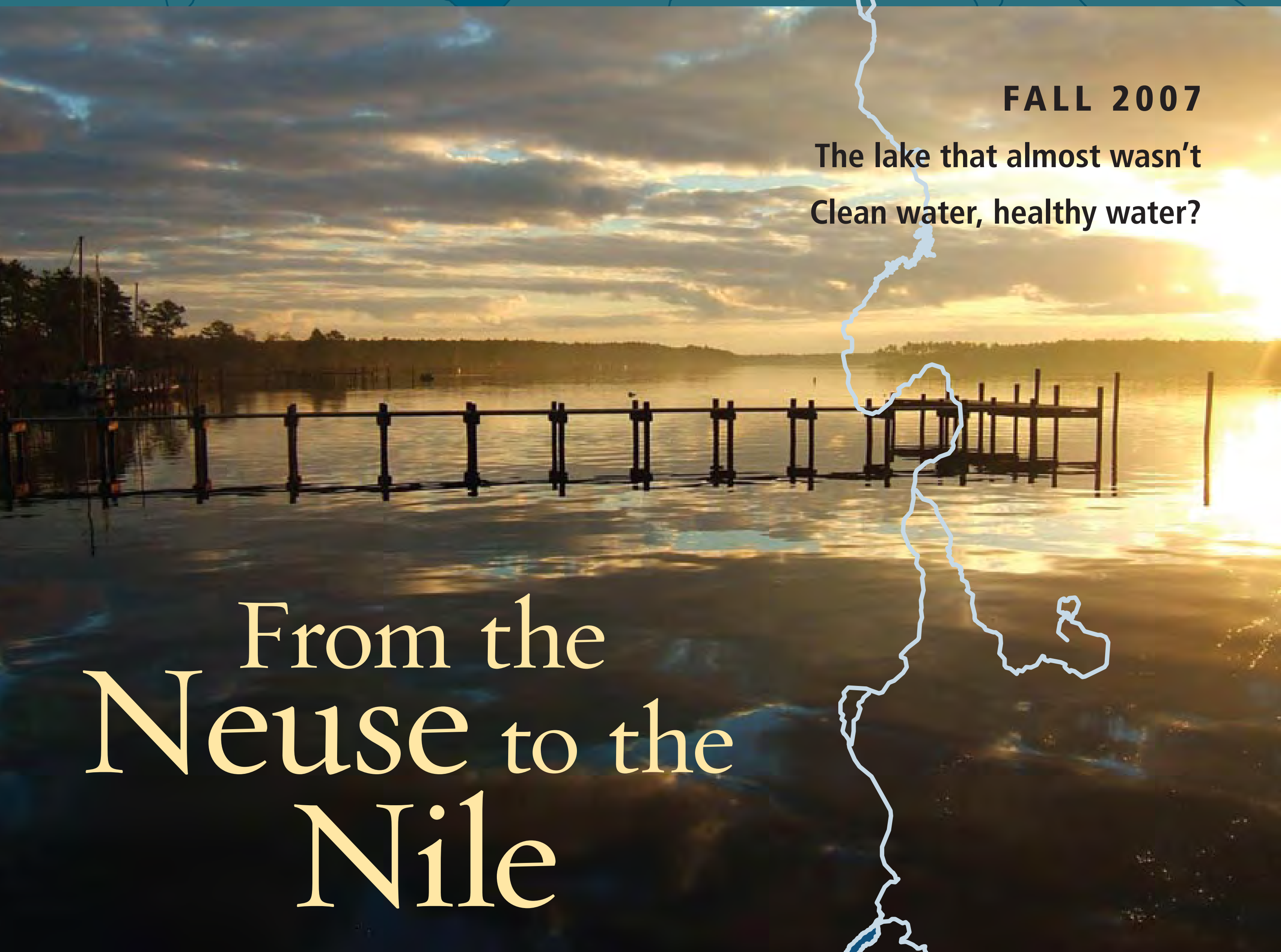
Carolina PUBLIC HEALTH

School of Public Health ▪ The University of North Carolina at Chapel Hill

FALL 2007

The lake that almost wasn't

Clean water, healthy water?



From the Neuse to the Nile

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Carolina PUBLIC HEALTH

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Front cover photo: The sun rises over a pier on Broad Creek near its intersection with the Neuse River close to Whortonsville, N.C. Cover photo by Mark A. Daniels.

Back cover photo: A felucca sails down the Nile River. Propelled by oars and lateen sails, these traditional wooden sailing boats are still in active use as a means of transport in Nile-adjacent cities like Aswan and Luxor, Egypt.

Carolina Public Health staff wish to thank UNC Department of Environmental Sciences and Engineering faculty who reviewed articles in this issue.

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UNC SCHOOL OF PUBLIC HEALTH

from the Dean's desk

DR. BARBARA K. RIMER

I got my public health education at a time when the mantra was that the danger of infectious diseases was quickly fading, and that in the future, chronic diseases would be the greatest public health threats. Yet, in North Carolina and around the world, we face old and new infectious diseases as well as chronic diseases, along with huge environmental threats. Of these threats, among the most far-reaching are those that involve water. Across North Carolina and around the world, crops that were, until recently, the heart of regional economies are withering. In developing nations, families who depended on those crops go hungry and drink from disappearing, often toxic, hard-to-reach water supplies. Here at home, farm incomes are threatened by drought-damaged crops at a time of severely tightened credit. We should not assume that there will always be safe water pouring from our faucets or available for irrigation. Recent droughts in the U.S. Southeast and floods in the Midwest show the unpredictability of water—we have both too much and too little—and as *E. coli* bacteria outbreaks have shown, our potable water supplies are vulnerable. Challenges that face us domestically may seem small when compared to the horrific challenges that confront so much of the world.

Consider the following:

- 1.1 billion people lack access to an improved water supply—approximately one in six people on earth.
- 2.6 billion people worldwide—more than 3 times the U.S. population—lack access to improved sanitation.
- Less than 1 percent of the world's fresh water (or about 0.007 percent of all water on earth) is readily accessible for direct human use.
- A person can live weeks without food, but only days without water.
- Millions of women and children spend several hours a day collecting water from distant, often polluted, sources.
- On average, every $1 spent on water and sanitation frees up $8 in costs averted and productivity gained. That's an astonishing social return on investment.

As if these figures were not sobering enough, the infrastructure that delivers clean water to those of us who have it is old, and it isn't being maintained in far too many parts of the U.S. The U.S. water infrastructure is living on borrowed time.

Changing these conditions—scarce, dangerous drinking water and endangered water infrastructure—demands another sort of infrastructure—a human, intellectual one. Our Department of Environmental Sciences and Engineering can be the heart and the brains of change, both here in North Carolina and around the world. As potentially daunting and disturbing as the picture described above may seem, we have reasons for optimism. That optimism is due to growing worldwide awareness that water is a scarce resource that must be nurtured and protected. I am optimistic because of the students, faculty and staff at the University of North Carolina at Chapel Hill, especially in our Department of Environmental Sciences and Engineering and colleagues elsewhere on campus, including the newly-formed Institute for the Environment. As you read the stories here, I hope you will emerge with new understanding of water, pride in the accomplishments of our faculty, staff and students and a commitment to take action on this issue.

Action might be intensely personal—changing our own water habits, volunteering to work with local or global organizations to clean up or maintain water systems, influencing policies to assure that water is good for all and not only those who can afford it, supporting students, staff and professors, or helping to create our new Global Water Institute. The problems discussed in this issue go to the heart of public health, the heart and safety of communities across North Carolina and around the world. How we deal with them will affect our well-being, quality of life, economies and the health of Planet Earth.

GILLINGS GIFT GIVES MEANS TO ANTICIPATE, ACCELERATE PUBLIC HEALTH SOLUTIONS

BY RAMONA DUBOSE

What do you do with $50 million?

"It's a great challenge to have — the opportunity of a lifetime," says UNC School of Public Health Dean Barbara K. Rimer. "And believe me, we've had plenty of people give us their ideas about how to spend the money."

PHOTO BY TOM FULDNER

The largest gift ever made to the University of North Carolina at Chapel Hill was pledged to the School of Public Health by former biostatistics professor Dr. Dennis Gillings, CBE (Commander of the British Empire), and his wife, Joan, a former staff member at the School. Gillings is now chairman and CEO of Quintiles Transnational Corp., the world's largest pharmaceutical services company.

In recognition of the donation, the School will be named the Dennis and Joan Gillings School of Global Public Health at the University of North Carolina, after a specified percentage of the pledge is paid.

"The words *global public health* reflect the fact that all public health is global, and that global health *is* public health," Dean Rimer says. "We are fully committed to North Carolina and its citizens, but we recognize the interconnectedness of all people in today's world. What we pioneer first in North Carolina may well have application in countries around the world. What we learn and apply in other countries will inform solutions to problems in this state and country. It is in the interests of North Carolina citizens that we help solve global problems, like AIDS, avian flu and lack of access to clean, safe water. We collaborate with and will continue to work with people all over the world to solve public health problems. Health threats do not recognize national borders—*global* also is *local*."

Rimer appointed Julie MacMillan, MPH, to lead Carolina Public Health Solutions—a new initiative funded by Dr. Dennis and Joan Gillings that is dedicated to accelerating public health impact across North Carolina and around the world. An alumna of the School's Department of Biostatistics, MacMillan was an executive at Quintiles for 16 years. For the past two years, she has served as a strategic planning consultant to the dean of the School of Public Health, and for several months, was acting associate dean for external affairs at the School.

"This gift is a great opportunity, and now, we must make the vision come true," MacMillan says. "We are committed to find the keys to accelerating solutions to public health problems across North Carolina and around the world. The Carolina School of Public Health is known for its outstanding research, teaching and practice. This gift is like jet fuel, giving us the means to achieve scale and have even greater impact."

> "This gift is like jet fuel, giving us the means to achieve scale and have even greater impact."

One way the gift will help do this is through creation of competitively selected Gillings Innovation Laboratories (GILs), which will focus concentrated efforts on major public health concerns.

The first Innovation Lab funded is The Center for Innovative Clinical Trials, which will develop methodology, solve practical problems, and educate people within and outside the university about current issues in clinical trials. The purpose is to accelerate and improve trials that, in some cases, are inefficient, lacking or even flawed in their design, or use outdated methods. Dr. Joseph Ibrahim, Distinguished Alumni Professor of biostatistics, one of the world's foremost experts in Bayesian methods, leads this center.

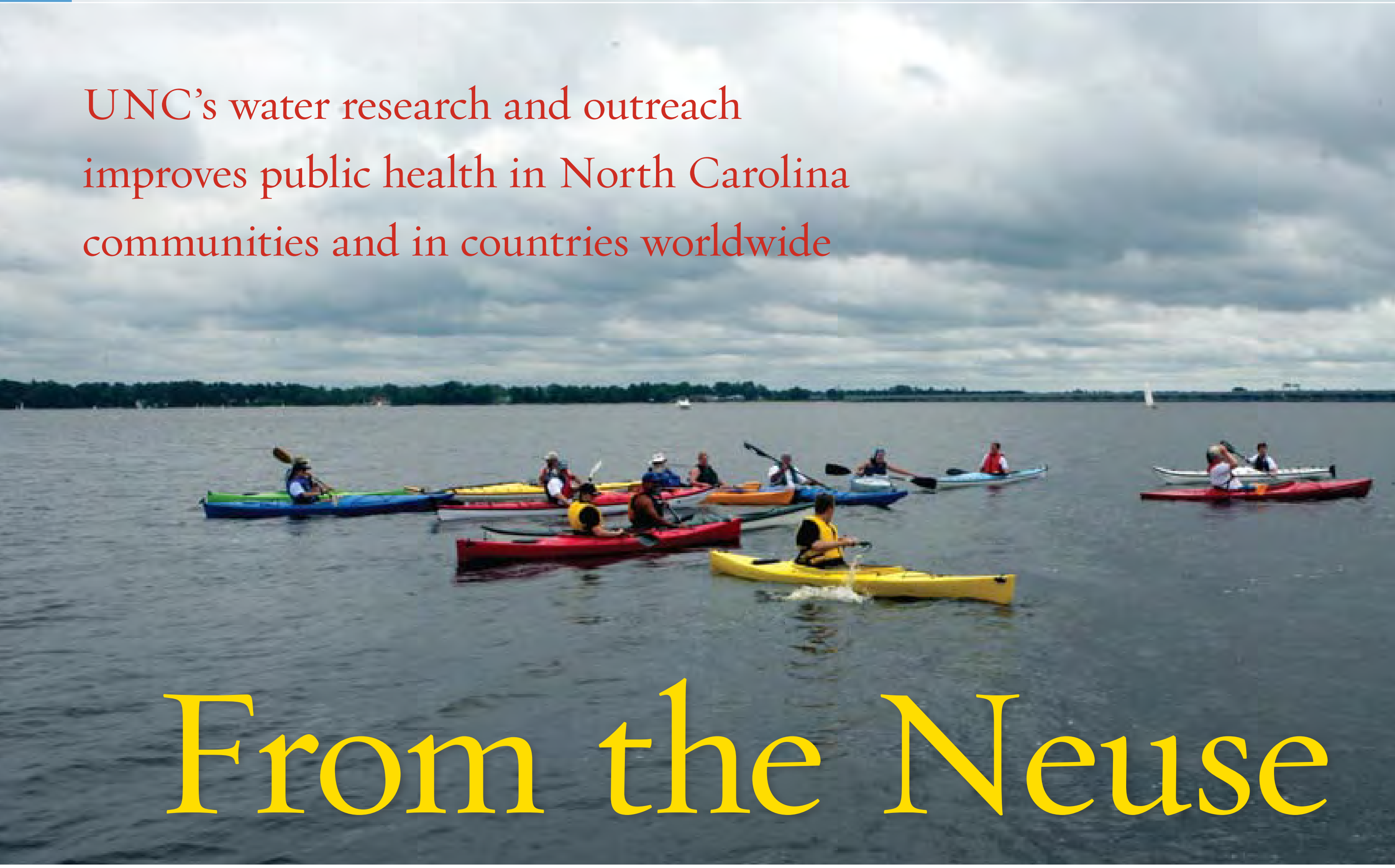
Another Innovation Lab is an interdisciplinary collaboration to devise better ways to bring safe drinking water into homes of low-income populations. Technologies to treat water in the home exist, but they are not always available to people they are intended to help. People often are reluctant to adopt new methods, such as chemicals, heat or filters. This GIL will offer an ideal forum to solve this problem through collaboration between UNC's renowned programs in public health, and the Kenan-Flagler Business School.

"We are very proud and grateful that Dennis and Joan Gillings have made this commitment to the School of Public Health," Dean Rimer says. "I am extremely fond of Dennis and Joan, and have tremendous admiration for their vision of how public health can improve the quality of life here in North Carolina and around the world." ■

PHOTO BY TOM FULDNER

UNC School of Public Health students, faculty, staff and guests (left) gather on February 21, 2007, in the atrium of the School's Michael Hooker Research Center at a reception to celebrate the $50 million pledge made to the School by Dr. Dennis Gillings and his wife, Joan (below and left).

PHOTO BY TOM FULDNER



UNC's water research and outreach improves public health in North Carolina communities and in countries worldwide

From the Neuse

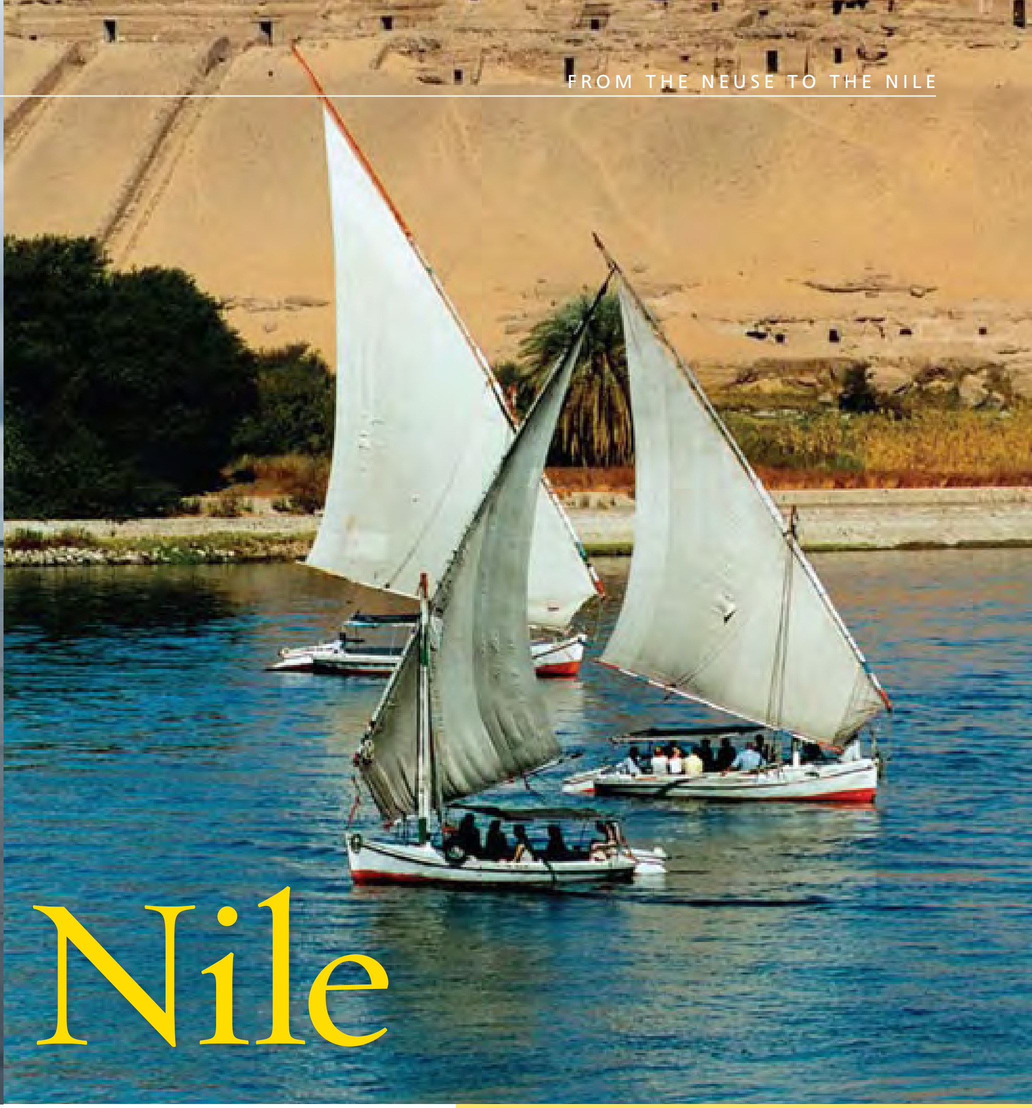
PHOTO BY RICK DOVE

Since Thorndike Saville and Herman Baity started UNC's sanitary engineering program in the 1920s, the University of North Carolina and its School of Public Health have played a crucial role in developing systems to supply, treat and distribute water. The impact of countless projects conducted by UNC School of Public Health faculty, students and staff have been felt, literally, from the Neuse River in North Carolina to the Nile River flowing across northern Africa.

Finding efficient and effective ways to supply and protect water across North Carolina and around the world is a defining mission of the School, particularly through its award-winning Department of Environmental Sciences and Engineering.

Water is a fundamental building block for all plant and animal life—indeed, the life of the planet. The human body cannot function without it to regulate temperature, carry nutrients and oxygen to cells, cushion joints, protect organs and tissues and remove wastes. Without water, we cannot grow and produce food or provide basic sanitation. Today, one billion people worldwide lack access to safe water. Polluted water supplies and poor sanitation and hygiene account for the majority of serious diarrheal diseases. Worldwide more than 1.8 million people (mostly children under age 5) die each year from diarrheal diseases, according to the World Health Organization.

North Carolina is not immune to water problems. For example, the Neuse River is one of eastern North Carolina's most important sources of water for drinking, irrigation and recreation. Tragically, agricultural runoff, filled with fertilizers and animal wastes, along with waste discharges from industries and municipalities, have resulted in fish kills, algal blooms and other signals of significant pollution. Renowned School experts, partnering with UNC's Institute for the Environment and the Coastal Environmental and



to the Nile

Microbiological Processes Lab within UNC's Institute of Marine Sciences in Morehead City, N.C., are searching for ways to renew and protect these precious waters.

Half a world away, UNC researchers are helping the Eastern Nile Council of Ministers assess cooperative water resources management for the world's longest river, which has supported civilizations since ancient times. This work is part of the Nile Basin Initiative, a regional partnership to promote economic development and fight poverty throughout the Nile Basin.

Kayakers circle on the Neuse River where the Neuse and Trent Rivers join in New Bern, N.C. (above, left). UNC researchers are studying the growth, death and travel patterns of pathogens that enter the Neuse River through human influence. The Nile River (above, right) and its tributaries run through Uganda, Ethiopia, Sudan and Egypt. UNC School of Public Health researchers are helping the Eastern Nile Council of Ministers assess cooperative water resources management for the Nile River.

UNC's water experts collaborate with local and global organizations, including the World Health Organization, World Bank, United Nations and its committees (including UNESCO), U.S. Agency for International Development (USAID), Rotary International, water utilities of various sizes, many businesses and national, state and local governments.

"The work being done by water experts at UNC's School of Public Health is strengthening the foundation for economic development and literally saving lives every day," says Dr. John Briscoe, World Bank country director for Brazil, former senior water advisor at the Bank and former professor of water resources at the School. "Beyond finding the technical and engineering solutions for water management, water supply and sanitation, UNC School of Public Health faculty and students are exploring ways to get governments and local people involved and invested in their own water systems so improvements can be maintained and sustained, and countries and communities can thrive." ■

The impact of projects conducted by UNC School of Public Health faculty, students and staff have been felt, literally, from the Neuse River in North Carolina to the Nile River flowing across northern Africa.

H.G. Baity

A pioneering environmentalist

BY LINDA KASTLEMAN

UNC SCHOOL OF PUBLIC HEALTH SANITARY ENGINEERING PROFESSOR DR. HERMAN G. BAITY WAS INTRODUCED BEFORE A SPEECH IN ENGLAND DURING THE 1950s AS "THE MAN WHO HAS DONE THE MOST TO INCREASE THE WORLD'S POPULATION."

"The audience howled with laughter," recalls Baity's son, Bill Baity, "but it is not entirely clear that they got the connection between his efforts to improve water supplies and the great drop in infant mortality."

Baity, who was UNC's second sanitary engineering faculty member, was so convinced that clean water was a public health issue worldwide that he fought to keep the department in the School of Public Health in Chapel Hill even when other engineering programs were moved to North Carolina State's campus in Raleigh when the UNC system was established. While on the faculty, he worked with the state's health department on clean water issues, and eventually became part of President Franklin D. Roosevelt's New Deal programs, bringing clean water and sanitation to people across the country. His work broadened. Soon, Baity became a world-renowned environmentalist, traveling throughout North and South America, Europe, Asia, the Middle East and Africa, addressing issues of water quality and wastewater treatment as a teacher, engineer and consultant to governments, companies and organizations worldwide. The School of Public Health has had strong global health roots since the 1940s.

