jiang, G. T. Yeh, and J. C. Parker. 2008. An adaptive local grid refinement and peak/valley capture algorithm to solve nonlinear transport problems with moving sharp fronts. *Transport in Porous Media Journal* 72: 53-69.

Zhang, F., J. C. Parker, S. C. Brooks, Y.-J. Kim, G. Tang, P. M. Jardine, and D. B. Watson. 2009. Comparison of approaches to calibrate a surface complexation model for U(VI) sorption to weathered saprolite. *Transport in Porous Media* 78: 185–197.

JEAN PERETZ

Peretz, Jean, Sujit Das, and Bruce E. Tonn. 2009. Evaluating knowledge benefits of automotive lightweighting materials R&D projects. *Evaluation and Program Planning* 32(3): 300-309.

JOHN SANSEVERINO

Sanseverino, J, M. Eldridge, A. Layton, J. Yarbrough, J. Easter, T. W. Schultz, and G. S. Sayler. 2008. Screening of potentially hormonally active chemicals using bioluminescent yeast bioreporters. *Toxicological Sciences* (doi: 10.1093/toxsci/kfn229).

GARY SAYLER

Bell, A., A. Layton, L. D. McKay, D. Williams, R. W. Gentry, and G. S. Sayler. 2009. Factors influencing the persistence of fecal bacteroides in stream water. *Journal of Environmental Quality* 38:1224-1232 (doi:10.2134/jeq2008.0258).

Debruyn, J. M., T. J. Mead, S. W. Wilhelm, and G. S. Sayler. 2009. PAH biodegradative genotypes in Lake Erie sediments: Evidence for broad geographical distribution of pyrene-degrading mycobacteria. *Environmental Science & Technology* 43: 3467-3473.

Debruyn, J. M. and G. S. Sayler. 2009. Microbial community structure and biodegradation activity of particle-associated bacteria in a coal tar contaminated creek. *Environmental Science & Technology* 43: 3047-3053

Henry, T. B., J. T. McPherson, E. D. Rogers, T. P. Heah, S. A. Hawkins, A. C. Layton, and G. S. Sayler. 2009. Changes in the relative expression pattern of multiple vitellogenin genes in adult male and larval zebrafish exposed to exogenous estrogens. *Comparative Biochemistry and Physiology, Part A: Molecular & Integrative Physiology* 154: 119-126

Sanseverino, J, M. Eldridge, A. Layton, J. Yarbrough, J. Easter, T. W. Schultz, and G. S. Sayler. 2008. Screening of potentially hormonally active chemicals using bioluminescent yeast bioreporters. *Toxicological Sciences* (doi: 10.1093/toxsci/kfn229).

MAGGIE STEVENS

Slayton, J. D., M. R. Stevens, H. D. Grissino-Mayer, and C. H. Faulkner. 2009. The historical dendroarchaeology of two log structures at the Marble Springs Historic Site, Knox County, Tennessee, U.S.A. *Tree-Ring Research* 65 (1):23-36.

BRUCE TONN

Das, S., B. Tonn, and J. Peretz. 2008. Application of economic evaluation techniques to automotive lightweighting materials research and development projects. *Research Evaluation* 17(2): 133-148.

Peretz, J., S. Das, and B. Tonn. 2009. Evaluating knowledge benefits of automotive lightweighting materials R&D projects. *Evaluation and Program Planning* 32: 300-309.

Poudyal, N., D. Hodges, B. Tonn, and S-H Cho. 2009. Valuing diversity and spatial patterns of open space plots in urban neighborhoods. *Forest Policy and Economics* 11: 194-201.

Tonn, B. 2009. Obligations to future generations and acceptable risks of human extinction. *Futures* 41(7): 427-435.

Tonn, B. 2008. Futures: The next big things. *Futures* 40: 909-912.

Tonn, B. 2008. A methodology for quantifying and aggregating the impacts of environmental scanning leads. *Technological Forecasting and Social Change*75: 595-609.

Tonn, B. 2008. Viewing economics through the prism of sustainable development and self-sufficiency. *In World Future 2008: Seeing the Future Through New Eyes*, 281-302. Bethesda, Maryland: World Future Society.

Tonn, B. 2008. *Review of Engaging the Future: Forecasts, Scenarios, Plans, and Projects*, by Lewis Hopkins and Marisa Zapata. Journal of the American Planning Association 74(1): 139-140.

Tonn, B., K. C. Healy, A. Gibson, A. Ashish, P. Cody, S. Lula, J. Mazur, D. Beres, and A. J. Ritter. 2009. Power from perspective: potential future United States energy portfolios. *Energy Policy* 37: 1432-1443.

Tonn, B. and D. MacGregor. 2009. Individual approaches to futures thinking and decision making. *Futures* 41: 117-125.

Tonn, B. and P. Carpenter. 2008. Technology for sustainability. In *Encyclopedia of Ecology*, 1st Edition, ed. Sven Erik Jorgensen and Brian D. Fath, 3489-3493. Oxford: Elsevier B.V.

CHRISTIAN VOSSLER

Vossler, Christian A. and Mary F. Evans. In press. Bridging the gap between the field and the lab: Environmental goods, policy maker input, and consequentiality. *Journal of Environmental Economics and Management*.