Baity was born in rural Davie County, N.C., in 1895. While a student at the University of North Carolina at Chapel Hill, he worked closely with Thorndike Saville, a Harvard-educated associate professor of hydraulic and sanitary engineering. Saville saw the need to study North Carolina water resources, and he founded a number of organizations to promote safe water supplies to the state's towns and cities. Baity said that Saville's "ebullient enthusiasm and his devotion to sanitary engineering in the cause of humanity" had inspired him to enroll in the two-year civil engineering undergraduate program, even though he already had completed a bachelor of arts degree. Later, at Saville's urging, Baity went to Harvard for graduate training and became the first person in the United States to earn a doctorate in sanitary engineering.

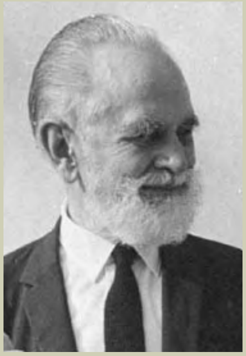


PHOTO COURTESY OF BILL BAITY

Dr. H. G. Baity

Baity returned to UNC in 1926 as a faculty member in sanitary engineering. While he was teaching at UNC, Baity also was an engineer with the N.C. State Board of Health until 1931, and from 1933 to 1936, he was North Carolina's director for Public Works Administration (PWA) efforts in the state. The PWA was part of Roosevelt's "New Deal."

He became dean of UNC's School of Engineering in 1932. When the state combined its three academic institutions (UNC-Chapel Hill, N.C. State College in Raleigh and N.C. Women's College in Greensboro) under one administration, the engineering school was relocated to the N.C. State campus in Raleigh. Baity fought to keep the sanitary engineering section in Chapel Hill, aligning it within the Division of Public Health in the School of Medicine (now the School of Public Health).

As his focus broadened to global water issues, Baity became a consultant to the U.S. Natural Resources Planning Board and the U.S. Public Health Service. He and his family moved to Brazil for 17 months while Baity oversaw a public works project funded by the U.S. government.

From 1952 to 1962, Baity was director of the environmental health division of the World Health Organization in Geneva, Switzerland, traveling to Europe, Asia, the Middle East and Africa to address issues of water quality and wastewater treatment.

In 1962, he returned to teaching at UNC. He retired in 1965 but continued to consult with the U.S. Agency for International Development and spent a year teaching at the University of Tehran, Iran.

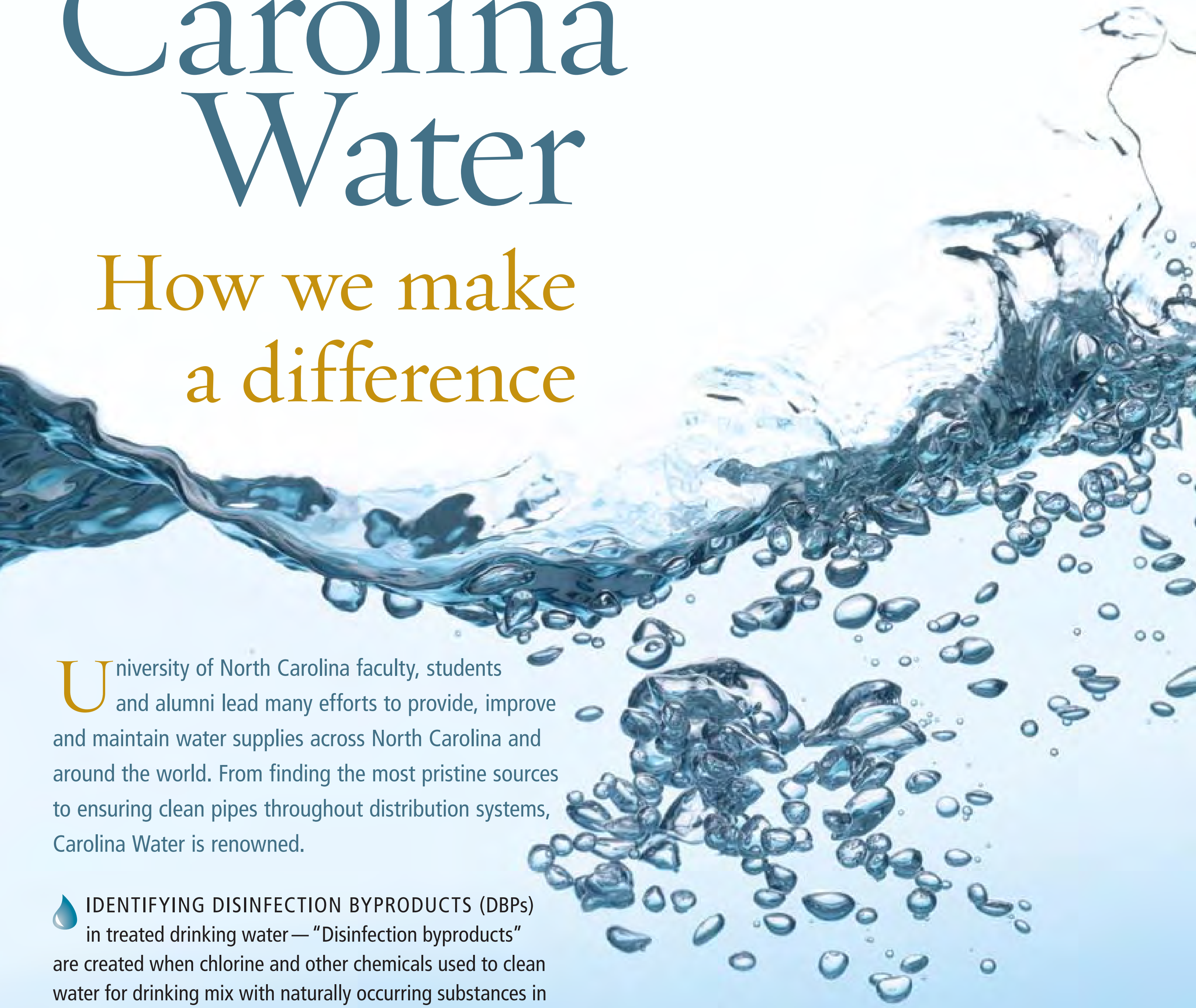
BAITY WAS A WORLD-RENOWNED ENVIRONMENTALIST AND EXPERT ON WATER QUALITY AND WASTEWATER TREATMENT WHO SERVED AS TEACHER, ENGINEER AND CONSULTANT TO GOVERNMENTS, COMPANIES AND ORGANIZATIONS WORLDWIDE.

Baity died in 1975 at age 79. The laboratory building on the UNC campus named in his memory is a fitting, if understated, tribute to this remarkable professor.

Carolina Public Health is grateful to Doug Eyre, Bill Baity and Philip Baity for their assistance with this article. ■

Carolina Water

How we make a difference



University of North Carolina faculty, students and alumni lead many efforts to provide, improve and maintain water supplies across North Carolina and around the world. From finding the most pristine sources to ensuring clean pipes throughout distribution systems, Carolina Water is renowned.

IDENTIFYING DISINFECTION BYPRODUCTS (DBPs) in treated drinking water — "Disinfection byproducts" are created when chlorine and other chemicals used to clean water for drinking mix with naturally occurring substances in the water. Unintended byproducts can be harmful and have been linked with cancers of the digestive and urinary tracts. UNC School of Public Health researchers have led the way in identifying these byproducts, understanding how they are formed and finding ways to control them. We helped the U.S. Environmental Protection Agency and other national and international regulatory authorities establish regulations to minimize DBPs.

ENGINEERING NEW APPROACHES to keep disinfection byproducts (DBPs) from forming during water treatment — As federal regulations that govern the level of DBPs in drinking water were developed and tightened, many water utilities had difficulty meeting these requirements. UNC water experts developed modifications of conventional water treatment practices to reduce the formation of DBPs in water treatment plants and minimize public exposure to these compounds.

COLLABORATING WITH DEVELOPING country communities in planning, building and maintaining their own water systems — In the 1970s and '80s, a number of well-intentioned groups and agencies built water systems in developing countries. They were disheartened when many of these systems were not used or maintained. UNC School of Public Health researchers helped come up with a new policy framework for planning water systems in developing countries. Along with developing country colleagues and students, they are finding ways to measure the needs of communities and their willingness and ability to pay for and maintain water system infrastructures. As communities have become involved in projects, the success rate of water systems implemented in these communities has risen.

EVALUATING WATER QUALITY in U.S. distribution systems to help cities and towns maintain drinking water purity — Water treatment practices in the United States are intended to maintain even levels of disinfectants throughout distribution systems to prevent potentially harmful bacteria from growing in the water at the far ends of the system. Carolina water experts have worked with numerous U.S. water municipalities to find out why bacteria sometimes crop up again in distribution systems and to discover ways to limit re-growth.

DEVELOPING INNOVATIVE WAYS to monitor water quality in lakes, rivers, estuaries and other bodies of water — UNC water experts have developed tests to quickly detect different kinds of bacteria in water that can be harmful to humans and fish. Two such tests can detect the DNA of *Enterococcus* and *E. coli* — bacteria found in fecal matter. Both tests can be completed in less than two hours. UNC water experts also co-direct FerryMon (*www.ferrymon.org*), an automated water-quality monitoring system aboard North Carolina Department of Transportation ferries that cross the Neuse Estuary and Pamlico Sound. FerryMon monitors these waters 365 days a year. UNC researchers collect and analyze water samples to quickly detect when water is polluted and may pose a danger to people or fish.

DEVELOPING WAYS TO REMOVE dangerous chemicals from groundwater — UNC water experts and their colleagues have developed patented processes to remove chlorinated solvents like trichloroethylene (TCE) and perchloroethylene (PCE) from contaminated groundwater. Chemicals left in groundwater can be a threat to public health for hundreds of years if not cleaned up. UNC researchers are working on better technologies to remove these chemicals.

IDENTIFYING PRISTINE WATER sources — The best way to deliver clean, high-quality water to people is to start with the most pristine source possible. UNC water experts have long promoted watershed protection and helped identify the most appropriate sources — in North Carolina, across the United States and abroad. An example is Cane Creek Reservoir in Orange County, N.C., which UNC researchers identified and helped develop.

TESTING HOUSEHOLD WATER filtration systems in developing countries — Students and faculty work with international organizations and businesses to test how well ceramic and biosand filters work in even the poorest homes in developing countries. UNC researchers are among only a few groups to have developed and tested these filters and then proven that using filters improves health. Both kinds of filters reduced the incidence of diarrhea by up to 40 percent. Our research has given international organizations data needed to step up distribution of these filters in developing countries.

PROMOTING WATER RECLAMATION as a way to manage limited water resources and protect public drinking water supplies — UNC water experts have been among the loudest voices advocating for water reuse in the United States and abroad. One strategy advanced by UNC researchers is a "dual distribution system" design with larger pipes to provide high-volume water for non-drinking purposes (like irrigation and fire protection) and smaller pipes to distribute and maintain clean water for drinking.

ESTABLISHING WATER RESOURCE management agreements between North Carolina cities and towns to help them weather water shortages — UNC water experts have been leaders in creating water-sharing agreements between North Carolina municipalities, both in the Research Triangle area and eastern parts of the state, to help communities survive periods of drought.

PHOTO BY DR. ZHANG LU, NANJING INSTITUTE OF GEOGRAPHY AND LIMNOLOGY

Quick—what's polluting the water?

BY ANGELA SPIVEY

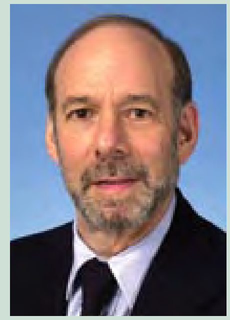
UNC School of Public Health researchers develop faster, better ways to warn when our waterways pose a danger to people or fish

At least a couple things can make a river or ocean unfit. For people, it's microbes — such as disease-causing bacteria, viruses, and protozoan parasites — that contaminate water when a sewer pipe breaks or a hog-waste lagoon fails. For fish, the danger can lie in nutrients, such as nitrogen, which are washed into waterways when wastewater is pumped in or runs off from fertilized land. Excess nutrients can cause overgrowth of algae. Algal blooms can upset the water's balance, causing dangerously low oxygen levels in some parts of the water.

For both these problems—microbial pathogen contamination and excess nutrients—Carolina School of Public Health researchers have been developing better, quicker ways to know when water is polluted.

On Monday, July 1, 2005, the thing you hope never happens did: a main sewer line from Wilmington, N.C., ruptured, spilling several million gallons of raw sewage into Hewletts Creek, a small tributary of the Cape Fear River. Swimming in water contaminated with sewage can cause diarrhea, abdominal cramps and skin infections. The state closed all the waters between the Wrightsville Beach bridge and the Intracoastal Waterway near Peden Point: no fishing, shellfishing or swimming.

To advise the state, scientists at UNC-Wilmington sampled the waters and performed tests for bacteria that are found in sewage, particularly *E. coli*. They also sent some bottom sediment samples to Dr. Mark Sobsey, Kenan Distinguished University Professor of environmental sciences and



Dr. Mark Sobsey

engineering at Carolina's School of Public Health and director of the School's Environmental Virology and Microbiology Laboratory. Sobsey tested the sediment for coliphages, which are viruses that infect *E. coli*. Coliphage levels are an indicator of fecal contamination and are good predictors of the presence of human enteric viruses, such as noroviruses and hepatitis A. Testing sediments was important since contaminants can persist in sediments, re-contaminating surrounding waters when disturbed by swimmers and changing weather conditions.

By July 4, the creek and surrounding waters were still closed. "The state and the local authorities were under tremendous pressure to open the beaches back up," Sobsey says. But he and his colleagues advised them to wait until coliphage levels were back to normal.

How long would that take? "We said, 'We'll have to keep measuring,'" Sobsey recalls.

The problem was, whenever the scientists brought a sample into the lab, with available

PHOTO BY RICK DOVE/WWW.DOVEIMAGING.COM

Aimee Trombley (right), age 6, of Carolina Pines, N.C., goes for a run along the south shore of the Neuse River below Carolina Pines.

Dr. Hans Paerl (previous page) samples a blue-green algae (cyanobacteria) bloom on Lake Taihu, in China, where he conducted research in July 2007. This lake has been impacted by toxic cyanobacterial blooms caused by excessive nutrient deposits from wastewater, industry and agriculture.

tests, it took a full day to get results—another full day of waiting. In the end, the state didn't lift the swimming and fishing advisory until July 10.

Wouldn't it have been great if scientists could sample water in the morning, then have an answer by afternoon?

When such an accident happens again, it's likely they will. Carolina School of Public Health researchers have had some promising successes developing quicker tests to detect fecal contamination.


PHOTO BY LINDA KASTLEMAN

David Love, a 2007 doctoral graduate from the School's Department of Environmental Sciences and Engineering, conducts a laboratory experiment. Love has developed a rapid fecal indicator test that can be used to monitor the microbiological quality of drinking, recreational and shellfishing waters.

Rapid DNA Detection

Rachel Noble, associate professor at the UNC-Chapel Hill Institute of Marine Sciences with an adjunct appointment in the Department of Environmental Sciences and Engineering at Carolina's School of Public Health, has developed rapid tests that detect the DNA of two different kinds of bacteria found in fecal matter—*Enterococcus* and *E. coli*. Both tests can be completed in less than two hours. "That means you could go out to the beach, take a water sample at 7 a.m., and by 9 a.m., you could close that beach with a warning sign if indeed it should be closed," says Noble, who is also on faculty at the UNC Institute for the Environment and directs the Institute's Morehead City (N.C.) Field Site.

Right now the U.S. Environmental Protection Agency (EPA) is evaluating Noble's *Enterococcus* test for approval to use in marine waters. The *E. coli* test isn't far behind, she says.

UNC School of Public Health researchers have developed rapid tests that detect the DNA of two different kinds of bacteria found in fecal matter—*Enterococcus* and *E. coli*. Both tests can be completed in less than two hours.

Noble's tests not only are quicker; they also are less expensive than some rapid assays in development. They avoid using a particular chemistry technique that carries a very high licensing fee. A rapid test isn't much good if the state of North Carolina, for instance, can't afford to use it. "Most water quality agencies operate on very small budgets," Noble says. "They have their hands tied as far as how much they can afford to spend."

Noble is also at work on a rapid test for a bacterium that is native to North Carolina's estuarine and coastal waters—*Vibrio vulnificus*. "This organism has caused deadly wound infections in people who are immunocompromised, such as people who are susceptible to infection, like people with diabetes," Noble says. "There have been some deaths in North Carolina as a result."

The test would be especially useful in waters used for shellfish harvesting. The bacterium can cause disease when people eat infected shellfish or swim in infected waters with an open wound.

A sudden success

Back in Sobsey's lab, David Love, a 2007 doctoral graduate in environmental sciences and engineering, has made a breakthrough in developing a three-hour test to detect coliphages (the viral pathogens that infect *E. coli*).

Before this success, Love had spent nine months looking for a DNA or RNA test for coliphages, without making much headway. Sobsey tells the story. "David came to me and said, 'I'm now thinking I should look at proteins—antigens. Has anybody tried what's known as particle or latex agglutination tests for this?'" Love knew that such tests are used in medical diagnostic labs to detect viruses in human fecal specimens.

PHOTOS BY THE NASA/GSFC/LARC/JPL, MISR TEAM

Satellite images such as these of the North Carolina coast (left) and Pamlico Sound (right), can tell researchers a lot. Satellites combined with bioptical sensors can provide data about the color of water, which can be used to tell scientists about water quality. UNC researchers are working with colleagues to use this technology to identify harmful algal blooms and clarity problems that might adversely affect seagrass, fish and shellfish habitats.

Sobsey told Love the idea was intriguing and had not been tried before. He suggested Love test it in the lab right away.

"Within two weeks, he had positive results: conceptual proof this would work," Sobsey says.

Coliphages are good candidates for a rapid test, because they're viruses which multiply quickly. "One virus makes thousands to tens of thousands within an hour," Sobsey says. But the challenge was developing a way to detect the viral growth almost immediately.

Love's test uses antibodies (immune proteins that attach to the coliphages) that are attached to latex beads. When the antibody-labeled beads are added to a water sample, if coliphages are present in the water, the antibodies (on the plastic beads) will stick to the coliphages. A positive result is easily visible as the plastic beads clump together in just a few seconds. The visual read-out and simple methods make this a good candidate for further development as a field-portable kit.

Love's success came just in time for him to use the research this summer in two studies of beach water quality and swimmer health in Orange County, California, and Fairhope, Alabama, and in his doctoral dissertation, which he defended in April 2007. The initial paper describing the new method was published in the July 2007 issue of *Applied and Environmental Microbiology*, one of the top journals in the field. It can be found online at *http://aem.asm.org/cgi/content/full/73/13/4110*.

Seeing safe water

Dr. Hans Paerl, Kenan Distinguished University Professor of marine and environmental sciences at UNC's Institute of Marine Sciences in Morehead City, N.C., and a joint professor in the Department of Environmental Sciences and Engineering, has long worked to improve sampling and other methods to continually monitor water conditions, so that when water problems occur, officials can intervene quickly.

Paerl co-directs FerryMon (*www.ferrymon.org*), an automated water-quality monitoring system aboard the North Carolina Department of Transportation ferries that cross the Neuse Estuary and Pamlico Sound. FerryMon has been monitoring these bodies of water 365 days a year since 2000. "The ferries are out there every day, intercepting the waters as they move down the Neuse and the Pamlico, and they can give us highly informative data that would not be obtainable with weekly or monthly monitoring programs," Paerl says. "If you suspect there is a problem—for instance, reports of people having rashes or diarrhea after having been in the water—FerryMon would be our early-warning tool to immediately collect space-time intensive samples and analyze them for potentially harmful explosive growths or "blooms" of algae and

> UNC researchers are working with colleagues to combine water sampling data with satellite and aircraft data to develop graphic indicators of water quality that could provide rapid warnings of potential problems due to algal blooms.


PHOTO BY ALAN JOYNER/UNC-CHAPEL HILL INSTITUTE OF MARINE SCIENCES


PHOTO BY DR. HANS PAERL

other water quality indicators that might adversely affect human health."

Paerl also is working with colleagues to combine water sampling data with satellite and aircraft data to develop graphic indicators of water quality that could provide rapid warnings of potential problems due to algal blooms. Doing this requires that Paerl, who's an aquatic ecologist, work with scientists who understand and interpret remote sensing images generated by optical sensors. "Collaborations with others outside your field make the whole greater than the sum of its parts," Paerl says. "We're trying to put our resources together with our partner at the EPA, Ross Lunetta, to address issues such as harmful algal blooms, problems with optimal transparency and clarity problems that might adversely affect seagrass, fish and shellfish habitats."

TIP: Join a community group to help restore a stream or clean a beach. For more information, visit: *www.nrcs.usda.gov/technical/stream_restoration.*

Satellites use bioptical sensors that provide data about the color of the water, which can be used to tell scientists about the water's quality. The color of water isn't random; it's determined in large part by its quality. Chlorophyll, the main pigment in plants and algae, turns the water green. Dissolved organic matter and sediments in the water turn it brown. In the Pamlico, for instance, a NASA satellite produces a snapshot of the water's transparency and clarity every few days. FerryMon provides daily measurements of water quality to calibrate satellite images. A computer can use mathematical algorithms to correlate both sets of data. What emerges are images whose colors correspond to various levels of water quality. So by checking the latest satellite images, researchers could instantly "see" today's water quality.

"We can look at color with a satellite and then use our indicators to calibrate it so we can scale it up for the entire system," Paerl says. "It's called groundtruthing: using real data from our monitoring programs to allow the optical sensors to be scaled up to apply to the entire estuary."

Paerl is seeking funding to try to do that. Because such a tool could provide an early-warning system, he says, "it would be very useful for looking at harmful algal blooms such as red tides or blooms produced by toxic blue-green algae—being able to spot them before they cause serious problems, or warn the public of potential health problems." ■


PHOTO BY RICK DOVE

Dr. Hans Paerl (above, left) filters algae samples incubated with nutrient additions to determine the effects nutrients have on algal bloom formation and growth rates. The samples were taken from Florida's St. Johns River, which periodically experiences algal blooms.

A ferryboat crossing North Carolina's Pamlico Sound (above, left) not only transports people and cars but also gathers water samples as part of FerryMon (*www.ferrymon.org*), an automated water quality system co-directed by Dr. Hans Paerl, UNC Kenan Distinguished University Professor of marine and environmental sciences.

A pelican swoops in for a landing on North Carolina's Neuse River (left).

Storm water run-off

A SIGNIFICANT POLLUTION SOURCE

PHOTO BY PAOLO PIOLI

PHOTO BY SAVE ARDMORE COALITION

UNC researchers explore how microbes behave in storm water

BY ANGELA SPIVEY

The nature of storm water makes it too expensive to treat for contaminants. "It doesn't come along very often, and when it does, there's a lot of it. As a result, building a treatment plant for these large, intermittent flows is often impractical," says Dr. Greg Characklis, associate professor of environmental sciences and engineering at Carolina's School of Public Health.

But storm water is a significant source of pollution.

"The clean water act of 1972 mostly addressed 'point sources' of pollution, such as municipal wastewater and industrial discharges," Characklis says. "We did a reasonably good job of cleaning those up, but we didn't get as much improvement in water quality as we thought we would." The next logical sources of contamination are 'non-point sources,' like storm water runoff, that are more difficult to identify and often contribute to water quality problems. After washing over lawns, driveways and parking lots, storm water runoff can carry with it chemical fertilizers, motor oil residues, even bacteria from pet and wildlife waste, all of which then run into drains that often lead directly to waterways. From there, these contaminants can end up in drinking water reservoirs or favorite swimming spots.

Characklis is working with Dr. Mark Sobsey, Kenan Distinguished University Professor of environmental sciences and engineering, and research assistant professor Dr. Chip Simmons to learn how microbes behave in storm water. They want to know, for example, what proportion of microbes actually stick to dirt and other particles.

After washing over lawns, driveways and parking lots, storm water runoff can carry with it chemical fertilizers, motor oil residues, even bacteria from pet and wildlife waste, all of which then run into drains that often lead directly to waterways. UNC researchers are studying how microbes behave in storm water.

Concerns about this have resulted in federal and state regulations mandating that storm water be treated. In most cases, this involves relatively inexpensive approaches, such as diverting storm water into settling basins. There, in the best case, the icky stuff—dirt, sand and contaminants that stick to them—settles out, leaving cleaner water to flow to the rivers and lakes.

But what about bacteria, which contribute to poor water quality at elevated concentrations and which, in some cases, can make people sick? These organisms are one of the most common non-point source contaminants but are not dense enough to settle out quickly on their own.

"If some of these organisms stick to the dirt and other denser particles, they might be effectively removed by these basins," Characklis says.

Understanding the extent to which these organisms associate with denser particles can be useful when building models for predicting where and when a stream or river will experience high levels of microbial contamination. However, relatively little is known about interactions between microbes and particles in storm water or how these interactions might change once storm water enters other water bodies, Characklis says.

Answering such questions will help them predict how the public's health can be affected by large storms. "These organisms end up in very different places depending on whether or not they're stuck to particles," Characklis says. "Therefore, information on microbe-particle attachment will help us predict where we might have the biggest water quality problems after a storm."

Environmental sciences and engineering graduate students in Characklis' lab, including Leigh-Anne Krometis, a doctoral student, and Patricia Drummey and Adrienne Cizek, both master's students, do the dirty job of sampling from retention basins. "We couldn't do this without the energy and ingenuity of graduate students," Characklis says.

TIP: Use pest management methods in your garden that minimize the use of chemical pesticides—a source of water pollution. If you must use pesticides, do so sparingly in targeted areas, and only when other methods are not successful.

The success of current and past efforts here in North Carolina has more recently led to a project with the New York Department of Environmental Protection, which is interested in tracking microbial movement in water supply reservoirs that serve New York City.

Sobsey is lending his expertise to identify organisms in water. Characklis developed a calibrated centrifugation technique to separate water samples to give a more accurate picture of the fraction of microbes that stick to particles (and may therefore settle out).

Past studies often have used physical filtration, based solely on particle size, as a means of separating particles and attached microbes. But Characklis' separation method takes into account density as well as size. "If you really want to find out about settling behavior, knowing something about both size and density is important," he says.

This work is funded by the N.C. Department of Environment, Health and Natural Resources and the New York City Department of Environmental Protection. ■

PHOTO BY LEIGH-ANNE KROMETIS

Patricia Drummey, a master's degree student in the School's Department of Environmental Sciences and Engineering, samples water from a "wet detention pond" in a new residential area of Durham, N.C. Wet detention ponds are designed to treat storm water runoff so that pollutants do not enter nearby streams that lead to drinking water sources.

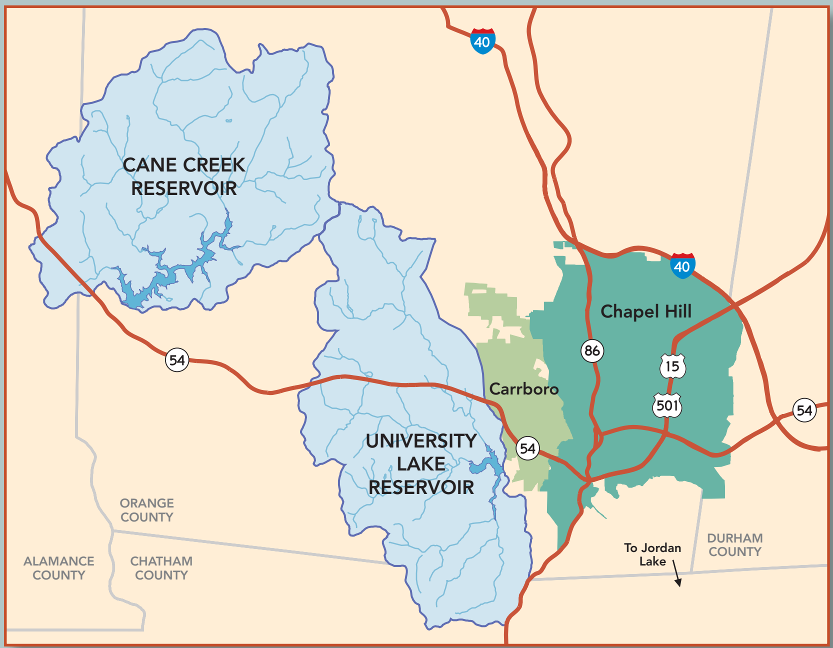
Drink it up!

BY EMILY J. SMITH

Identifying and protecting high-quality drinking water sources crucial for communities worldwide

PHOTO BY LINDA KASTLEMAN

PHOTO BY LINDA KASTLEMAN



MAP COURTESY OF THE ORANGE (COUNTY, N.C.) WATER AND SEWER AUTHORITY

The Cane Creek Reservoir (above) provides water for Chapel Hill and Carrboro, N.C., and the campus of the University of North Carolina at Chapel Hill. The reservoir also offers recreational fishing and boating to visitors. Dr. Daniel A. Okun identified the reservoir site. Okun is UNC Kenan Distinguished University Professor Emeritus of environmental engineering.

The map to the right shows the watershed regions for Cane Creek Reservoir and University Lake Reservoir in light blue.

For more than five decades, Dr. Daniel A. Okun has been a champion of protecting drinking water resources in North Carolina communities and around the world. In his animated, deeply committed style, he urges communities to draw their drinking water from the highest quality sources and make every effort to prevent their pollution. Okun, who served as chair of the Department of Environmental Sciences and Engineering in the UNC School of Public Health from 1955 to 1973, has worked in 89 countries and lectured and provided expert testimony to municipal planning committees and legislative committees, courtrooms, municipal water organizations and city debates in numerous cities throughout the U.S.

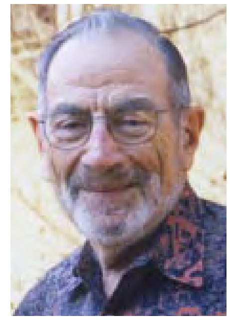
"There's no question that communities should use the highest-quality drinking water sources," Okun says. "Polluted sources should not be used unless other sources are economically unavailable."

In North Carolina, Okun is known for his role in identifying and developing the Cane Creek Reservoir, 11 miles west of Carrboro, N.C. Cane Creek now is the primary water source for the towns of Chapel Hill and Carrboro as well as the University of North Carolina at Chapel Hill.

In 1952, University Lake (located two miles west of Chapel Hill) was the only water supply for the towns, and by extension, the University, which owned the water system. The University and the towns were growing fast, and Okun realized a new water source soon would be needed. The design of University Lake would not allow sufficient expansion to provide enough water for UNC and the surrounding communities. For more than a decade, Okun worked with his students to come up with solutions for a new water supply source.

"It was very difficult to make a decision about the best way to go. At that time, topographical maps for the area west of Chapel Hill didn't exist," Okun says. "Then we got the first print of topographical maps the federal government was making of the area west of Chapel Hill. We saw facing us right there the ideal site. Once we had the new area mapped, it became clear that Cane Creek was a very good option from many standpoints. One important reason was that there was no urban or industrial development out there."

By this time, however, the University's Board of Trustees was making plans to obtain water from nearby Jordan Lake reservoir, being built by the U.S. Army Corps of Engineers at no cost to the state of North Carolina. Built primarily for flood control, Jordan reservoir would also be a water supply and recreation source for nearby communities. Okun argued forcefully against its use as a drinking water source since the reservoir would receive agricultural, industrial and urban discharges from communities, such as Greensboro, that lay upstream.



Dr. Daniel Okun

During this time, opposition to the construction of Cane Creek Reservoir also heated up, Okun says.

"Groups of land developers in the region banded together to persuade the farmers on Cane Creek that a dam on the creek would be detrimental to their financial interests," Okun says. "They took their interests to court which extended construction of Cane Creek Reservoir by almost a decade, raising its cost."

In the end, credit for construction of Cane Creek goes to the University, Okun notes. UNC owned the water utility and decided to yield its water system to a newly created public entity—the Orange Water and Sewer Authority (OWASA). At Okun's recommendation, the University Trustees made building Cane Creek Reservoir a condition for transfer of the water system to OWASA. Cane Creek Reservoir now holds four times more water than the city's original source.

"It took time to build the dam, but now we are assured of having water of high quality for the foreseeable future," Okun says.

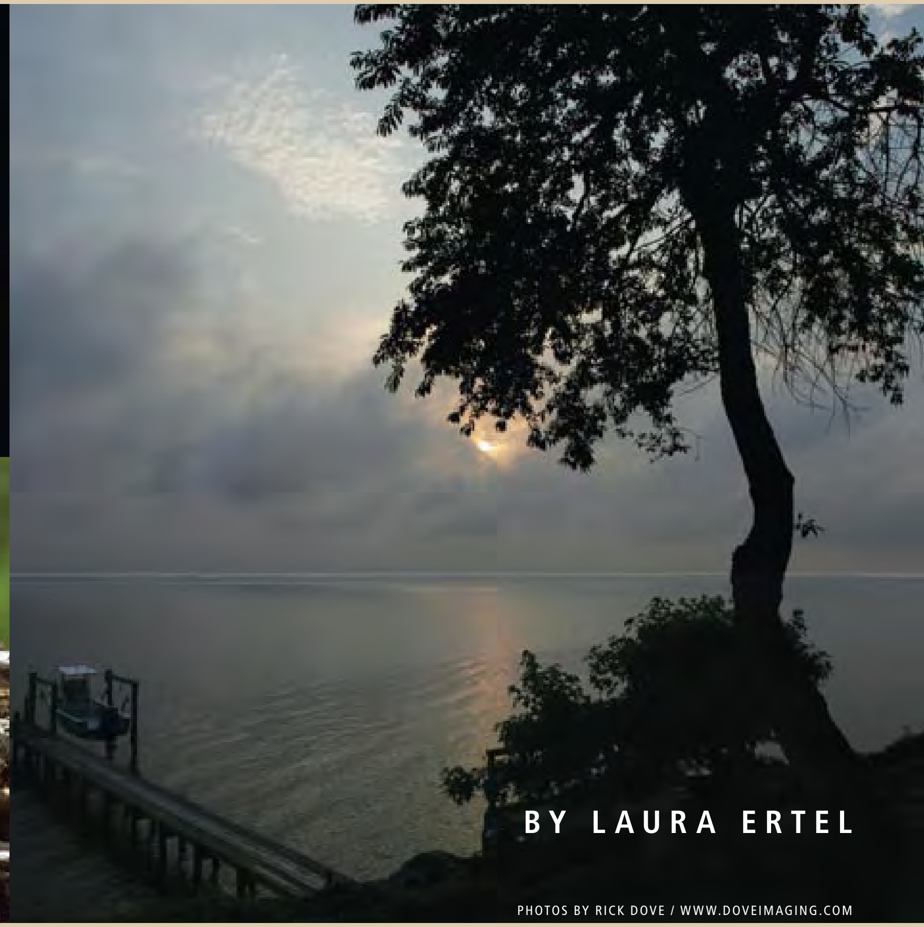
"The Cane Creek Reservoir saga is a perfect example of how our environmental scientists make a difference," says Dean Barbara K. Rimer. "Their laboratories include our rivers, fields and the air we breathe. By tackling the challenging problems faced by our communities, faculty, staff and students in our Department of Environmental Sciences and Engineering have advanced science while making us safer." ■

> "Once we had the new area mapped, it became clear that Cane Creek was a very good option from many standpoints. One important reason was that there was no urban or industrial development out there."

TIP: If you fertilize your lawn, use a phosphorus-free fertilizer or one with a low phosphate level. On every fertilizer bag there is a string of three numbers. The middle number indicates the phosphorus content. Look for one that does not exceed 3. Phosphorus promotes algal blooms which removes oxygen from water and kills fish, aquatic plants and animals.

PROTECTING THE NEUSE RIVER ESTUARY





BY LAURA ERTEL

PHOTOS BY RICK DOVE / WWW.DOVEIMAGING.COM

UNC scientists shed light on how humans are affecting the ecology of the Neuse River Estuary — and our health

The Neuse River Estuary is a valuable resource for North Carolinians: a source for food, recreation and, for many residents, their livelihoods. But with coastal development and the growth of homes and industries along the Neuse River Basin, the ecology of this vital estuary is changing — and those changes may affect our health.

An estuary is the area at the mouth of a river into which ocean tides flow, mixing salt water from the ocean with fresh water from rivers and streams. Estuaries are important habitats for bird and marine life, including many fish and shellfish used for food. Estuaries also act as filters of the water coming downstream and provide a buffer from flooding. The slow-moving, brackish Neuse River Estuary flows into the Pamlico Sound.

UNC researchers are studying the growth, death and travel patterns of pathogens that enter the Neuse River through human influence (e.g., storm water runoff, wastewater spills) and bacteria that are native to estuaries like the Neuse.

Over the past four years, an interdisciplinary team of UNC oceanographers, epidemiologists, environmental modelers and microbiologists have come together on the *Ecology of Infectious Disease* project to understand the changes taking place in the Neuse River Estuary. What happens to pathogens as they are released and travel through the Estuary? What happens to people who come into contact with these pathogens?

Dr. Douglas Crawford-Brown, professor of environmental sciences and engineering in the UNC School of Public Health and director of the UNC Institute for the Environment, is the principal investigator for the *Ecology of Infectious Disease* project, funded by the National Science Foundation and the National Institutes of Health.

Crawford-Brown and fellow UNC researchers have studied the growth, death and travel patterns of pathogens that enter the river through human influence (e.g., storm water runoff, wastewater spills) and bacteria that are native to estuaries like the Neuse. They also have studied the effects of wind, tides and the mixing of salt and fresh water on how far these pathogens travel through the estuary, how long they live, and the impact of excess nitrogen and phosphorus released into the river by nearby hog farms and agricultural fertilizer.

TIP: Use non-hazardous, biodegradable and phosphorous-free laundry and dishwashing detergents and household cleaning products. Phosphorus promotes algal blooms that kill fish, aquatic plants and animals.

Several exciting results already have come out of the project. Applying the same approach they used in rapid detection tests for *Enterococcus* and *E. coli* bacteria (see page 13), the UNC team is fine-tuning a rapid, accurate and sensitive test they have developed for *Vibrio vulnificus*, a potentially harmful bacteria native to estuaries like the Neuse. *Vibrio* infections are generally a problem only for people with compromised immune systems, including the very young or very old. Infections are rare but can be fatal. In the aftermath of Hurricane Katrina, four people died after suffering wounds in flood waters that contained *Vibrio vulnificus*. The test has garnered national interest as a tool to protect public health around waterways.

UNC investigators also shed light on *how* bacteria move through the estuary. "These pathogens 'hitch a ride' with other materials in the water," explains Rachel Noble, a co-investigator on the study and adjunct faculty member at the UNC School of Public Health. "If you're a bacteria, and you attach onto a piece of algae, you'd be more likely to sink, so you won't travel as far as if you attach yourself onto a very small, suspended particle that lets you float down the river."

Another key finding: Likelihood that this contamination will affect humans increases significantly during and after "extreme events" such as heavy rainfall, heavy wind, hurricanes or tropical storms. These events bring more storm water runoff into the river and churn up pathogens that have settled to the bottom so they become re-suspended. Even after the rain or wind subsides, these pathogens continue to float downstream, creating a continuing risk, even as people think it's safe to return to the water.

"We've made great advances through this project, but there's a lot more to do," notes Noble, who holds joint appointments with the UNC Institute of Marine Sciences and the UNC Institute for the Environment. The next step is to use emergency room data to see if there is a link between these findings and incidence of health problems in populations along the Neuse. It's this crucial link to human health that makes this project so special.

Ultimately, findings from the *Ecology of Infectious Disease* project can benefit North Carolinians who live near or visit many of the state's shallow estuaries or who enjoy food harvested from these waterways. While change along our waterways may be inevitable, there may be steps we can take to protect our health and our environment.

Dr. David Weber, professor of epidemiology in the UNC School of Public Health, is a co-investigator on this project. Weber is also professor of medicine and pediatrics in the UNC School of Medicine and medical director of the Departments of Hospital Epidemiology, Occupational Health, and Environmental Health and Safety at UNC Hospitals. ■

Dr. Rachel Noble samples water from the Neuse River Estuary.

PHOTO BY SCOTT TAYLOR

Where will we get the water?

An engineer with an affinity for economics envisions the possibilities

BY ANGELA SPIVEY

PHOTO BY LINDA KASTLEMAN

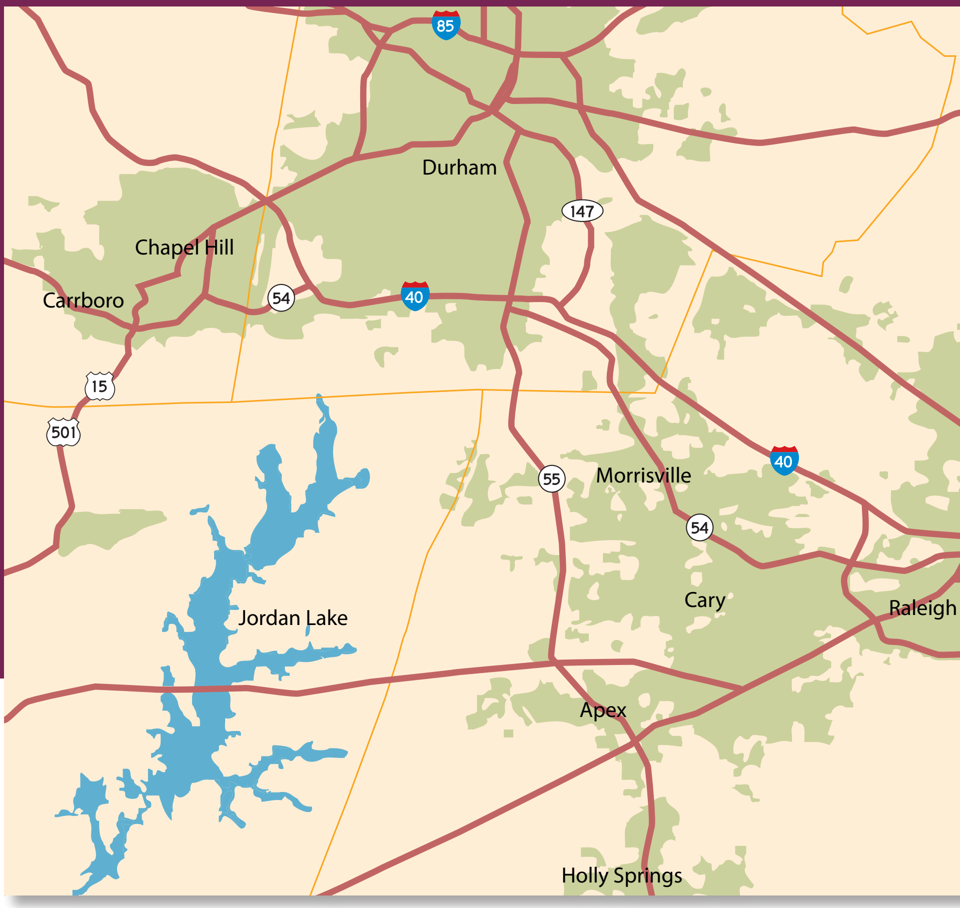
In the rural eastern part of North Carolina, the soil is dark and fertile, and the groundwater historically has been abundant. There, whole towns — like Kinston — get much of their water supply from ground water, pumped up from aquifers.

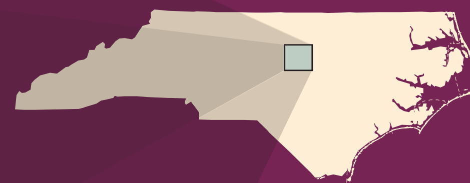
In the more densely-populated Research Triangle region of the state, most people use surface water from man-made reservoirs. While water occasionally has been scarce in the Triangle and other parts of central North Carolina, periods of scarcity often could be managed through relatively simple measures, such as restrictions on lawn watering. However with North Carolina's growing population, water demands everywhere are increasing. Cities and towns are starting to plan how they'll meet their needs in 20 or 30 years.

Enter Dr. Greg Characklis. An associate professor of environmental sciences and engineering, Characklis and some hardworking graduate students have been looking at all the different possibilities, the might-bes and the what-ifs. He crunches the numbers to figure out which water supply scenarios will be most efficient and cost-effective. Then he offers suggestions for rules and plans that towns can put into place when water shortages become reality.

Many of Characklis' papers feature equations that you'd need to be an economist or mathematician to understand. The equations model supply and demand as well as the cost of pumping water out of the ground or a river, treating it, and delivering it. "I fell amongst economists as a PhD student," Characklis says with a laugh.

TIP: If you're concerned about a water issue in your state, write your U.S. Senator, your Congressperson in the U.S. House of Representatives or your representative in your state's legislature. For U.S. Senate information, visit: *www.senate.gov/general/contact_information/senators_cfm.cfm*. For U.S. House of Representatives information, visit: *www.house.gov/writerep*. For state legislature contact information visit: *www.ncsl.org/public/leglinks.cfm*.





Water authorities for Chapel Hill and Durham, N.C., are working with UNC researchers to plan for water usage decades from now. Population in this area is growing while water resources are becoming increasingly scarce. One solution being discussed is to augment water supply in these communities with water from Jordan Lake, piped from the water treatment plant in Cary, N.C.

Jordan Lake (previous page) is located in North Carolina's Piedmont and contains almost 14,000 acres of water.