Collins, Jill P. and Christian A. Vossler. In press. Incentive compatibility tests of choice experiment value elicitation questions. *Journal of Environmental Economics and Management*.

Vossler, Christian A., Timothy D. Mount, Robert Thomas, and Ray Zimmerman. In press. An experimental investigation of soft price caps in uniform price auction markets for wholesale electricity. *Journal of Regulatory Economics*.

Suter, Jordan F., Christian A. Vossler, and Gregory L. Poe. 2009. Ambient-based pollution mechanisms: A comparison of homogenous and heterogeneous groups of emitters. *Ecological Economics* 68(6): 1883-1892.

Evans, Mary F., Christian A. Vossler, and Nicholas E. Flores. 2009. Hybrid allocation mechanisms for publicly provided goods. *Journal of Public Economics* 93(1-2): 311-325.

Suter, Jordan F., Christian A. Vossler, and Gregory L. Poe. 2008. Experiments on damage-based ambient taxes for nonpoint source polluters. *American Journal of Agricultural Economics* 90(1):86-102.

JIE (JOE) ZHUANG

Peipei, Zhao, Mingan Shao, and Jie Zhuang. 2009. Fractal features of particle size redistributions of deposited soils on the dam farmlands. *Soil Science* 174 (7): 403-407.

Knappett, Peter S., Monica B. Emelko, Jie Zhuang, and Larry D. McKay. 2008. Transport and retention of a bacteriophage and microspheres in saturated, angular porous media: Effects of ionic strength and grain size. *Water Research* 42(16): 4368-4378.

McCarthy, John F., Jan Ilavsky, Julie D. Jastrow, Lawrence M. Mayer, Edmund Perfect, and Jie Zhuang. 2008. Protection of organic carbon in soil microaggregates via restructuring of aggregate porosity and filling of pores with accumulating organic matter. *Geochimica et Cosmochimica Acta* 72: 4725-4744 (doi:10.1016/j.gca.2008.06.015).

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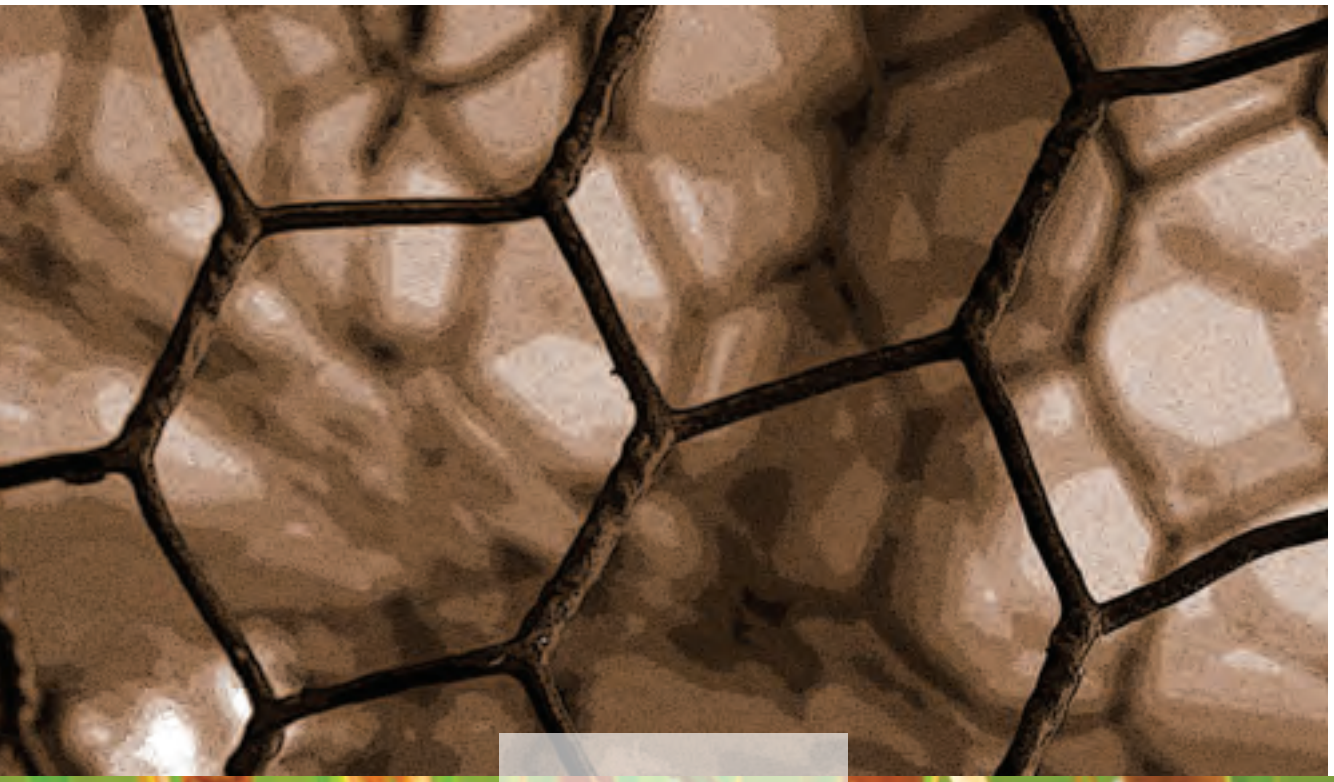

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