Drying up down east

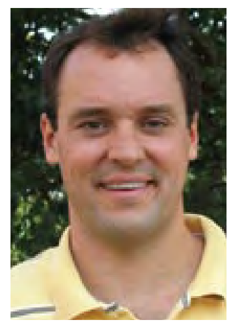
Groundwater is a fairly inexpensive source of water for eastern North Carolina because it's relatively clean, Characklis says. "You pump it up, perform some simple treatment, put it in the pipes, and you're done. Surface water has been exposed to all sorts of things, so it's dirtier, and the treatment required to make it potable is more involved and more expensive."

But if everyone "down east" keeps tapping the groundwater supply faster than the rainfall can replenish it, water levels in the aquifer will drop. This can lead to two problems. First, wells may go dry because they are not deep enough, and drilling deeper wells is expensive. Second, the aquifer formations that store groundwater can lose their ability to do so.

"They've been pumping water out of those (underground) formations faster than water's been percolating down into them as a result of rainfall," Characklis says. "Over time, as you remove the water, some of these strata that hold the water can become weaker and compact, leading to a permanent loss of storage capacity."

In 2001, in response to such problems, North Carolina mandated a plan to wean many communities off ground water over a 16-year period. The state issued permits that, roughly every five years, reduced the amount of ground water each community was allowed to pump. "Some communities are looking at a 75 percent reduction in their pumping capacity," Characklis says.

The logical solution may be to make up the difference with surface water from the Neuse and Tar rivers. But, little surface water treatment capacity exists in the region, and it is expensive to build. Also, many of the towns are located far from a river and would need to build costly pipelines to access surface water. As a solution, Characklis and Brian Kirsch, a doctoral student in environmental sciences and engineering, have proposed a two-pronged approach. This involves building several large regional surface-water treatment plants to serve communities close to the rivers and having those served by these plants transfer their groundwater pumping permits to communities located farther from the rivers.



Dr. Greg Characklis

"We tried to strike this balance between how big to build these surface-water treatment plants, what communities are joining them, and what communities acquire the existing pumping permits to continue using groundwater. The trick is figuring out how to do this for the lowest cost," he says.

Tapping backup water for the Triangle

The Triangle area has its own water worries as more people flock to its combination of universities, high-tech industry and available land. "We get a fair amount of rain (in the Triangle), but we've got a population density that's increasing to the point that water is becoming more scarce," Characklis says. "If growth continues, we're going to have to develop more and more expensive water resources."

When local water authorities for Chapel Hill (Orange County) and Durham plan for water usage 20 to 30 years from now, they foresee having enough water to meet demand most days, but not at times of peak demand, such as hot days when everyone wants to wash their cars and water their lawns.

One solution is drawing water from Jordan Lake, from which the nearby town of Cary gets its water. When the reservoir was built, both the Orange Water and Sewer Authority (OWASA) and Durham were allotted a bit of that capacity for water supply.

In the next 30 years, as water demand continues to grow, OWASA and Durham may need to cash in on their rights to Jordan, if only to put off building new reservoirs as long as possible. “Every year that you delay spending 20 to 30 million dollars results in significant savings,” Characklis says.

Another concern is that no pipeline runs from Jordan Lake to OWASA’s treatment plants. One possible fix: Cary already draws water from Jordan Lake into its treatment plant and has a pipeline for pumping treated water to Durham’s system, which then connects to OWASA’s.

But Cary officials are not likely to treat and send water away without ensuring they have enough to meet the demand of their own residents. As for OWASA and Durham, they want to be reasonably sure that Cary will have the capacity to treat and send water to them when they really need it.

PHOTO BY JEANINE DENITTO

In 2001, North Carolina mandated a plan to wean many communities off ground water over a 16-year period in an effort to prevent ground water resources from drying up. Water from North Carolina’s Tar River (above) may become a water source for some North Carolina communities that traditionally have relied on ground water sources.

UNC researchers are helping create water-sharing agreements between North Carolina municipalities to help communities weather periods of drought.

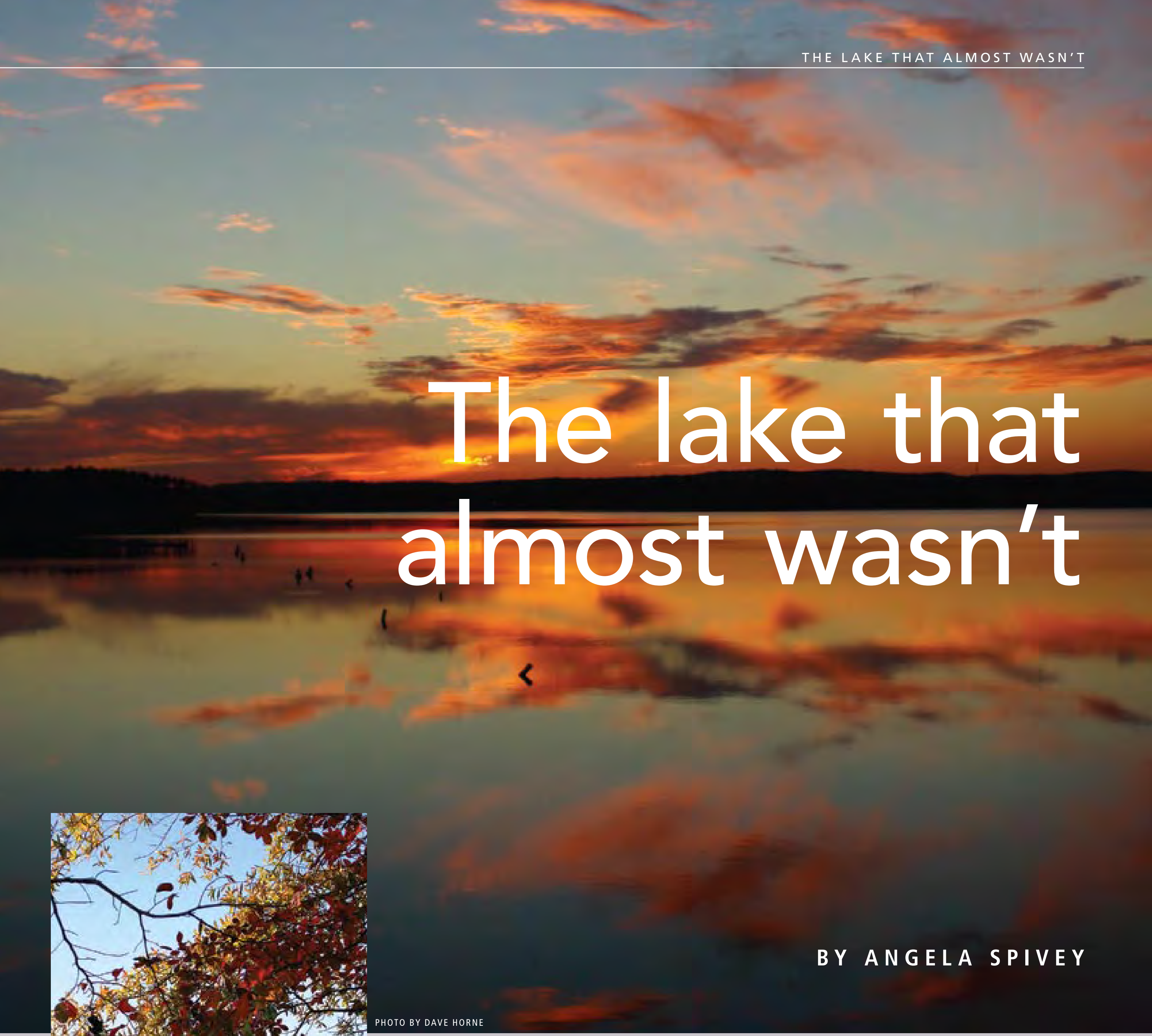
Characklis’ job is to offer these towns the information they need to develop rules for negotiating water transfers in a fair and cost-effective way. “The idea is to try to help these communities develop more sophisticated contracts so that everybody knows when water is available and when it isn’t. There need to be rules in place so everybody’s clear on what they get out of these agreements,” he says.

The calculations get as detailed as the size of water pipes between the towns. “If this pipeline is really big, such that Durham can get a lot of water from Cary very quickly, then it may be willing to let its reservoir levels drop fairly low before it requests water,” Characklis says. “But then, Durham has paid for this big pipe that may sit idle a lot of the time. There are always trade-offs.”

Characklis’ team (which includes Reed Palmer, a 2006 master’s degree graduate from the Department of Environmental Sciences and Engineering, and Casey Caldwell, a master’s degree student in the same department), will complete their analysis next year, at which point they will make recommendations to stakeholders. Characklis notes that Durham and OWASA appear to be seriously exploring the water-transfer idea. “In the long run, our results suggest that having Durham and OWASA access Jordan Lake—a supply that’s already been built—has the potential, depending on how the contracts are written, to be significantly less expensive than having either of them build additional reservoirs themselves.”

For many areas of North Carolina, with all the uncertainties involved—development, climate change—exploring different options for supplying water is becoming a necessity. “A flexible approach—relying not on just one big reservoir, but on a mix of reservoirs, ground water and transfer contracts—may be best,” Characklis says.

The Eastern North Carolina project was funded by the North Carolina Water Resources Research Institute. The OWASA/Durham project was supported by the N.C. Urban Water Consortium as well as the city of Durham, the town of Cary, and OWASA. ■



The lake that almost wasn't

BY ANGELA SPIVEY

PHOTO BY DAVE HORNE

PHOTO BY NICOLE FICERE CALLAHAN

Today, people in the North Carolina Piedmont think of Jordan Lake (almost 14,000 acres of water in Chatham County, 25 miles southwest of Raleigh) as a good place to boat, fish or swim. But in the 1960s and into the '70s, the idea of creating a man-made lake in that spot was a topic of heated debate for the growing Chapel Hill community, and even within the UNC School of Public Health.

The sun sets over Jordan Lake (right). Located 25 miles southwest of Raleigh, N.C., the lake draws people from miles away to boat, fish and swim its 14,000 acres of water. Ospreys and colonies of nesting bald eagles have made the lake their home.

PHOTO BY DAVE HORNE

The lake was intended to prevent another flood like the one that caused $4.7 million worth of damage in Fayetteville, N.C., in 1945. The Army Corps of Engineers proposed to dam the Haw River, creating a reservoir that would come to be named after U.S. Senator B. Everett Jordan.

Predictions about the results varied widely, even among scientists. Some thought the water would be okay for boating and swimming, but not for drinking. Others thought the lake would become a "cesspool" of stagnant water, unfit even for recreational use. That prediction was driven by the fact that the upper parts of the Haw and New Hope rivers, which would feed the lake, received discharges from wastewater treatment plants in Greensboro, Graham, Chapel Hill and other communities.

Dr. Charles Weiss, now emeritus professor of environmental sciences and engineering at the UNC School of Public Health, says he was drawn into the debate because at that time, he and his students had been studying water quality of the major feeder streams to the proposed lake as well as the quality of other existing man-made lakes in the North Carolina Piedmont. Weiss joined the faculty in 1956 and was the first limnologist (scientist who studies lakes, rivers, and streams) in UNC's Department of Environmental Sciences and Engineering.

Weiss believed that most of the predictions about Jordan Lake were too dire. He had been using water of the Haw and New Hope rivers as natural labs to teach his students sampling and analytical methods to assess water quality. His studies over several years indicated that these rivers and Jordan Lake would have the ability to assimilate nutrients in the treated wastewater discharges from the upstream communities. "The proposed reservoir's size and other characteristics were no different than any other man-made lake in the (North Carolina) Piedmont," Weiss says.

Congress authorized the dam in 1963, and construction started in 1970. But the controversy over the projected water quality of Jordan Lake, including a 1971 lawsuit by environmental groups, held up completion of the dam for years. As litigation continued, Weiss was funded by the Army Corps of Engineers and the Water Resources Research Institute to study the reservoir and identify wastewater treatment practices needed upstream to avoid problems that might lead to excess algal growth. He conducted additional studies after the lake was completely filled in 1983, confirming that the lake's

PHOTO BY ANDREW BYWATER

levels of heavy metals and phytoplankton were at or below state standards.

Today, the lake is certainly not a cesspool. It meets North Carolina water quality standards for supply and recreation and was recently described in the New Hope Audubon Society Newsletter as a North Carolina treasure. Although it's best known for recreational uses, Weiss points out that in 2003, the National Audubon Society named Jordan Lake among the top 10 near-city birding areas. "It has colonies of nesting bald eagles and ospreys hovering over the lake fishing," he says. "Its recreational value has exceeded predictions—in 2006, approximately 12.6 million people visited the lake."

Even Triangle-area environmental groups acknowledge the benefits of the lake that almost wasn't. But they are concerned about keeping it clean for all its uses. In January 2007, three groups—the Haw River Assembly, the Southern Environmental Law Center and Environment North Carolina—called Jordan Lake a "vital resource," and asked the state's Environmental Management Commission to do more to protect

PHOTO BY DAWN WRIGHT

it from pollution that has come with ever-increasing development. The groups asked the commission to step up a deadline for

Jordan Lake's recreational value has exceeded predictions – in 2006, it was visited by approximately 12.6 million people.

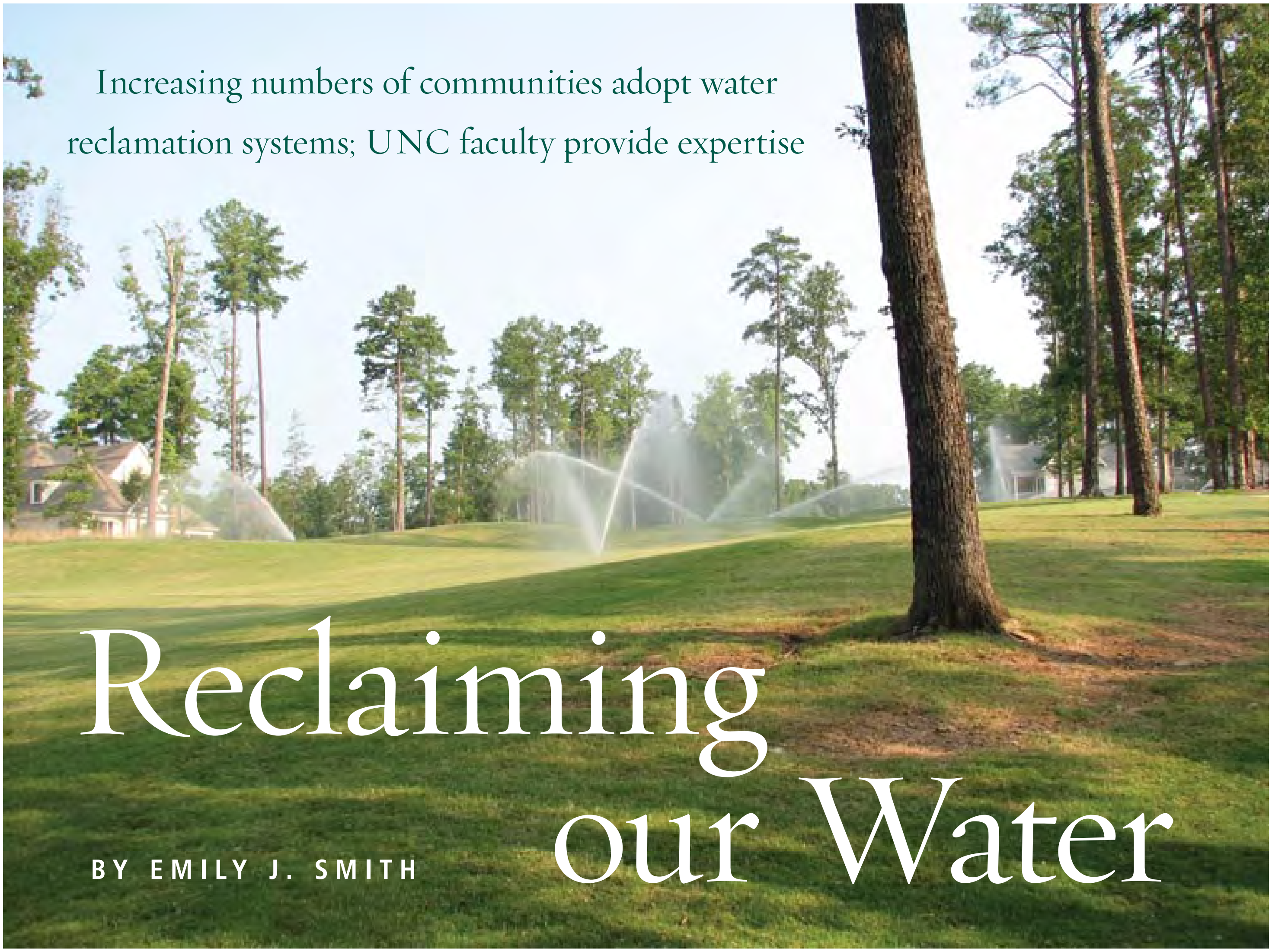
wastewater treatment plants to reduce nitrogen discharges into the lake and also called for specific requirements to protect the lake from polluted storm-water runoff.

The lake does have its problems. As a source of drinking water, "it's challenging to treat," says Dr. Francis DiGiano, professor of environmental sciences and engineering at the School. Even so, the town of Cary and northern Chatham County get their drinking water from the lake. Chapel Hill and Durham are also considering using their allotment of the lake's water if necessary to meet projected long-term demand (see page 22).

TIP: Rather than wash your car in your driveway, on the street or in your yard, take it to a commercial car wash that recycles water to save water and eliminate the runoff of harmful pollutants.

Cary has not had a problem meeting regulations with its water from Jordan. But to do that, they use "ozonation" as the first step of treatment. In this process (which uses ozone gas to treat the water), bacteria and some viruses are killed. But given that chlorine disinfection is also practiced at the end of this water treatment process, the more important roles of ozonation are to significantly reduce offensive taste and odors associated with algal activity in Jordan Lake and allow greater removal of organic material that could otherwise form disinfection byproducts (see page 34). "If you're looking at current-day regulations and modern treatment technology, Jordan Lake has the potential to produce acceptable water quality that meets regulations, which is the case for the town of Cary, although tighter regulatory control of contaminants could make it more challenging to treat the water in the future," DiGiano says.

Northern Chatham County, on the other hand, gets its water from the same location in Jordan Lake but has reported several incidents of unacceptable levels of contaminants. The Chatham plant uses conventional chlorine-treatment technology, which is less costly than ozonation. They may be paying the price in quality. "When you're encouraging urbanization in an area where there is no ample water supply, you are sometimes forced into lesser quality water. This means far more attention needs to be given to high-quality water treatment technologies to protect customers," DiGiano says. ■



Increasing numbers of communities adopt water reclamation systems; UNC faculty provide expertise

Reclaiming our Water

BY EMILY J. SMITH

PHOTO BY LINDA KASTLEMAN

Cities across the United States and throughout the world face water shortages due to drought and increased demand from burgeoning suburbs. Global climate change soon may further exacerbate shortages. To help relieve the problem, increasing numbers of cities, and even small communities, are implementing reclaimed water systems for non-potable (non-drinking) purposes. While perhaps only 3 percent of all wastewater generated in the United States is reused, 30 to 40 percent of the total water demand someday could be met by reclaimed water.

Four decades ago, reclaiming wastewater for landscaping, crop irrigation, fire protection, toilet-flushing or similar uses was controversial. During that era, Dr. Daniel Okun, now Kenan Distinguished University Professor Emeritus of environmental engineering at Carolina's School of Public Health, authored a journal article on the topic and submitted it to a prominent sanitary engineering academic journal. The article was initially refused. The journal editor later agreed to publish it only if rebuttals could be published alongside it. Okun was way ahead, but the times have caught up with him.

"These days, hundreds of cities worldwide have reclaimed water systems and many—especially those in California and Florida—couldn't survive without them," says Okun.

Increasing numbers of U.S. golf courses like The Preserve at Jordan Lake, in Chapel Hill, N.C. (left), use reclaimed water to irrigate the green.

In 1973, he helped plan the first, and one of the largest, municipal reclaimed water systems in the world in St. Petersburg, Fla.

In many communities around the world, reclaimed water also is used in air conditioning cooling towers, industrial processing and construction. It's also used for irrigating golf courses, ball fields and playgrounds, cleaning vehicles, buildings and streets, and creating environmental enhancements such as ponds, fountains and urban streams. Its cost ranges from half to equal the amount paid for drinking water.

Water reuse involves a "dual water system"—a conventional potable (drinking) water distribution system and a similar system for the reclaimed water. Since most U.S. cities already have water supply and wastewater collection and treatment facilities, those adopting reclaimed water systems must retrofit their systems to include more steps of wastewater treatment that can produce higher quality water for reuse. Also, they must construct distribution pipes and a storage tank for the reclaimed water.

Many communities believe the trouble and expense is worthwhile. In predominantly suburban Cary, N.C., reclaimed water is used for lawn irrigation. Some water municipalities, like the Irvine Ranch Water District in California which serves the city of Irvine and portions of Tustin, Newport Beach, Costa Mesa, Orange and Lake Forest, are installing dual systems in new areas and retrofitting older communities with water lines. In fact, California, in 1968, was the first state to adopt standards for water reclamation. The state hired Okun as a consultant for more than a decade during that era to help refine those standards.

"Since California was a leader in this area, they were setting the stage for other states to follow," Okun says. "While I was working with them, the Irvine Ranch Water District became the first U.S. utility to require that all high-rise buildings in the city use reclaimed water for toilet-flushing and air conditioning. I worked with them to set the regulations for this."

Since then, more than 40 states have adopted reclaimed water guidelines or standards.

Some communities have adopted water reclamation systems because of the need for additional water supplies; others have initiated systems to reduce the costs of wastewater disposal. For St. Petersburg, it was both. Since the 1920s, the city had been drawing water from wells in adjacent counties, some as much as 40 miles away. In the 1970s, legislation drawn up by the neighboring counties of Pasco, Hillsborough and Hernando prevented St. Petersburg from developing further municipal wells in those counties. With St. Petersburg's population continuing to grow, the city realized that without other water sources, it soon would be facing water shortages.

TIP: Support projects that use reclaimed wastewater for irrigation and other uses. For more information about reclaimed water, visit: *www.wateruse.org.*

Additionally, new state regulations passed by Florida at that time required stringent removal of nutrients, such as phosphorus and nitrogen, from treated wastewater before it was discharged into Tampa Bay or other surface waters. Upon investigation, city officials realized that it would be less expensive to upgrade their water plants with a reclaimed water treatment system than to meet the state's requirements for discharging into surface waters.

Today, St. Petersburg's reclaimed water system provides 37 million gallons per day to more than 10,600 customers, primarily for lawn irrigation, and significantly contributes to reducing demands on the city's potable water system. Hydrants, pipes and fittings for the potable and non-potable systems are color coded to avoid cross connections between the lines.

Raleigh, N.C., soon will be joining the hundreds of communities nationwide that have implemented reclaimed water systems for non-drinking purposes. The first phase of a 30-year plan is under design. The completed system is expected to have approximately 145 miles of pipeline, two pumping stations and three storage tanks.

> "These days, hundreds of cities worldwide have reclaimed water systems and many – especially those in California and Florida – couldn't survive without them."

Raleigh, like many North Carolina communities, faces increasing periods of drought and water-use restrictions. The new water reclamation system could solve many of the city's water problems. The project is predicted to cost around $86 million, paid with funds from sewer and water fees. City officials say the new system will save the city approximately $18.5 million when fewer gallons of the state's precious drinking water are diverted for other purposes. Furthermore, less demand on the city's potable water system will mean the city won't be forced to search for new water sources or plan for expansions as quickly. ■

CREATING SUSTAINABLE WATER SYSTEMS

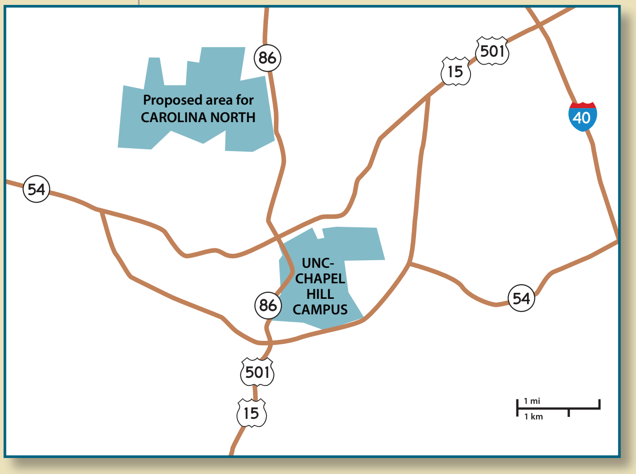
BY EMILY J. SMITH

TIP: Replace your old toilet—the largest water user inside your home. Toilets made before 1993 use 3.5 to eight gallons per flush, while new high-efficiency models use 1.6 gallons or less—up to 80 percent less than older toilets.

The UNC School of Public Health is working with UNC officials and the Orange (County, N.C.) Water and Sewer Authority (OWASA) to explore the possibility of implementing a water research and educational outreach zone in Carolina North—the living and learning campus proposed a few miles north of Carolina's main campus in Chapel Hill, N.C.

The Carolina North draft plan proposes to develop about 25 percent of the 900-acre tract over the next 50 to 70 years. University leaders envision the new campus will be a mixed-transit development, with classrooms, labs, homes, schools, community spaces, offices and commercial buildings in a campus-and-village setting that respects the ecology of the site.

School of Public Health faculty hope the proposed new campus also will be home to a project called One Hydrosphere. With seed money from UNC's Office of Research and Economic Development and the UNC Institute for the Environment, Dr. Mike Aitken, chair of the School's Department of Environmental Sciences and Engineering and Dr. Fran DiGiano, an environmental sciences and engineering faculty member, have begun consideration of this collaborative research, education and public outreach project for sustainable water resource management at Carolina North. They foresee facilities and programs devoted to demonstrating how reclaimed water and cutting-edge technologies can reduce the environmental impact (or "footprint") related to water consumption in new urban centers. Their idea is consistent with UNC Chancellor James Moeser's stated vision of Carolina North as a model of sustainability. "The name 'One Hydrosphere' emphasizes the continuous cycling of water through natural processes and human use. Within this cycle, wastewater reclamation has become an increasingly important component of prudent water resource management," says Aitken.



In May, Aitken and DiGiano convened about 40 individuals, including representatives of higher education groups, private sector, state government, K-12 science educators, UNC facilities planners and OWASA. They met in Chapel Hill for a day-long workshop to plan how the One Hydrosphere concept might be developed and eventually used.

Workshop participants brainstormed about ways One Hydrosphere could foster collaborative research opportunities and serve as an educational outreach facility to promote water quality and sustainable water resource management across the region and state. They also discussed ways to integrate the water conservation and reuse theme into the mission of Carolina North. Doing so would involve constructing a dual water distribution system on the new campus: one for drinking water and one for reclaimed water. A satellite wastewater treatment plant would need to be constructed to prepare the water for reuse.

The reclaimed water could be used for toilet flushing, air conditioning cooling towers, landscape irrigation, and environmental enhancements such as ponds and streams on the new campus.

"If a wastewater treatment plant and dual distribution system were put in Carolina North for water reuse, it would be the first in the country that wasn't retrofitted into a college or university campus, but planned and built from the beginning," says DiGiano. ■

Sharing the Nile

UNC faculty help countries find ways that work

BY EMILY J. SMITH

All along the Nile River in northern Africa, the lives and livelihood of many nations rest on its life-giving waters. Throughout much of history, countries on the Nile have worked largely in isolation to develop and implement their plans for the use, conservation and development of the Nile Basin's resources. Yet, if they work together, they can be much more successful and efficient. Now, in the early 21st century, countries are finding that cooperation can open new opportunities for trade and development.

"This is already happening," says Dr. Dale Whittington, UNC School of Public Health professor of environmental sciences and engineering. "Ethiopia has started to export beef to Egypt. This is in part due to the new atmosphere of friendship and trust in the Nile basin. In the future, one can imagine Ethiopia exporting hydroelectric power to both Egypt and Sudan, and Egypt, bringing capital and technical expertise to irrigation projects in Ethiopia."

Whittington is a consultant to the World Bank and a member of a panel of international experts studying the main water resource issues facing the Eastern Nile countries of Ethiopia, Sudan and Egypt. The panel is examining the pros and cons of different opportunities for joint, multipurpose investments for these countries. This work is part of the Nile Basin Initiative, a regional partnership to promote economic development and fight poverty throughout the Nile Basin.

The Nile—one of the longest rivers in the world—flows north through Sudan and Egypt. Its two tributaries, the White Nile and the Blue Nile, begin in Uganda and Ethiopia respectively. Nile countries face two major water resource challenges, Whittington says: climate change and a limited quantity of surface water in a region with extreme poverty.

"Since completion of the Aswan High Dam (on the Nile), Egypt has enjoyed a secure, reliable supply of water. However, the challenge for Egypt now is how its current water security will be affected by future upstream water withdrawals," Whittington says.

"Meanwhile, Sudan faces three difficulties that Egypt confronted before the completion of the Aswan High Dam: lack of sufficient water storage to supply its irrigation schemes in drought years, damage from floods, and the sedimentation of its reservoirs and irrigation systems." Whittington says that in Ethiopia, the main hurdles are food security and the need to improve the livelihoods of poor rural households. "Like Egypt and Sudan, Ethiopia wants to expand its irrigated agriculture sector," he says, "but the country faces many difficulties, including soil erosion, land degradation and the high cost of infrastructure development."

We hope Egypt, Sudan, and Ethiopia continue to work cooperatively to address the water resources and development challenges of the Eastern Nile Basin, Whittington says. ■

UNC researchers are helping the Eastern Nile Council of Ministers assess cooperative water resources management for the Nile River (right). This work is part of the Nile Basin Initiative, a regional partnership to promote economic development and fight poverty throughout the Nile Basin.

Community Commitment

Key to successful water services

UNC faculty contribute to the development of new policy framework

BY EMILY J. SMITH

Developing countries often struggle to establish reliable water and sanitation services which are critical to improving their economy and the health of their people. Over the years, wealthier nations and charitable organizations have tried to help by building water systems to make life easier and healthier for the people living in these developing areas.

Often, though, these well-intentioned efforts have failed because they did not take into consideration the perspectives of the people they were intended to help, says UNC School of Public Health environmental sciences and engineering professor Dr. Dale Whittington. Whittington has worked with fellow environmental sciences and engineering professor Dr. Donald Lauria and Dr. John Briscoe, former UNC School of Public Health professor of water resources and now World Bank country director for Brazil, to change this dynamic. In the mid-1980s, the three men helped develop a new policy framework for planning water systems in developing countries, one that considers perspectives of the people the water systems serve.

"In the 1960s, '70s, and into the '80s, engineers working with national governments and development banks like the World Bank, the Asian Development Bank, and others, thought that the challenge of providing water for poor communities was simply one of deciding whether people should get conventional systems or so-called "appropriate technologies," says UNC School of Public Health environmental sciences and engineering professor Dr. Donald Lauria. "They decided how large the systems would be and what the designs would be. Communities themselves had little or no voice in the planning process. No one asked them what level of service they wanted, whether they were willing to pay more for a higher level of service, or even if they would use the system if it were built. Hundreds of millions of dollars were being invested, but decisions were based on untested assumptions. Over time, it became apparent that this top-down approach wasn't working. After the systems were constructed, the targeted beneficiaries often didn't use them, and they fell into disrepair."

The reasons people didn't use water systems were varied, Lauria says. Sometimes, fees to connect to systems were too high for them, or water utilities simply were not interested in connecting additional households. Other times, families already had solved their water supply problems by putting in rain catchment systems or private wells.

Lauria, Whittington and Briscoe and their developing country colleagues and students conducted surveys in communities where water improvements are being considered to find out what kinds of improvements people want and how much they were willing to pay for them. Since developing country governments cannot afford to underwrite all costs of maintaining water systems in communities, people who will be using systems must be able to pay for them.

"I don't think it's necessary to do a willingness-to-pay study in every community prior to embarking on a water supply improvement project, but I do believe it's important to understand household demand for improved water services when one designs a rural water supply program or a water and sanitation investment program for a large urban area," Whittington says. "Planners need to understand household demand for improved water and sanitation services so that they don't build something that people do not want or cannot afford. But equally important, planners should not build something that is too modest, when in fact people may want and be able to pay for better services than the government or donor believes is the case."

Briscoe notes that this approach has been part of a revolution in how agencies and professionals think about the provision of services. There have been two major elements to what amounts to a revolution in the way in which services are provided. The first element was to put demand into the equation—to find out what people want and what they are willing to pay for. The second element, influenced by the rise of institutional economics, was to assess how supply organizations worked, and how legal, regulatory and incentives led to better performance.

Progress on water and sanitation infrastructure is expensive. In the best case, it will take years before everyone in developing countries has access to improved water and sanitation services. In the meantime, Whittington and Lauria are studying ability and willingness to pay for typhoid and cholera vaccines to prevent these life-threatening waterborne diseases. Working with the International Vaccine Institute, with funding from the Bill and Melinda Gates Foundation, Whittington and Lauria are studying consumer demand for typhoid and cholera vaccines in India, China, Vietnam, Indonesia, Pakistan and Mozambique.

"Even the poorest countries provide free vaccinations for infants against six infectious diseases: measles, tetanus, pertussis (whooping cough), polio, diphtheria and tuberculosis," Lauria says. "In countries where typhoid and cholera epidemics periodically occur, free vaccinations are usually provided for limited periods, but there are no programs that routinely offer free vaccinations against these diseases because governments cannot afford to do so."

Furthermore, most developing country health departments assume that routine vaccinations for any disease should be offered free of charge, Lauria notes. Hence, since health departments can't offer free typhoid and cholera vaccines, they don't offer them at all.

Still, UNC research in this area has found that the public health pay-off for such vaccine programs could be quite great and that even poor people are willing to pay for vaccines against these diseases.

"Charging user fees for typhoid and cholera vaccines seems to conflict with the public health objective of reducing typhoid and cholera cases, but there is no practical alternative," says Whittington. "These vaccines only last for about three years, and international donors are simply not going to pay for these vaccination programs indefinitely. We need to find a financially sustainable model for making these vaccines available to people who want them." ■

Nepalese women (above) gather to wash clothes, bathe and collect water at community water spigots in Kathmandu, Nepal.

A Nepalese man (left) carries water through the streets of Kathmandu, Nepal.

Dr. Donald Lauria (page 32, top) greets children in the streets of Dakar, Senegal.

Dr. Dale Whittington (page 32, bottom) at work in Kathmandu, Nepal.

Clean water, healthy water?

Assessing the health risks of treated drinking water

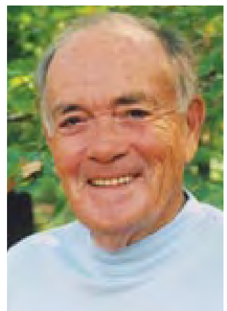
BY KATHLEEN KEARNS

Are substances used to purify drinking water creating other dangers? That's one of the biggest challenges the drinking water industry faces. It's also one that Carolina School of Public Health researchers are taking a lead to investigate.

Many municipalities and companies that provide drinking water add chlorine to disinfect raw water, killing bacteria and other potentially harmful substances found in ground and surface water. As scientists have known for some time, chlorine reacts with substances in the water and forms byproducts that may be harmful to human health. These disinfection byproducts (DBPs) may be linked with bladder cancer, miscarriage and birth defects. Concern over such adverse health effects has grown in recent years as more DBPs have been identified. Officials who operate water treatment facilities grapple constantly with a critical question: how do you remove harmful substances from raw water without creating new harmful substances in the process? The ongoing effort to answer that question depends on research into how DBPs form, how to detect them, which of them are harmful and what health impacts they can have. These questions drive some of the faculty and students in the Department of Environmental Sciences and Engineering.

Finding the source

Carolina School of Public Health Environmental Sciences and Engineering professor Dr. Russell Christman, now retired, did pioneering work on the detection of DBPs and the mechanisms of their formation. His interest was piqued in 1974 when Johannes Rook, a chemist at a water plant in Rotterdam, Netherlands, discovered chloroform (or trichloromethane) in the finished drinking water of that city's water plant. Rook hypothesized it was produced when the chlorine used for disinfection reacted with organic matter—extracts from leaves, bark, soil, etc., from the natural biosphere—in raw water. After U.S. Environmental Protection Agency Scientist John Bellar found chloroform in treated water in Cincinnati, Christman and his colleague, UNC School of Public Health Environmental Sciences and Engineering Professor Dr. J. Donald Johnson, now retired, took up the challenge of discovering why.



Dr. Russell Christman

"Johnson was a world-class chlorine chemist," Christman says. "His interests and mine in natural organic matter were a natural combination. Given the complexity of natural organic matter and the great reactivity of chlorine, we suspected that there were many more products than chloroform and that most of them would be more acidic." Using mass spectroscopy and a modified extraction procedure, Johnson, Christman and their team ultimately found 100 or more DBPs that presented potential health hazards.

"It established that most of the products were in fact polar acids, notably dichloroacetic and trichloroacetic acids," Christman explains. In other words, chlorine's interaction with natural organic matter was creating these compounds. In fact, many of the products did not contain chlorine, but those that did were worrisome from a health perspective. "I was on the National Drinking Water Advisory Council for the Environmental Protection Agency (EPA) at the time and can tell you that our results and those of other scientists were the subject of intense discussion," Christman says. "The quandary that's set up is how to balance the risk between disinfection to control disease transmission and that created by the disinfection process itself. This debate continues today."

Dr. J. Donald Johnson

In 1979, the EPA began regulating trihalomethanes as a group and since then has established regulations for additional DBPs, including the principal chlorinated acids.

Christman and Johnson followed up their work with a series of studies to see whether other water disinfection methods, including using chloramines, chlorine dioxide and ozone, produced DBPs. To varying extents, Christman says, they all do.

The team's work in identifying many of the compounds created in the water disinfection process led both to regulation of those known to be harmful and to investigations by other scientists into whether more of the compounds were dangerous. In National Cancer Institute and EPA studies, a number of compounds turned out to be carcinogenic. Christman says that one compound for which the team can claim joint discovery—MX, a cyclical organic structure

> The work of UNC researchers in identifying compounds created in the water disinfection process led to regulation of compounds known to be harmful and to investigations by other scientists into whether other compounds are dangerous.

that contains chlorine and oxygen—was "off the scale in the toxicology index."

"Fortunately, our work with Dr. Leif Kronberg, a visiting scientist from Abo Akademi University in Turku, Finland, established that MX concentrations in drinking water were a thousand times less than trihalomethanes," Christman says.

EPA began regulating more DBPs in the late 1980s. Epidemiologic studies followed, but they were plagued by the difficulty of determining exactly what was in the water that study subjects were exposed to, given that both their water sources and the day-to-day levels of DBPs in that water would change. "You couldn't sort out statistically whether these products were causing these health problems. Even animal toxicity tests are difficult to interpret as animals are exposed to single compounds, whereas people drink the entire DBP mixture," Christman says.

As other scientists wrestled with the health implications of the discoveries he'd helped make, Christman returned to his original research interest, the structures of natural organic matter. He estimates that only about half of the DBPs created when chlorine reacts with the organic matter in raw water have been identified to date. Since Christman completed his work, other researchers, notably Dr. Susan Richardson of the EPA, have used the latest, most advanced instruments to help identify many more compounds.

Officials who operate water treatment facilities grapple constantly with a critical question: how do you remove harmful substances from raw water without creating new harmful substances in the process? UNC researchers are helping answer that question.

Detecting DBPs

The search for DBPs continues at UNC with interdisciplinary teams. Analytical and environmental chemist Dr. Howard S. Weinberg, assistant professor of environmental sciences and engineering, recently was asked by the EPA to look for what are called "emerging DBPs." An expert toxicology review identified 50 potentially harmful compounds and asked Weinberg and colleagues to develop detection methods, then to look for them in drinking water treatment plants across the country.

The team targeted plants that treat water high in organic material and/or bromide, which often occurs from saltwater intrusion or natural background. Chlorine can react with bromide and natural organic material to produce bromine- or iodine-containing compounds, which may have adverse health impacts even more significant than those associated with currently regulated DBPs.

Weinberg's role was to develop methods to detect emerging DBPs. He and his colleagues tracked occurrence of the 50 chosen compounds. They found 28 additional, previously unidentified DBPs as well. They also discovered, or in some cases confirmed, that while disinfectants other than chlorine (ozone, chlorine dioxide and chloramines) result in lower levels of the regulated DBPs, they create higher levels of several emerging DBPs than chlorine does.

Though their impact on humans remains to be studied, the new compounds are highly toxic in animals, Weinberg says. "It turns out that the iodine-containing species are sometimes hundreds of times more toxic than the chlorine-containing ones, but they're found at much lower levels. That means we need to be developing methods that are much more sensitive for these emerging contaminants. What we are learning is that if we find a toxic compound in drinking water today that doesn't have iodine, we need to be prepared to go look for the iodine form, because it could be orders of magnitude more toxic than the ones we're currently regulating or considering for future regulation."

Weinberg has new projects underway to study implications of emerging DBPs on animal health. Meanwhile, the EPA is using the occurrence data he and his team collected to evaluate the next level of regulation.

"Regulations we have in place now are based on science that took place in the 1970s," Weinberg says. Partly because of the work Weinberg did on the 50 compounds, the EPA is establishing a faster track to regulate chemicals newly found in drinking water. The agency has adopted many of the analytical methods Weinberg developed as the official methods that utilities and government laboratories must follow to generate the data used to regulate the compounds.

Weinberg and his Carolina colleagues also have evolved new procedures to measure some currently regulated haloacetic acids, including those containing bromine. Their methods generate very precise and reliable results, a level of accuracy essential to studying these compounds' impacts on human health.

DBPs and pregnancy loss

Since the 1970s, DBPs have been linked with cancers of the digestive and urinary tracts, particularly bladder cancer. The EPA has set regulatory levels aimed at limiting lifetime exposure. More recently, however, the potential risks of *acute* exposure also have raised concern, particularly in determining if DBPs might contribute to miscarriage or pregnancy loss. In 1998, a large cohort study in Northern California reported that pregnant women who consumed high levels of total trihalomethanes, one of the major classes of DBPs, suffered increased risk of pregnancy loss. In 2000, the EPA and the American Water Works Association Research Foundation asked an interdisciplinary team from Carolina to conduct a five-year, $3.5 million investigation into the issue. The conclusion that DBPs did *not* appear to increase the risk of pregnancy loss surprised the scientific community.

Dr. Philip Singer, director of the Drinking Water Research Center and Daniel A. Okun Distinguished Professor of environmental engineering, led the water side of the study; Dr. David A. Savitz, then chair of the Epidemiology Department at UNC and now professor of community and preventive medicine and director of the Institute for Epidemiology, Biostatistics and Prevention at Mount Sinai School of Medicine, led the reproductive health side. The team also included Weinberg, Dr. Amy H. Herring, associate professor of biostatistics at Carolina's School of Public Health, and Katherine E. Hartmann, then associate professor of epidemiology at the UNC School of Public Health and obstetrics and gynecology at the UNC School of Medicine, and now deputy director of the Institute for Medicine and Public Health at Vanderbilt University Medical Center in Nashville, Tenn.


Dr. Philip Singer

TIP: Minimize the use of garbage disposals and save gallons of water. Throw food waste in a trash can, or better yet, start a compost pile.

The interdisciplinary approach was critical. "To address the concern with drinking water and reproductive health," Savitz says, "it is essential to accurately measure both the exposure of concern (contaminants in drinking water) and the health outcome (pregnancy loss). That calls for a range of expertise, including drinking water engineering and chemistry, obstetrics, epidemiology and biostatistics." Water utility personnel in the study communities also had a key role; they provided technical information, water samples and complementary data.

The team chose three study locations: one where people were exposed to high levels of brominated DBPs, another where they were exposed to high levels of chlorinated DBPs and a third where exposure to either one was very low. The first two systems used chloramines rather than chlorine for disinfection. This led the team to eliminate a problem in previous studies: when chlorine is used for disinfection, DBPs continue to form in the water distribution system, and DBP exposure can vary depending on how far a subject lives from the treatment plant. "People who live very close to where water is treated (with chlorine) are probably exposed to lower levels of DBPs and those far away to higher levels," Singer explains. With chloramine disinfection, DBP exposure is relatively constant throughout the system.

"We had very close monitoring of the subjects' water quality," Weinberg says. "We monitored the trihalomethanes, the haloacetic acids and the total organic halide (a surrogate measure for the sum of all organohalogen-containing DBPs) every week and were able to prove that we were capturing the levels in all the consumers' drinking water." The study team also surveyed how much tap water and how much bottled water people drank and how much exposure they had through showering and bathing.

The epidemiology team interviewed approximately 2,400 pregnant women about the course and outcomes of their pregnancies, conducted early pregnancy ultrasounds and, in some cases, reviewed medical records. By assessing exposure more carefully, and by bringing together environmental engineering and epidemiological expertise, the study team obtained results that were more valid than those of earlier studies. The result was a strikingly different assessment: that high personal trihalomethane exposure did not increase risk of pregnancy loss.


Dr. Andrew Olshan

Work in this area continues. Caroline Hoffman, a doctoral student in epidemiology, is using data from the study to determine whether DBP exposures affect other reproductive health measures, including birth weight, preterm birth and infertility. Dr. Andrew Olshan, chair of the Department of Epidemiology, and colleagues at UNC and the EPA assessed DBPs and male reproductive health, one of the first epidemiologic studies of this relationship. The study generally found no association between exposure to levels of DBPs near or below regulatory limits and decreased semen quality in their study group. Study results are published online in *Environmental Health Perspectives* at *www.ehponline.org/members/2007/10120/10120.pdf.* ■

PHOTO BY REED PALMER

Filtering Water in Homes

UNC faculty and students travel to Cambodia and the Dominican Republic to study technologies to provide clean drinking water to those who need it most.

BY EMILY J. SMITH

In developing countries throughout Asia, Africa and Latin America, clean water can mean the difference between life and death. Worldwide, more than 1.8 million people — mostly children under five — die each year from diarrheal diseases, many of which are caused by unsafe water.

These are facts all too familiar to UNC School of Public Health researcher Dr. Mark Sobsey, Kenan Distinguished University Professor of environmental sciences and engineering. Sobsey works in the Dominican Republic, Cambodia, South Africa, Indonesia, Ghana and Honduras with a team of UNC graduate students and post-docs to test the efficacy of simple household water filtration devices in removing waterborne pathogens and reducing the incidence of diarrheal disease.

"Effective filtration technologies have the potential to bring safe drinking water to many people in developing countries around the world who don't have access to it now," says Sobsey, who also directs the School of Public Health's Environmental Virology and Microbiology Laboratory. "We can tremendously improve people's health and quality of life if we can help them get a reliable source of clean, safe drinking water."

Although point-of-use household water treatment filters have been used in developing countries since the 1990s, objective data on their effectiveness are scant. It's for this reason that Sobsey and his team have been conducting randomized controlled trials and other prospective cohort studies of the effectiveness of different filter designs: porous ceramic filters, and also biosand filters — concrete or plastic containers that filter water through layers of biologically-active gravel and sand. All are designed for use in even the most rudimentary of homes.

Results from studies of the ceramic and concrete biosand filters conducted by the UNC team last year in the Dominican Republic and Cambodia look promising. Both kinds of filters reduced the incidence of diarrhea by up to 40 percent in households that used them.

Dr. Joe Brown, who earned his doctoral degree in environmental sciences and engineering from UNC in August 2007, led the Cambodian studies on the ceramic filters.

Research was conducted in Prek Thmey, a rice-farming village on the Bassac River, 20 kilometers downstream from Phnom Penh — the country's capital — and also downstream from one of the main outfalls for Phnom Penh's open sewers. In this village — the name of which means "new water" in Cambodian — one in five children is sick with diarrhea at any given time.

One-hundred and eighty households in the community participated in the study, conducted in collaboration with Resource Development International, a Cambodian-

A Cambodian man (left) transports clay water filters in a ceramic water filter factory near Phnom Penh run by Resource Development International (RDIC), a Cambodian-based nonprofit organization. UNC scientists are conducting research on the filters in collaboration with RDIC. Ceramic filters are designed so that water passes through them but bacteria and viruses do not. Each filter is tested and sold, at cost, for about $8, along with a plastic bucket to store filtered water and a lid to go over the filter/bucket unit. A Cambodian worker (above) operates a hydraulic press mold that takes wet clay mixture and forms it into a pot-shaped filter. Filters are used in Cambodian homes like the one shown here (right).

based nonprofit organization. Sixty received standard ceramic filters commonly distributed by nongovernmental organizations working in Cambodia; 60 received ceramic filters modified by UNC researchers to increase virus removal; and 60 households (the "control" group) didn't get filters.

"Technologies perform differently in the field than in the lab," says Brown. "For this reason, it's important to consider how they're used when evaluating their effectiveness."

Before distributing filters, UNC researchers collected baseline data from study participants on water quality and source, water sanitation and hygiene practices, and socioeconomic indicators. After the filters were distributed, they made bi-weekly visits to households for 22 weeks, collecting samples of treated and untreated water in each household and health data on family members.

Lab results from the study found that both ceramic-filter designs reduced *E. coli* bacteria by approximately 99 percent and MS2, a virus, by 90 to 99 percent. The presence of *E. coli* indicates the possible presence of fecal contaminants in a water sample and when ingested, pathogenic strains of it and similar pathogenic bacteria like *Salmonella*, *Campylobacter* and *Shigella* species are common causes of diarrhea.

Ceramic water filters are designed so that filtered water flows into an enclosed five-gallon plastic bucket with a side tap to dispense clean water.

"The filters are not as effective as boiling water, but because filtered water is stored securely, it is less likely than boiled water to get re-contaminated by people putting their hands or utensils into it," says Brown.

In fact, safe water storage is one of the bonuses of these household water treatment filters.

"Village-scale water systems are great, but if people don't have a tap in the house, they're going to be out collecting water in a bucket and bringing it back to be stored. That's where it gets contaminated," says Brown.

Brown has been intensely involved in researching filters. In 2006, he also conducted a study, funded by UNICEF and the World Bank, to explore the effectiveness of ceramic water filter use in households that had received one between 2002 and 2006 from development organizations working in that area.

"Two nongovernmental organizations in Cambodia have put tens of thousands of these filters into households over the past four years, and UNICEF said, well, we'd really like to invest in this technology, but we need to know how effective they've been," says Brown, explaining the reasoning for the study.

Brown started the project by getting a list of all households that had received ceramic water filters from these organizations over the past four years. From that list, he randomly selected 600 households across three provinces to participate in the study. Of these, 506 households were located, up to four years after receiving filters.

"People who had more of an awareness of water and sanitation issues were more likely to continue using the filters," says Brown. "Also, people who had bought their own filters were more likely to continue using them — they were more invested in the technology. A lot of people who had been given filters weren't using them."

PHOTO BY DR. JOE BROWN

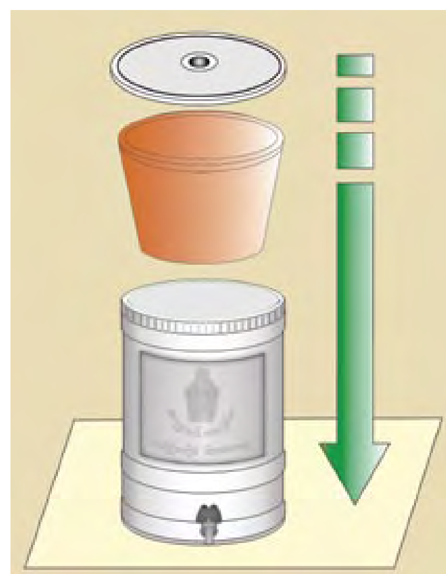


DIAGRAM BY MICKEY SAMPSON

Chhoun Bunnara (above, left) a Cambodian research colleague working with UNC scientists, shows a man how to use a ceramic filter. The man lives in the west-central Cambodian village of Kampong Lourng, a floating village on Tonle Sap Lake.

Water passes through the porous ceramic filter (diagram above) into a plastic receiving container, where it is dispensed via a tap to prevent re-contamination of the water.

In a second part to this study, 80 of the 506 participating households still using their filters were matched with 80 households in a control group living in similar circumstances who had never had filters. In comparing the two groups, the study found that the group using filters had about 50 percent fewer cases of diarrheal disease than those without filters.

A similar study of concrete biosand filter use in Cambodia is underway, directed by Kaida Liang, who earned her master's degree in environmental sciences and engineering from UNC in August 2007. Those study results are due later this year.

Biosand filter use in the Dominican Republic

UNC research on the efficacy of concrete biosand filters is also ongoing in the Dominican Republic.

An initial field study of their effectiveness began in 2005 when UNC School of Public Health researchers recruited approximately 180 households in two villages near Bonao, Dominican Republic, to participate in the project. They monitored households without filters for four months, assessing the rate of illness. Then, about half the houses (approximately 80) were given concrete biosand filters. All households then were monitored for another six months. The team's initial analysis showed the filters reduced diarrheal disease among household members by an estimated 47 percent, including among highly vulnerable young children less than 5 years old. Field analyses conducted on more than 100 household filters near Bonao also found that the filters reduced the amount of *E. coli* in the water by 93 percent.

> "Effective filtration technologies can bring safe drinking water to many people in developing countries who don't have access to it now. We can tremendously improve people's health and quality of life if we can help them get a reliable source of clean, safe drinking water."

"Over time, as people use the filter, it gets better at filtering the water," says Dr. Christine Stauber, who earned her doctoral degree in environmental sciences and engineering from UNC in August 2007 and helped direct the project. "This is because with time, a 'biolayer' grows on the surface of the sand in the filter. As that biolayer gets thicker, it helps filter the water."

UNC School of Public Health researchers returned to Bonao in summer 2007 to learn whether people were still using the filters and whether the filters were still producing improved drinking water. Results are expected later this year.

Dr. Gloria Ortiz, a UNC postdoctoral fellow and native of the Dominican Republic who helped direct the project, said residents told her that the filters make a great difference in their lives.

"They told me they no longer worry about sick children who miss school, or about taking the children to the doctor or finding money to buy medications to treat diarrhea," she says. "Many told me that since they've been using the filters, no one in their house had gotten a single case of diarrhea. This is a tremendous step in improving their health and well-being."

UNC-based lab studies on the efficacy of biosand filters in removing *E. coli* bacteria and viruses found that when water is left in the sand filter for longer periods of time (10 to 20 hours), more bacteria and viruses are removed from the water.

"We're conducting studies now to find out how long the pause time should be

Plastic and metal containers (below) store unfiltered water in a Dominican Republic home. Water stored this way is prone to contamination. For this reason, biosand and ceramic water filters being tested by UNC researchers are designed so that filtered water flows into enclosed containers with side taps to dispense clean water.


PHOTO BY DR. GLORIA ORTIZ

UNC researchers have been conducting randomized controlled trials of the effectiveness of porous ceramic filters and biosand filters that filter water through layers of biologically-active gravel and sand. Both kinds of filters were found to reduce the incidence of diarrhea by up to 40 percent in households that used them.

PHOTO BY DR. CHRISTINE STAUBER

Yakira Morillo and her daughter (above) standing next to their biosand filter in Jayaco, Bonao, Dominican Republic.

Lab worker Aideé Liranzo de Villar (below) processes water samples to detect bacterial contamination in the laboratory of Dr. Mirna Peña de Guerra in Bonao, Dominican Republic.

to get improved performance and why the concentration of harmful microbes decreases when water is left in the filter for several hours," says Mark Elliott, a doctoral student in environmental sciences and engineering who is overseeing the research and has directed more than a half-dozen biosand-filter lab studies since 2004.

Elliott hypothesized that the *E. coli* bacteria may stick to the particles of sand in the filter or that the biolayer on the surface of the filter may contribute to the microbial reductions.

UNC-led research on the efficacy of plastic biosand filters is in developmental stages in Honduras, Ghana and Indonesia, says Sobsey. The projects are funded by International Aid, a nongovernmental organization based in Michigan. A sustainability study of the biosand filter is underway in the Dominican Republic. This project is funded by the U.S. Agency for International Development (USAID).

"USAID has become a big promoter of household water treatment technology. However, they're reluctant to support any technology that does not have the evidence of reducing diarrheal disease in the field," says Sobsey. "They're also interested in sustainable technologies. For this reason, we've conducted studies in places where they think they can most efficiently begin to introduce these filters and achieve large-scale coverage."

Sobsey notes that the ceramic and biosand water filters are "something of a status symbol" in developing countries. "People can point to the filters and say, 'Look, I have a water filter. It makes my water cleaner.' People have a sense that their families are healthier because they have a water filter."

The filters also empower people at a household level to take responsibility for their water, Sobsey says. ■

PHOTO BY DR. CHRISTINE STAUBER

Carolina students bring fresh water to Cambodian school children

BY EMILY J. SMITH

Throughout many parts of Asia, naturally-occurring arsenic in groundwater is a critical public health problem. Chronic arsenic exposure has been linked to cancer of the skin and internal organs, lowered birth weights in babies, increased incidence of respiratory disease, hearing loss in children, impaired skin sensation and other health problems.

UNC School of Public Health students who volunteered in Cambodia include Dr. Joe Brown; Angella Rinehold and Reed Palmer, both 2006 master's degree graduates in environmental sciences and engineering; Joshua Hunn, a 2007 master's degree graduate in environmental sciences and engineering; and Jamie Perin, a doctoral candidate in biostatistics at UNC.

Five students from the UNC School of Public Health set out in August 2006 to solve this problem — for 1,200 students at a primary school outside Phnom Penh, Cambodia. As members of the UNC chapter of Engineers Without Borders, UNC volunteers worked with the community of Dey Ut to create an alternative source for the school's drinking water, replacing an arsenic-contaminated well.

Volunteers helped design and build a rainwater harvesting system and plan for the project's sustainability through community involvement and education. Dr. Francis DiGiano, professor of environmental sciences and engineering at Carolina's School of Public Health, served as an advisor for the project. Numerous other UNC School of Public Health students helped plan and fundraise for the project.

Working with the Cambodian-based nonprofit organization Resource Development International, volunteers in Cambodia helped build three 30,000 liter tanks fed by rainwater harvested from the roofs of three school buildings. UNC volunteers also designed a "foul-flush system" that captures the first rainwater that lands on each roof and diverts it away from the holding tanks. The first flush of water often contains dust, insects, bird waste and other debris that could compromise the holding tank water quality. After the water is flushed, it flows into the holding tanks. Ceramic filters are in each school classroom to further filter the water.

PHOTO BY JOSHUA HUNN

Reed Palmer (left) poses with three Cambodian school children. Palmer was one of five UNC School of Public Health students who traveled to Cambodia in August 2006 to help create an alternative source of drinking water for the school in the community of Dey Ut. The existing source had been an arsenic-contaminated well. Naturally-occurring arsenic in groundwater is a critical public health problem throughout many parts of Asia.

Funding for the project came from the North Carolina and Cambodian Rotary Club chapters, the Student Global Health Committee, and many other donors, including students and faculty in the UNC School of Public Health.

The UNC chapter of Engineers Without Borders was founded in 2004 by Dr. Joe Brown, a 2007 doctoral degree graduate in environmental sciences and engineering and other graduate students in the School's Department of Environmental Sciences and Engineering. More information about the organization can be found at *www.unc.edu/ewb-usa*. A description of the Cambodia work is listed under "projects." ■

Membrane technologies enable water reclamation

Membrane technologies have potential to purify reclaimed water for a multitude of uses, says Dr. Francis DiGiano, professor of environmental sciences and engineering at Carolina's School of Public Health, who has investigated these technologies for the last 15 years.

Dr. Francis DiGiano (above) displays two membrane filter samples in his laboratory at the UNC School of Public Health. The filter on the right is a hollow fiber microfilter (low-pressure) membrane cartridge formerly used in a drinking water treatment plant. The filter on the left is a reverse osmosis (high pressure) membrane unit. It is a small-scale unit designed for pilot-testing in water treatment plants. Full-scale units are 4 feet or longer and may be as large as 16 inches in diameter. Membrane technologies such as these have potential to purify reclaimed water for a multitude of uses. A close-up of the membranes is shown right.

"Membranes are made of either synthetic organic polymer or inorganic ceramic materials that hold back contaminants but have pores or open spaces that allow water to pass," DiGiano says. "They can remove high levels of particles, bacteria, viruses and trace organic chemicals from wastewater that is being reclaimed for reuse. Membrane technologies refer to the many ways that membrane material can be designed into large-scale treatment devices to purify millions of gallons of water each day."

Treatment designs can be tailored to fit specific water reclamation objectives, DiGiano says. For instance, membranes designed to remove bacteria and viruses can be used for treating reclaimed water intended for fighting fires in order to assure fire fighters of the water's safety. Nearly all chemical contaminants can be removed by certain membrane technologies to create reclaimed water fit for use even in microchip production.

"Membrane technology is essential to achieve the highest possible removal of trace levels of organic contaminants and viruses," DiGiano points out. "This is necessary in California and Arizona, for example, where reclaimed water is returned to the groundwater, and after natural purification and dilution with native groundwater, may eventually be withdrawn for water supply."

Membranes also can be used to improve upon conventional wastewater treatment techniques that depend on bacteria to biodegrade contaminants in the wastewater. In this process, known as "membrane bioreactor technology," membrane materials are formed into hollow fibers or flat sheets. DiGiano likens the fibers to bundles of bucatini, or hollow spaghetti, and the sheets to layers of lasagna. Either fibers or sheets are submerged into a tank in which high concentrations of bacterial cells are present.

"The membrane material holds back essentially all bacteria as well as other smaller particles that would otherwise escape conventional biological treatment plants," DiGiano says. "This is an important advantage to this technology."

Using membrane technology for water reclamation permits multiple uses of the same water, thus limiting withdrawals from clean drinking water resources. "In this way, our water resources are better preserved or sustained for future generations," DiGiano says. (See water reclamation article on page 28.) "In the extreme, closed-loop water recycling (pure water, to wastewater, to pure water, over and over again)—as practiced on space ships for non-potable (non-drinking) purposes—is the ideal goal of water sustainability."

Membrane bioreactors may be a key to global water sustainability, says DiGiano, emphasizing a point that he and 13 other water experts from around the world agreed upon at a 2003 conference DiGiano organized at the Rockefeller Study and Conference Center in Bellagio, Italy. During this time, DiGiano was a Fulbright scholar at the Milan Polytechnical University studying European membrane bioreactor technology.

"At the time, several western European countries had become early adopters of this technology, and the largest plant was in Brescia, Italy," DiGiano says. "I think that the largest plant is now in the U.S., but in fact, European countries tend to experiment more willingly with new technologies than the U.S."

The Bellagio group agreed that affordability, small size and ease of operation make membrane bioreactors well-suited for water reclamation in developed and developing countries alike. While this technology has been available for about a decade, its potential for decentralized water reclamation in urban and suburban centers has been undervalued. Membrane designs typically require far less space and have more aesthetic appeal than traditional wastewater treatment facilities. Building small, decentralized membrane bioreactors avoids the expense of conveying water to a large, centralized wastewater treatment plant and subsequent return by long reclaimed-water pipelines for local reuse.

DiGiano also has investigated membrane technologies closer to home. Last year, he completed a pilot project in Greensboro, N.C., to compare which low-pressure membrane technologies (microfiltration or ultrafiltration) could remove the most contaminants prior to treating the water with one of two high-pressure membrane technologies (nanofiltration or reverse osmosis). Contaminants can clog membranes and thus limit water flow through the filtration system.

"To carry the pasta analogy further, when membranes are used to treat wastewater, some of the contaminants that are removed stick to the membrane surface, just as tomato sauce would stick to spaghetti or lasagna," says DiGiano. "This prevents water from passing through and thus forces use of higher and higher pressure to produce the same amount of water each day. As the 'sauce' builds up, it finally becomes necessary to stop the process and remove it by chemical means. So, the engineering goal is to minimize the rate at which this foulant layer builds up so as to limit the number of times each year that the entire membrane system must be stopped and chemically cleaned to remove the 'tomato sauce.'"

TIP: Save water by choosing a fuel-efficient vehicle. It takes 44 gallons of water to refine one gallon of crude oil.

The fouling problem is particularly critical when nanofiltration or reverse osmosis are needed to produce very high-quality reclaimed water. These high pressure membranes have very small openings through which almost-pure water can pass, leaving behind more than 90 percent of the chemical contaminants and 99.9999 percent of viruses.

In the Greensboro study, effluent from the conventional wastewater treatment plant was passed through a pilot plant containing low- and high-pressure membranes in series. The high-pressure membranes make possible high removals of organic contaminants that would otherwise not occur. In studying two low-pressure membrane pretreatment processes (ultrafiltration and microfiltration), DiGiano found that ultrafiltration (which has pores ten times smaller than microfiltration) was the better pretreatment. "Still, some things passed through that caused fouling of the reverse osmosis membranes," says DiGiano, "so there is still room for improvement."

"Membrane technology is essential to achieve the highest possible removal of trace levels of organic contaminants and viruses (from reclaimed water)."

The study found that using either microfiltration or ultrafiltration in combination with high-pressure membranes (either nanofiltration or reverse osmosis) produced water with nearly complete elimination of viruses and greater than 90 percent removal of organic contaminants.

The system tested in Greensboro is much more expensive than using low-pressure membranes alone, DiGiano says. "You need to apply a lot of pressure to push the water through very tight polymeric structures that reject viruses and trace organic chemicals. But the benefit is higher quality water that could expand the range of opportunities for water reclamation," he says. ■

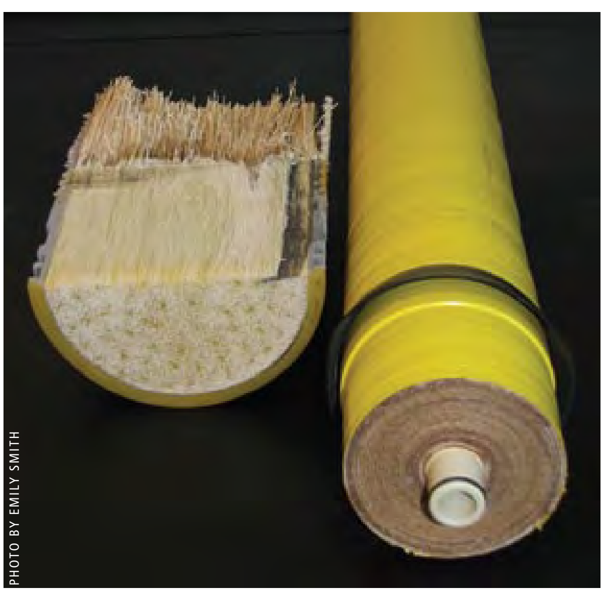


PHOTO BY EMILY SMITH

Cleaning contaminated groundwater more effectively

BY KATHLEEN KEARNS

Sometimes, very harsh, dangerous chemicals are spilled, thrown or leaked into important drinking water sources. They are hard to remove from water, especially groundwater, and they can be deadly.

A good example of these dangers was chronicled in the book (and movie) *A Civil Action*, which was based on a spill of the chemical trichloroethylene (TCE) that contaminated groundwater in Woburn, Mass., and caused a cluster of leukemia cases.

Cleaning up subsurface systems contaminated with chlorinated solvents, such as TCE, is one of the most difficult problems in the environmental sciences field, says Dr. Cass Miller, professor of environmental sciences and engineering at the UNC School of Public Health. "Such compounds are long-lived in the environment, of health concern at very low concentrations and devilishly difficult to remove once released into the subsurface." Miller and colleagues have developed patented processes to remove chlorinated solvents like TCE and perchloroethylene (PCE) more effectively than current approaches can. During the last several years, they've been working to advance, improve and better understand this technology.

More than half of all Superfund sites are contaminated with TCE, Miller points out. (In 1980, Congress created the Superfund program to clean up the nation's hazardous waste sites.) Many Department of Defense installations, including North Carolina's Camp Lejeune, have groundwater contaminated with such chlorinated solvents. Cleaning up this kind of contamination presents a host of challenges. One is the nature of the solvents themselves: they're heavier than water and tend to move downward because of gravity. "They tend to sink below the water table," Miller says. "These contaminants can reach significant depths below the subsurface."

Because they move through groundwater and spread through a variety of subsurface conditions and materials that can't be seen or completely characterized — various mixtures of sand, silt, clay and rock — their flow patterns are very complicated. Solvents leave some of their mass behind in clays and silts, and they can pond up on the surface of impermeable substances in the earth.

TIP: Dispose of household contaminants safely to avoid polluting groundwater. Collect old batteries, used antifreeze, paint and chlorinated solvents and take them to the landfill.

"This is what makes it so difficult to remediate," Miller says. "Solvents trapped in porous materials such as sands, silts and clays beneath the earth's surface can be a source of groundwater contamination and a threat to public health for over a hundred years if left unremediated."

As water moves through a contaminated region, some toxins are dissolved into it and become threats to public health. "The common technology to remove such contaminants is called 'pump and treat,'" Miller says. "A well is established between the contaminated region and any source of supply that you want to protect. As you pump that well, the idea is that you'll remove water and contaminants from the source region. This hasn't worked very well."

Miller's solution is to use brine, in this case, a calcium bromide mixture that is denser than both the solvents and water, to remediate a contaminated system. "We inject brine into the system, and because it's denser, it can displace some of the contaminants upward and


Dr. Cass Miller

provide a barrier to prevent further vertical migration downward. If we mobilize these contaminants and move them downward, and we have a brine layer as a barrier, then they'll stop at the barrier. Then we can remove them with an extraction well." The method uses a food-grade surfactant (a wetting agent) to move the contaminants downward.

Miller's team recently tested the process in a field study at Dover Air Force Base in Delaware. "Nature is complicated," he says, "and though we try to make complicated systems in the laboratory, the size and the complexity of those can never really mimic what's in nature." The Dover facility had an impermeable clay layer 40 feet beneath the surface, and the test area had double-steel barriers to prevent groundwater contamination outside of the test region.

Funding was obtained from the National Institute of Environmental Health Sciences through UNC's Superfund Basic Research Program; RETEC, a national environmental consulting firm; and the Dead Sea Bromide Group, an international partner. Miller's team then deliberately contaminated the Dover site with PCE and attempted to remove it. This field study was instrumental in helping to mature their understanding and move them in the direction of further refinements to the process.

"We learned we were able to add brine to the system, achieve the densities we wanted to achieve, and were therefore able to control any mobilized PCE," Miller says. "Importantly, we were able to recover the brine from the system efficiently and in economical concentrations. Unfortunately, we didn't remove all the PCE. We're doing follow-up work in the laboratory to further improve the process, understand the economics of the method through mathematical modeling and, along with our two partners, prepare for another field application." ■

Reducing health risks of treated wastewater

BY KATHLEEN KEARNS

The 16,000 municipal wastewater treatment plants in the United States produce about 6 million tons of biosolids every year, and all those solids have to go somewhere.

More than half of the biosolids are applied to agricultural land, according to estimates. The rest are incinerated or spread on forest land or in landfills. Depending on how source sludge has been treated, biosolids may be pathogen-free (Class A), but most are currently treated by Class B processes, which do not destroy all pathogens.

Both classes are allowed to be spread on agricultural land—biosolids, in fact, are considered a useful amendment in the soil. But the practice is not without controversy, and there are many restrictions on where and when Class B biosolids can be applied because of concerns about exposing humans to serious health risks.

"We know bad things can happen when fecal matter with undesirable levels of pathogens is applied to agricultural land," says Dr. Mark Sobsey, UNC Kenan Distinguished Professor of environmental sciences and engineering in the UNC School of Public Health. "Think of recent outbreaks of *E. coli* from contamination of spinach or lettuce because fecal matter from people or animals got on food which we eat raw. Pathogens can also migrate into groundwater."

UNC School of Public Health researchers have investigated innovative treatment methods that result in safer Class A biosolids and are developing a protocol to investigate health concerns that might be ▸▸

related to the application of biosolids on agricultural fields.

Sobsey and Dr. Michael Aitken, chair of the School's Department of Environmental Sciences and Engineering, recently completed a project for the city of Columbus, Ga., to investigate whether a conventional sludge treatment process could be adapted to produce Class A biosolids. In most sewage treatment plants today, wastewater goes through a multi-step process that aerates it and allows impurities to settle in a series of basins. What settles out contains biodegradable solid material that can attract vectors of disease (such as insects or rodents) and so must be treated before being released into the environment.

Dr. Michael Aitken

"Usually, the treatment is another biological process, referred to as the digestion process," Sobsey explains. "In many places, that process is done without oxygen at moderate temperatures — either ambient outdoor temperatures or a little higher. While that process is reasonably effective at degrading some of the organic matter in sludge and making it more stable, it doesn't do much to kill off pathogens."

Billy Turner, president of Columbus Water Works in Georgia, earned a master's degree in environmental sciences and engineering from Carolina and was well acquainted with the expertise on tap here. With funding from the Environmental Protection Agency (EPA), Columbus Water Works invited Aitken and Sobsey to investigate whether using higher temperatures — a process called thermophilic anaerobic digestion — would meet the EPA's standards for producing Class A biosolids.

PHOTO BY JAQUI BROOKS

Approximately 3 million tons of biosolids (treated sludge) produced by U.S. wastewater treatment plants are applied to agricultural land each year. UNC researchers are investigating innovative treatment methods that result in safer Class A biosolids and are developing a protocol to investigate health concerns that might be related to the application of biosolids on agricultural fields.

Thermophilic anaerobic digestion degrades organic matter and reduces pathogens through the combined effects of biological activity and exposure to temperatures in the mid-50s Celsius. The process has been well known for several decades, and laboratory and field studies have documented that it reduces disease-causing microorganisms to very low levels.

UNC School of Public Health researchers have found that treating sludge with a process called thermophilic anaerobic digestion removed all viruses, bacteria and parasites.

The problem, Sobsey says, was that "the way it's typically carried out does not allow for all the sludge to be exposed to the higher-temperature digestion process long enough to have its load of pathogens sufficiently reduced. The project in Columbus intended to document that if the process was applied in such a way that all of the sludge could get exposed to the digestion process at thermophilic temperatures for a sufficient period of time, then indeed it would have its pathogen content dramatically reduced to the low levels EPA requires to be considered a Class A process."

Aitken and Sobsey first ran experiments in the laboratory to document performance of the process. A national environmental engineering firm, Brown and Caldwell, took time and temperature conditions Aitken and Sobsey determined to be adequate and designed a prototype system at the Columbus plant to meet them. Modifications ensured that all the sludge would be treated at known temperatures for a known period of time, long enough to get rid of the pathogens.

Aitken and Sobsey documented that at the end of the modified process, the biosolids were free of viruses, bacteria and parasites. The EPA approved Columbus Water Works' method as a Class A procedure. The prototype system received an award for excellence in environmental engineering from the American Academy of Environmental Engineers.

"We suspect the process will become more widespread, and of course, that was the goal," Sobsey says. "A lot more utilities will be able to make only minor modifications to their processes and have the benefits of being able to get Class A sludge."

Developing protocols

Aitken also has been working with Dr. Steven Wing, UNC School of Public Health associate professor of epidemiology, to develop protocols for investigating reports of health concerns that may be related to the application of biosolids on agricultural fields. "What's driven both projects is the underlying concern that potential human-health impacts of land application of biosolids have really not been well established," Aitken says. "Municipalities like Columbus are much more interested in producing Class A biosolids because, by destroying the pathogens, they have removed a significant health concern." Complaints about land application of Class B biosolids have been so vociferous in some areas that some communities have prohibited the practice, Aitken notes.

Wing, the principal investigator for the project, says that some people who live near sites where biosolids have been applied report respiratory, gastrointestinal and dermatologic problems that they attribute to exposure to pollutants that migrate off-site. Biosolids contain nutrients and have value for the soil for agriculture, he notes, but they also can contain endotoxins, live pathogens, metals and chemicals that run off from streets or are flushed down the drain by industry. "When the material is applied to land, it can in some situations move off-site in the air. It's also possible that when it rains, the material could migrate down into groundwater or run off into local surface water."

The protocol on which the team is working includes a health questionnaire that could be administered by a responding agency, such as a health department. It also includes various means to acquire information about sources of sludge; how sludge was treated, stored and applied; and its potential to migrate off-site. "We're also including guidelines that could be used by an agency if they felt they needed to go on-site and investigate through inspection and other measures," Wing says. The information that's gathered also could be entered into a large database, which would facilitate an epidemiological study of links between biosolids and health. The project is funded by the Water Environment Research Foundation, a research agency supported by various wastewater utilities, state agencies, industries and consulting firms, as well as by the EPA. ■

UNC faculty train North Carolina wastewater treatment plant operators

Dr. Donald Francisco

More than 7,200 North Carolina wastewater treatment plant operators owe their training to Dr. Donald Francisco, clinical professor emeritus of environmental sciences and engineering at the UNC School of Public Health. Francisco coordinated the North Carolina Annual School for Wastewater Treatment Plant Operators for 32 years (1971 to 2003). The curriculum and instructors are approved and selected by a committee of the N.C. Water Environment Association. Francisco chaired that committee for 33 years. In 2003, in recognition of his service, the N.C. chapter of the American Water Works Association and Water Environment Association, named Francisco the first recipient of a new award named in his honor—the "Donald E. Francisco Educator of the Year Award." ■

TIP: Keep your septic system in good working order. Mow the septic field often, inspect your tank annually and pump it out at least every three to five years. Failing septic systems leach organic wastes that can cause excessive algae growth and disease-producing pathogens in water sources.

UNC researchers recently completed a project for the city of Columbus, Ga., exploring whether a process called thermophilic anaerobic digestion could reduce the number of disease-causing microorganisms in sludge treated by this process. They found that the process removed all viruses, bacteria and parasites from the sludge. The thermophilic anaerobic digester prototype in Columbus (right) was constructed by modifying a conventional sludge treatment processing system.

GETTING WATER TO YOUR TAP

BY EMILY J. SMITH

UNC researchers study ways to improve water distribution systems to maintain integrity of drinking water; Dual water systems may provide solution

Many efforts are made by water treatment facilities across the United States to purify water meant for drinking. But when water leaves treatment plants, do the pipes that carry it maintain its integrity? How long does it take for water to travel from the treatment plant to homes and businesses, and how pure is the H_2O that comes out of the tap? These are questions that Dr. Francis DiGiano, professor of environmental sciences and engineering at Carolina's School of Public Health, has spent his career answering.

"Our research has shown that water quality can deteriorate within drinking water distribution systems. Although epidemiological evidence is still scant, poor quality water can expose water customers unnecessarily to health risks such as bacterial infection," says DiGiano.

The most well-documented water quality problems in distribution systems are loss of disinfecting power and subsequent re-growth of bacteria, notes DiGiano, who has worked with North Carolina water municipalities in Raleigh, Durham, Cary, Greenville and Carthage, among others, to study the issue. His research involves determining the "residence time" of water in a distribution system (the length of time it takes water to travel through the distribution system) and also measuring chlorine levels in the water. Chlorine has been used by water municipalities to disinfect drinking water since the early 1900s. Its introduction dramatically reduced the incidence of waterborne disease in this country and is considered one of the great public health successes of this century. Research has shown, however, that when chlorine levels in the water distribution system decline, bacteria can grow.

Many utilities, including some in North Carolina, have switched from "free chlorine" to "combined chlorine" for water disinfection to prevent formation of disinfection byproducts (see p. 34). While combined chlorine is supposed to last longer in the distribution system than free chlorine, DiGiano has measured considerable loss in some parts of distribution systems he has investigated. This means that we may be exposed to bacteria in the water we drink.

"The cause-and-effect relationship between bacterial re-growth and specific

TIP: Hot water pipes are likely to have more corrosion. To avoid contaminants that may be in drinking water, let the water run for several minutes on the first draw in the morning. Never drink from the hot water faucet or use this water for cooking.

water quality parameters has not been well established because many interdependent variables are involved. Clearly, the loss of disinfectant, which is closely linked with long residence time, is a very important factor," DiGiano says "Additionally, pipe materials, temperature, length of time the water stays in the distribution system, use of storage tanks, presence of biodegradable organic matter in the water, type of disinfectant used, and the inactivation rate of disinfectant all are important."

The aging water distribution infrastructure in the United States also plays a role in the re-growth of bacteria in pipes. More than 20 percent of pipes in the United States are over 40 years old. It's much higher in cities with populations of 100,000 or more, where more than 40 percent of pipes are older than 40 years. In fact, 6 to 10 percent of the pipes in cities are more than 80 years old, DiGiano says.

Made of cast iron, older pipes are prone to corrosion. Over time, these older pipes can develop layers of encrusted corrosion inside them that slow or block water flow and provide crevices where bacteria can hide. Equally important, corrosion-induced reactions cause both free chlorine and combined chlorine to disappear, a finding that DiGiano observed both in the laboratory and in several North Carolina distribution systems he has studied. This was the subject of a paper he published with the American Water Works Association in 2005 along with graduate student, Weidong Zhang, that won the association's annual best paper award. The paper is available online at *www.awwa.org*.

In the United States, pipes installed today are made either of cement-lined ductile iron or polyvinyl chloride (PVC). Corrosion is less likely with cement linings and completely eliminated with PVC. However, PVC pipes are not used in the large diameters needed by many cities. They are also subject to chemical intrusion and may be more apt to break, increasing the chances for bacterial contamination to the system, DiGiano says.

UNC School of Public Health research has shown that water quality can deteriorate within drinking water distribution systems. Poor quality water has the potential to expose water customers unnecessarily to health risks such as bacterial infection.

Regardless of pipe material, prolonged time in the pipes causes water quality deterioration. Long water pipelines, caused by suburban sprawl, increases the time water is in the pipes, decreases chlorine residuals in water distribution systems and increases the likelihood of bacterial growth.

"In Greenville, South Carolina, for example, water has to travel 40 miles to get to homes across the city from where it's treated," DiGiano says.

One solution to this problem might be to build "booster" treatment plants in U.S. cities where water has to travel long distances, he says.

Dual water systems

Since cast iron pipe replacement programs are underway in many U.S. cities, another option is to replace corroded pipes with "dual water systems." One set of pipes carries reclaimed wastewater treated for non-potable (non-drinking) uses, like toilet-flushing, irrigation and fighting fires; another smaller set of pipes carries drinking water. Even more feasible is use of dual water systems in new communities.

Dual water systems could result in higher-quality drinking water, notes Dr. Daniel Okun, Kenan Distinguished University Professor Emeritus of environmental engineering at UNC, who developed the distribution design.

The key idea in reducing pipe diameters in drinking water systems is to shift the fire protection function from potable water to the reclaimed water supply. "Water distribution systems in U.S. cities have been designed to meet fire code, so the diameter of pipes is much greater than it has to be to provide homes and businesses with what they need for daily use," Okun says. "Since fires don't happen all the time, water spends a long time getting from where it's treated to where it's consumed, and the longer it spends in the pipe, the more time it has for reactions to occur that degrade the quality." ■

PHOTO BY RAMONA DUBOSE

Elliott DuBose, age 6 (above), takes a slurp from a drinking fountain after a football game.

Cast-iron pipes (like the one to the left) are prone to corrosion over time. Layers of encrusted corrosion inside pipes can slow or block water flow and provide crevices where bacteria can hide. UNC researchers are working with North Carolina water municipalities to study this issue.

SCHOOL PROJECT GROWS INTO ACCLAIMED WaterPartners International

BY CHRIS PERRY

During a trip to Guatemala in the 1980s, Gary White took a side trip to a slum in Guatemala City.

PHOTO BY SARAH BRAMLEY, WATERPARTNERS INTERNATIONAL

"I was shocked at what I saw—sewage in the streets and highly contaminated, community water barrels," says White, who was an undergraduate at the University of Missouri-Rolla at the time.

The experience changed his life—and he has changed the lives of others throughout the world.

In 1993, while earning a master's degree at UNC's School of Public Health, White and fellow student Marla Smith-Nilson founded WaterPartners International, a charitable organization dedicated to improving water supply and sanitation conditions of people living in developing countries.

Today, WaterPartners International collaborates with local, non-governmental organizations (NGOs) in Africa, Asia and Central America to help water-poor communities build cost-effective, sustainable water systems.

Funded primarily by grants and private donations, WaterPartners holds annual *Water*

PHOTO BY HEATHER ARNEY, WATERPARTNERS INTERNATIONAL

An Ethiopian girl (left) pauses for a drink while collecting water from a new hand pump in Tigray, a region in northern Ethiopia bordering Sudan and Eritrea.

Rashana and Maizabeen of Vinayakngar, Hyderabad, India (above), are two beneficiaries of a WaterPartners International project in their community. Here, they demonstrate how they carried water before their community had a water connection.

for Life fundraising dinners in cities across the United States. The dinners, started by White in 1990, laid the foundation for the organization and earned White the support of his Chapel Hill classmates and teachers.

"In Gary's first year (at Carolina's School of Public Health), it quickly became apparent that he had tremendous leadership skills," says Dr. Donald Lauria, professor of environmental sciences and engineering at Carolina and White's academic adviser. "During one of the school breaks, Gary led a group of graduate students to the capital city of Honduras. He had convinced them to spend their own money for travel costs. When I learned of it, I was enormously impressed."

White had planned to let Catholic Relief Services determine the students' activities in the slums of Tegucigalpa. But when Lauria heard about the trip, he suggested the students collect data on the rate people arrived at public water points called standposts.

Lauria, who studies community water supply and sanitation in developing countries, knew that water flowed from these outdoor faucets intermittently and that the users—poor people with no other water source—often had to wait hours for the water to come on. "Sometimes the water would come on in the middle of the night, and people would jump out of bed to go collect it in buckets," he says.

Lauria recommended the students track the kinds of containers people brought to the standposts, size of the containers, how long it took to fill them, how many people came for water, and how many waited in line. Students collected these data from early morning to late at night in a part of the city where the urban landscape changes quickly to rural. White later analyzed the data, which formed the basis for his master's thesis.

White and Smith-Nilson tapped expertise at the School to help guide WaterPartners International. The first advisory board included Lauria and other UNC faculty renowned worldwide for their water expertise, including environmental sciences and engineering professors Drs. Daniel Okun, Francis DiGiano, Dale Whittington, Philip Singer and David Moreau.

"Our role was to challenge Gary, Marla and other students to think about what was unique about their organization compared to other NGOs," says Lauria.

Other organizations gave communities new water systems—often poorly designed—as gifts, preventing the communities from becoming self-sufficient. "Many parts of the world are littered with hundreds of thousands of water systems that don't work," Lauria says. "What needs to be done is to help local communities become more self-sufficient."

WaterPartners helps communities improve their own water resources by locating and certifying partner organizations in developing countries—mostly NGOs—that manage water projects with community-member involvement. Partner organizations mobilize the community, organizing local water committees that oversee the construction and ongoing maintenance of water projects. Few organizations—about one in twenty that apply—meet WaterPartners' high standards for certification.

"One of WaterPartners International's keys to success is that water supply decisions are driven at the community level, from the bottom up instead of top down," says Jennifer Platt, a former School of Public Health classmate of White's, who's now director of operations for WaterPartners.

Community residents perform much of the labor to implement their water solutions, while WaterPartners provides engineering knowledge and assistance for sound technical designs. The organization provides oversight for each project by monitoring and evaluating the financial and program accounting of its partners, ensuring a more effective use of donor funds.

"The irony for many people in developing countries is that safe water may be close by but inaccessible, forcing them to spend hours each day walking to collect water from contaminated sources," says White. He recalled a neighborhood in Ethiopia where "women were walking six hours a day to get water—filthy water—when clean water was available a few meters below their feet. They simply lacked the knowledge and capital needed to drill a well and install a hand pump."

White says that in addition to supplying communities with life-saving, clean water, the organization's efforts reduce the large amounts of time people—mostly women and girls—spend each day collecting water. "This saved time can be used to produce income or attend school, activities that can improve quality of life and transform entire communities," he adds.

PHOTO BY MICHAELA MECKEL, WATERPARTNERS INTERNATIONAL

Felipe, Ganuario and Jose, members of the water committee in Gualcea, Honduras, check on the water distribution line that runs from the tank to the community of Gualcea.

WaterPartners has experienced tremendous growth in the past two years. "When I started in 2005, we had three full-time staff members; now, we have 20," says Platt.

Platt, who earned her master's degree in environmental management and policy in the Department of Environmental Sciences and Engineering, now has two WaterPartners offices outside of the United States—in India and Kenya. Staff members provide front-line monitoring and on-the-ground support for water projects in their part of the world.

In 2002, White received the School's Harriet Hylton Barr Distinguished Alumnus Award, presented to one outstanding alumnus each year by the UNC School of Public Health Alumni Association.

"Gary has such a gigantic heart," says Lauria. "It's hard to find that level of compassion almost any place in the world."

For more information about WaterPartners International, visit their Web site at *www.water.org.* Smith-Nilson now leads Water 1st International, an organization she founded in 2005. More information about Water 1st International can be found at *www.water1st.org.* ■

For World Bank's Briscoe, Study of water is vital, moving

BY LINDA KASTLEMAN

"There is going to be no more water," says Dr. John Briscoe, stating the inevitable. "We have to be better at managing what we have."

Dr. John Briscoe

Briscoe, World Bank country director for Brazil and one of the world's leading water experts, has spent his career helping people around the globe better manage their finite water resources.

A native of South Africa and graduate of Harvard University, Briscoe was professor of water resources at the UNC School of Public Health from 1981 to 1986. In April 2007, he presented the School's annual Foard Lecture on water and human well-being.

He has worked with government water management agencies in South Africa and Mozambique and with the International Center for Diarrheal Diseases Research in Bangladesh. Associated with the World Bank since 1986, he has held numerous positions in research, operations and policy. In 1996, he became senior water adviser at the Bank, managing its more than $50 billion in programs focused upon water resources, irrigation, hydropower, and water and sanitation. He has been the Bank's country director for Brazil since 2005.

"Water is not a global issue," Briscoe says. "It's a collection of local issues. There are a host of water problems—drought, flood, scarcity, quality issues. Despite the variation, we need to think of water in an integrated manner. We need to make sure there is broad involvement by all the stakeholders and that there is an efficient use of limited capital. These are the common elements, but they manifest themselves differently in different natural and sociopolitical environments."

Briscoe began his water career as a civil engineering student at the University of Cape Town, South Africa.

"What I liked about the study of water was that it was vital, moving," he says. "It dealt with society. For a person who likes to do different things in his life, it's a perfect choice—since in a career having to do with water, one has to know natural science, the environment, history, culture, economics, finance. There is always another angle from which to look at the topic."

Briscoe was principal author of the World Bank's 2003 water strategy, which reversed a Bank trend toward withdrawing from large water projects. It can be found online at *http://siteresources.worldbank.org/INTINFNETWORK/Resources/water.pdf.*

"Developing countries need infrastructure or they can't grow and people can't rise out of poverty," he says. "The Bank is now investing a lot in large water infrastructure. They are working to ensure that the poor can get benefits and the environment is protected."

He has advice for students now studying for careers in water management.

"For this generation of students, who will be leaders of the next, the issues around water, economic development and public health will be vitally important for the foreseeable future. Everywhere you look, there are floods, droughts, pollution. Conflicts are growing—between cities and farms, between consumption and conservation, between states, and even between nations. These challenges are exacerbated by climate change. Malthus was wrong about many things, but mostly right when it comes to water." (Thomas Robert Malthus, 1766-1834, an English political economist and demographer, predicted that human population would increase at a faster rate than food supply, thus causing severe shortages.)

"Water is not a global issue. It's a collection of local issues."

"I would say to students, no matter what your course of study in economic development, public policy, environment, engineering or public health, UNC can offer you a wide-ranging, interdisciplinary exploration of these important issues. UNC is strong on its own, but its proximity to and collaborations with Duke University and North Carolina State University allow the opportunity for a world-class education and exposure to every aspect of dealing with water issues." ■

SCHOOL'S NUTRITION RESEARCH INSTITUTE GEARING UP IN KANNAPOLIS, N.C.

Fact:
What we eat—and how much—plays a huge role in how long and how well we live.

Finding:
Although nutrition recommendations often are made for the "average" person, we differ tremendously in our metabolism and nutrition requirements.

Future:
Soon, it may be possible to make individualized nutritional recommendations.

"We have much of the methodology available that could allow us to understand why people's metabolisms are so different," says Dr. Steven Zeisel, Kenan Distinguished University Professor of nutrition and pediatrics in the UNC School of Public Health and the School of Medicine. "But more work needs to be done to make sense of these pieces we have. The beginnings of the techniques are there, but we have much refining to do."

Zeisel is director of the Nutrition Research Institute (NRI), a new part of the UNC School of Public Health located on the N.C. Research Campus in Kannapolis, about 30 miles northeast of Charlotte, N.C. The campus is a public-private partnership, spearheaded by David Murdock, former CEO of Dole Food Company, Inc. At age 84, Murdock appears to have more energy and stamina than many people half his age.

"Mr. Murdock believes his diet is the reason he is so healthy at his age," Zeisel says. "And he is convinced nutrition holds the key to improving all our lives and health."

So is Zeisel, whose distinguished career has made him one of the top nutrition researchers in the world. Zeisel's research combines studies of molecular mechanisms for how nutrients function with human studies on nutrient requirements and effects.

NRI will use cutting-edge genomic and metabolomic biotechnology to develop innovative approaches to understanding the role of diet and activity in normal brain develop-

Center uses cutting-edge biotechnology to develop innovative approaches to understand the role of diet and activity in human health

ment, in the prevention of cancer and in the prevention and treatment of obesity and eating disorders. Metabolomics is the systematic study of metabolites—small molecules generated in the process of metabolism.

Why center this research in Kannapolis, which was a textile mill town until the giant Pillowtex plant (once owned by Murdock) closed in 2003?

Because—with a $1 billion-plus investment by Murdock, $30 million a year from the state, huge investments from local governments and other businesses, including Red Hat and Biomarker Group—the N.C. Research Campus is drawing researchers from all over the country. N.C. State University already has broken ground on its Institute for Advanced Fruit and Vegetable Science. Duke University has committed to basing research efforts there, as have a number of other universities in the state, and the N.C. Community College System.

PHOTO BY RAMONA DUBOSE

"Here, we can bring minds together that can approach these issues from many different perspectives," Zeisel says. "We can do this here on a level beyond anything else being done in the United States."

They all will have access to new facilities and state-of-the-art equipment. For example, Murdock purchased the world's first actively-shielded 950 MHz superconducting magnet, a two-story, eight-ton machine that will allow scientists to delve into the three-dimensional structures of molecules and study their interactions with greater depth and clarity.

The equipment will be housed in the David H. Murdock Core Laboratory facility on the N.C. Research Campus. The Core Lab building was the first to be built, followed closely behind by NRI's 125,000-square-foot research building, to be completed in April 2008. Zeisel plans to recruit 18 faculty members and their research teams. They will work in Kannapolis and hold appointments at UNC-Chapel Hill.

"This institute will result in breakthroughs in how we use nutrition to enhance human health," Zeisel says. "We will be able to tailor recommendations on nutrition to the individual and not just give general guidelines. We can change how nutrition is practiced, and by so doing, change people's lives."

For more information, visit *www.nri.unc.edu*. ■

PHOTO BY RAMONA DUBOSE

The David H. Murdock Core Laboratory facility (left) on the N.C. Research Campus in Kannapolis, N.C., will house state-of-the art equipment that will allow Nutrition Research Institute (NRI) scientists to study how nutrition can enhance human health. NRI is a new part of the UNC School of Public Health. The building is to be completed by the end of 2007.

Dr. Steven Zeisel, NRI's director and Kenan Distinguished University Professor of nutrition and pediatrics in the UNC School of Public Health and School of Medicine, stands in front of the construction site of NRI's new 125,000-square-foot research building, slated to be completed in April 2008 (above).

UNC School of Public Health AWARDS & RECOGNITION

2006 – 2007

For more information on these and many other faculty, student and staff awards, honors and recognitions, visit www.sph.unc.edu/school/recognitions.

WITHIN THE SCHOOL AND UNIVERSITY:

Susan T. Ennett, PhD, associate professor of health behavior and health education, and **Aaron E. Blair, PhD**, an alumnus of the School who earned his MPH from the Department of Epidemiology, were this year's recipients of two prestigious School honors, the **Greenberg Alumni Endowment Award** for excellence in teaching, research and service and the **Barr Distinguished Alumni Award** for achievements and contributions to the field of public health.


Dr. Lawrence Kupper

Lawrence Kupper, PhD, Alumni Distinguished Professor of biostatistics, received UNC's 2007 Distinguished Teaching Award for Lifetime Achievement, in recognition of teaching excellence.

Karl Umble, PhD, program planner and evaluator for the North Carolina Institute for Public Health (NCIPH), received the 2007 Balderson Award for Support of Public Health Leadership Development at the National Public Health Leadership Network annual conference in St. Louis. The award honors an individual who promotes training programs for public health leaders.

The University named five endowed **distinguished professorships** in the School of Public Health in 2006-07:

Gerardo Heiss, MD, PhD, Kenan Distinguished Professor of epidemiology

Joseph Ibrahim, PhD, Alumni Distinguished Professor of biostatistics

Barry Popkin, PhD, Carla Smith Chamblee Distinguished Professor of global nutrition

Mark Sobsey, PhD, Kenan Distinguished Professor of environmental sciences and engineering

June Stevens, PhD, American Institute for Cancer Research Distinguished Professor of nutrition

Peggye Dilworth-Anderson, PhD, professor of health policy and administration and director of the Center for Aging and Diversity in the UNC Institute on Aging, has been appointed to the National Advisory Council on Aging (*www.nia.nih.gov/AboutNIA/NACA*), which advises the National Institute on Aging, part of the U.S. National Institutes of Health. The appointment was effective January 1, 2007, and runs through December 31, 2010.

ACROSS THE NATION AND THROUGHOUT THE WORLD:

Michael D. Aitken, PhD, chair of the School's Department of Environmental Sciences and Engineering (ESE), has been named a board-certified member of the American Academy of Environmental Engineers. He joins fellow ESE professors Drs. Phil Singer and Francis DiGiano in this prestigious professional society.


Dr. Margaret Bentley

Margaret "Peggy" Bentley, PhD, associate dean for global health and professor of nutrition, was selected as an ambassador in the Paul G. Rogers Society for Global Health Research at Research!America. Ambassadors support research efforts by reaching out to policy makers, media and the public and explaining the hope and importance of research.

Francis DiGiano, PhD, professor of environmental sciences and engineering, received the A.P. Black Award from the American Water Works Association for outstanding

Daniel A. Okun, PhD, UNC Kenan Distinguished University Professor Emeritus of environmental engineering, was honored in September 2006 with the International Water Association's prestigious Grand Award, a tribute to his outstanding international achievements as a water engineer and scientist. Okun accepted the award at the opening ceremony of the World Water Congress in Beijing, China.

In May 2006, he also received a Lifetime Achievement Award from the Environmental and Water Resources Institute of the American Society of Civil Engineers.

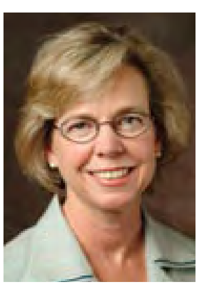
A pioneer of integrated water management, Okun spent much of his career studying the interdependencies between water supply and waste water disposal. His extensive résumé includes global experience in water resource management, a wide variety of consultancies, and an extensive list of honors and publications. His contributions have been both diverse and farsighted.

PHOTO BY THE NEWS & OBSERVER

Okun served as chair of the Department of Environmental Sciences and Engineering at the UNC School of Public Health from 1955-1973. He retired from teaching in 1982 but continued to consult with engineering firms, the World Bank, the World Health Organization, and the U.S. Agency for International Development, and he provided services to water-related organizations in 89 countries throughout the world.

achievement in water supply research. The award recognizes outstanding research contributions to water science and water supply, rendered over time. Former winners from UNC include **Drs. Russ Christman** (1987), **Phil Singer** (1995) and **Mark Sobsey** (2001).

Michael Kosorok, PhD, professor and chair of the Department of Biostatistics, was elected as a fellow of the Institute of Mathematical Statistics. Kosorok joined four faculty in the department who have received this honor, including Drs. Joseph G. Ibrahim, Alan F. Karr, Danyu Lin and Pranab K. Sen.



Dr. Lisa LaVange

Lisa LaVange, PhD, professor of biostatistics and director of the UNC Collaborative Studies Coordinating Center, is president of the Eastern North American Region (ENAR) of the International Biometric Society (IBS). UNC School of Public Health has a strong history of leadership in the society, with four School alumni or faculty—including Jim Grizzle, Peter Imrey, Gary Koch, and the late Bernard Greenberg—having served as the society's president. IBS is the largest professional organization of biostatisticians in the world, drawing its 5,800 members from more than 25 countries.

Sheila Leatherman, MSW, health policy research professor at the School, was awarded the title of Honorary Commander of the Most Excellent Order of the British Empire by Her Majesty Queen Elizabeth II. Leatherman received the honor in recognition of her valuable contribution to reform of the British National Health Service.

Danyu Lin, PhD, and **Donglin Zeng, PhD**, professors in the School's Department of Biostatistics, were accorded a rare honor for non-Britons—to read a paper to the Royal Statistical Society (RSS). The paper, given at the RSS Ordinary Meeting in London in January 2007, presented a new statistical methodology used to solve difficult public health problems such as reliable assessments of treatment effectiveness, precise descriptions of the effects of environmental and genetic factors on disease development, and accurate predictions of patient outcomes. Lin is the Dennis Gillings Distinguished Professor of biostatistics.

Thomas Ricketts III, PhD, professor of health policy and administration and director of the North Carolina Rural Health Research Program and Program on Health Policy Analysis at UNC, has been named editor of the *North Carolina Medical Journal*. Ricketts had been associate editor for the past four years.

Dr. Thomas Ricketts III

Philip Singer, PhD, Daniel A. Okun Distinguished Professor of environmental engineering and director of UNC's Drinking Water Research Center, received the acclaimed Athalie Richardson Irvine Clarke Prize for excellence in water research from the National Water Research Institute. The prize recognizes outstanding research scientists who have demonstrated excellence in water-science research and technology. Singer also received the 2006 Gordon Maskew Fair Award from the American Academy of Environmental Engineers (AAEE), given to a board-certified member of the Academy judged to have made a substantial contribution to environmental engineering through exemplary professional conduct, recognized achievements, and significant contributions to the control of the quality of the world's environment.

Dr. James A. Swenberg

James A. Swenberg, DVM, PhD, Kenan Distinguished Professor of environmental sciences and engineering, received the Society of Toxicology (SOT) Merit Award, presented in recognition of his distinguished career in toxicology.

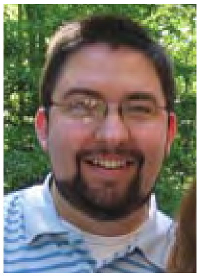
Steven Zeisel, MD, PhD, Kenan Distinguished Professor of nutrition and pediatrics, received the Bristol-Myers Squibb/ Mead Johnson *Freedom to Discover* Award for Distinguished Achievement in Nutrition Research. Zeisel was recognized for landmark contributions to understanding of metabolism and the function of choline, an essential nutrient that influences human development and brain, liver and muscle function. Zeisel also received the American College of Nutrition Award for distinguished achievements over a lifetime in the field of nutrition at the annual meeting of the organization on September 27, 2007, in Orlando, Fla.

STUDENTS AND RECENT ALUMNI:

Several students from the School were honored at spring 2007 student recognition ceremonies for their research, leadership and service. Among winners of the UNC Graduate School's Impact Awards were **Lynnette Phillips**, **Danielle Haley**, **David Rosen**, **Sheryl Abrahams**, **Emily Bobrow**, **Melissa Roche** and **Katherine Karriker-Jaffe**. Phi Beta Kappa inductees this year included **Lily Penelope Clark**, of Washington, D.C.; **Victoria Yizhi Ding** of Hattiesburg, Miss. and Raleigh, N.C.; and **Kristen Elizabeth Ziara**, of Okemos, Mich.

April Clark, **Robin Hunt** and **Jessica Thompson**, graduate students in the School's Department of Health Policy and Administration, won third place in a national health care competition sponsored by the National Association of Health Services Executives.

Doctoral candidates **Elizabeth J. King** (health behavior and health education), **Abigail Norris Turner** (epidemiology) and **Emily Bobrow** (maternal and child health) presented research at the Global Health Council's 34th annual international conference on global health, May 29 – June 1, 2007, in Washington D.C. The presentations completed the students' participation in the National Investigators in Global Health (NIGH) Program, a competitive abstract submission and selection program designed to highlight exemplary research, policy and advocacy initiatives of new and future leaders in global health and empower participants with global health advocacy skills. GHC selected 14 out of 300 abstracts for inclusion in the program. The University of North Carolina at Chapel Hill had three participants, the highest number from any university.



Brad Wright

Brad Wright, doctoral candidate in health policy and administration, received an award from Kaiser Family Foundation for an essay outlining the health policy platform of an imaginary 2008 presidential candidate and proposing a strategy for communicating the plan to the public.

LETTERS TO THE Editor

I write to compliment you on your most recent issue on health disparities. As a courtesy, many schools of public health share their alumni magazines with each other. Given the consistently interesting coverage in *Carolina Public Health*, I examine every issue. I was moved to write this time due to the importance of the subject of health disparities and, frankly, its timeliness for those of us living in Michigan. Last November, the state's voters passed a citizen's initiative that bans affirmative action. As such, we at the University of Michigan are especially sensitive to issues related to diversity and disparities. And, of course, addressing health disparities lies at the foundation of our field. It is embedded in our School's mission statement and constitutes a focal point for much of our research and teaching. As your issue so vividly demonstrates, the same holds true for UNC. I commend your faculty and students who devote so much time, energy, and evident devotion to this crucial issue.

Incidentally, we take great pride that your Dean, Barbara Rimer, is an MPH graduate of the University of Michigan School of Public Health. Despite being relatively new at the job, Dean Rimer has rapidly emerged as one of the leaders among the deans of the nation's public health schools. UNC is fortunate to have her at the helm.

Kenneth E. Warner, PhD
Dean and Avedis Donabedian Distinguished University Professor of Public Health
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Top health consultant thanks School *for* "ticket" *to* success

Deniese Chaney

As a teenager, Deniese Chaney worked summers. Instead of flipping burgers at a fast food restaurant or ringing up purchases at a shoe store, she typed, filed and kept patient records at a medical diagnostics clinic. Her aunt was an employee at DukeHealth and had urged her to give the health care field a try. Chaney did — and liked it so much she has remained in health care for 35 years.

"It's a constantly evolving field. You're constantly learning, and there are always new challenges," she says. "Over time, it becomes a way of life. You know more about it than you do about anything else."

Chaney now has a master's in health policy and administration from Carolina's School of Public Health, highly regarded expertise in medical imaging, and an executive position at Accenture LLC in the Health and Life Sciences practice. She has come a long way from her clerical summer job. Now, she wants to give something back to the school that contributed significantly to her professional growth.

Chaney hopes that the $25,000 gift she gave to the School of Public Health to help fund the graduate education of a student in health policy and administration will afford other people the chance to step out of the box and expand their horizons.

"Anybody who has lived through what I've lived through, who has experienced a certain plateau in their career such that they couldn't move forward, will appreciate what a master's education can do. It opens doors. It's a ticket. I want other people to have that ticket," says Chaney, who serves on the School's Public Health Foundation Board of Directors.

For three years in the late 1980s, Chaney balanced the demands of graduate school with a full-time job. Employed by the UNC School of Medicine at the time, she worked at MacNider Hall on the Carolina campus from 7 a.m. to 9 a.m., walked across the street to the School of Public Health's Rosenau Hall to take classes, walked back to the Radiology Department at noon, and stayed there until evening.

Chaney says that while such a schedule was difficult to manage, it enabled her to fund the part of her education that wasn't covered by the UNC-Chapel Hill employee tuition program.

"If I hadn't been allowed to take classes while working full time, I wouldn't have gotten that piece of my education, and I wouldn't have had the growth opportunities I've had," she says. "I feel immensely grateful to the School, and I want other students there to have similar opportunities."

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RENOWNED ENVIRONMENTAL ENGINEERING PROFESSOR CONTINUES HISTORY OF GIVING

When Dr. Daniel A. Okun, Kenan Distinguished University Professor Emeritus of environmental engineering, retired from the UNC School of Public Health in 1982, the department he chaired for almost two decades was several times bigger than the one he joined in the 1950s. Under Okun's leadership, the Department of Environmental Sciences and Engineering's narrow focus on a program in sanitary engineering had expanded to a comprehensive, interdisciplinary environmental sciences and engineering program—now ranked among the country's top 10, according to *U.S. News & World Report.*

Even in retirement, Okun continues to add value to UNC. "Dan has a history of giving to the university," says Dr. Michael D. Aitken, chair of the Department of Environmental Sciences and Engineering. "He's been a consistent donor to our department for many years."

Okun's contributions have funded a range of development efforts, from student scholarships to the construction of buildings and facilities. This year, Okun gave a gift to the Department of Environmental Sciences and Engineering to name the department chair's suite in Rosenau Hall.

"The opportunity to directly associate the suite with Okun is a significant honor for the department," Aitken says.

Okun has been recognized by virtually every professional organization in his field for excellence as an engineer, scholar, teacher and public servant. His 50-year career advocating the protection of drinking water resources, use of appropriate water technology infrastructures in developing countries, and responsible water supply planning has brought untold prestige to the School.

"We are grateful to Dan first for his leadership, and second for his generosity," says Aitken. "He helped put the Department of Environmental Sciences and Engineering on the map."

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Former student endows School with scholarship *for the* physically challenged


Dr. Nguyen V. Dat

Dr. Nguyen V. Dat still remembers when, as a student working toward his Ph.D. in biostatistics at the University of North Carolina at Chapel Hill in the late 1970s, he had flown into Atlanta, Ga., for a conference sponsored by the American Statistical Association.

Dat and a few other graduate students from his department had picked up their luggage and were discussing the best way to reach their hotel. Someone suggested taking the train, which would drop them off a mere couple of blocks from where they were staying. Most found the idea appealing, but Dat took a cab instead.

Dat, now vice president for clinical research at Abraxis BioScience, Inc., a global company that develops, manufactures and markets a broad portfolio of pharmaceutical products, contracted polio as a child. The disease left his right leg paralyzed. There was no way he could have carried his luggage and walked two blocks at the same time.

"I paid $30 for a taxi, instead of just $1 for the train," recalls Dat. "I've gone through this a million times, and I know how it feels—a student who is physically challenged usually spends more money for what he needs than a student who is not."

To raise awareness for the needs of physically challenged students and to give a little something back to the school that financed his entire doctoral education, Dat made a gift to the School of Public Health to endow an annual scholarship for a graduate student in the Department of Biostatistics. The Nguyen V. Dat Endowed Scholarship gives preference to physically challenged students. In any given year, if no physically challenged student qualifies, it may be awarded to someone else.

"I've wanted to do this for a long time," says Dat. "I feel it's the best thing I can do to inspire other schools to do the same thing. I think using Carolina as an example is good since it has one of the best schools of public health in the country. If nothing else, I'm hoping to inspire people to contribute to the scholarship so it can help more people like me."

Prior to making a scholarship gift to the School, Dat had been making contributions to the Department of Biostatistics every year. He is a longtime part of the School of Public Health's Honor Roll of Donors.

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Every gift is vitally important to the UNC School of Public Health and deeply appreciated. To conserve resources, gifts under $100 are acknowledged on the School's Web site where a complete list of donors can be found. (www.sph.unc.edu/giving)

We have made every effort to ensure the accuracy of our Honor Roll lists. We regret any errors or omissions that may have occurred and ask that you advise us of corrections needed by contacting Stephanie Money at 919-966-3722 or stephanie_money@unc.edu. The School of Public Health is extremely grateful for your continued support.

Rosenau Society *Gifts*

July 1, 2006 to June 30, 2007

The Rosenau Society is named in honor of Milton J. Rosenau, the first dean of the School of Public Health. Membership in the Rosenau Society is limited to benefactors making a minimum unrestricted contribution of $1,000+ to either the School of Public Health or one of its departments. Membership must be renewed on an annual basis.

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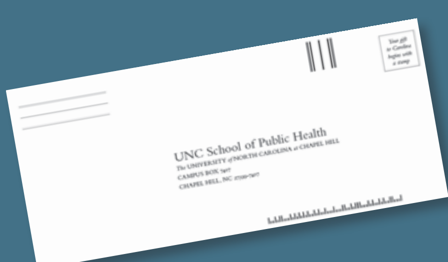
Fred Brown Jr., MPH and Laura Brown —

Promoting public health collaboration and synergy

SOME OF FRED BROWN'S FONDEST MEMORIES AS A UNC SCHOOL OF PUBLIC HEALTH GRADUATE STUDENT took place in a student lounge in Rosenau Hall. "Students and professors went there to relax, share stories and discuss ideas," says Fred, who is managing director of business development for Carolinas HealthCare System in Charlotte, N.C., and president of the Public Health Foundation at UNC. "Those interactions were a very important part of my education."

With the School growing and federal support shrinking, Fred and his wife Laura decided to fund construction of a student government association office in Rosenau Hall where more students can congregate. The office will be named in their honor. "We've seen the School grow in stature and make contributions to health care not only nationally but globally, and we believe a large part of that is due to how much it encourages people to share ideas and collaborate," Fred says.



The UNC School of Public Health's continued excellence depends on you. By naming a room in Rosenau Hall or the Michael Hooker Research Center, you can help cultivate ideas that may some day change the world. For more information on how you can help, call Peggy Glenn at (919) 966-7612, or e-mail her at pglenn@unc.edu. Complete the enclosed envelope and invest in our collaborative future.

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