tx H$_2$O

A Publication of the Texas Water Resources Institute

Summer 2013

TECHNOLOGY & WATER

Computer models, electron beams, irrigation efficiencies and more

Texas A&M AgriLife Research
Texas A&M AgriLife Extension Service
Texas A&M University College of Agriculture and Life Sciences

Working to make every drop count

Welcome to the Summer 2013 edition of *txH2O*. This issue highlights technologies developed and enhanced by The Texas A&M University System researchers to help the state meet its growing water and food needs in this era of shrinking available water supplies and budgets.

As we face declining water supplies, growing populations and emerging contaminants, the development and implementation of new technologies are increasingly necessary to help us meet future needs. Much of our future water requirements may be met through the application of yet to be developed or underdeveloped technologies. Almost 25 percent of future unmet water demands are anticipated to come from implementing conservation programs and technologies, 10 percent from reuse systems and another 4 percent from desalination technology.

The Texas A&M System has placed a high priority on meeting these needs and significant advances are being made to develop and apply new technology. Computer models and other decision support tools are helping decision makers, from agricultural producers to regulatory agencies. Crop breeders are applying molecular methods to accelerate improvements to help meet growing food demands with less water. Significant advancements are being made to increase agricultural irrigation efficiency. And, technology is being enhanced for reusing wastewater and improving the treatment of wastewaters.

Now more than ever, the Texas Water Resources Institute is committed to advancing water research and education, and *txH2O* is an integral part of that work. The institute is inviting individuals and organizations to become a part of the *txH2O* team by becoming sponsors. Sponsors will be recognized for their support by having their name and/or logo published in each issue of the magazine. For more information on how to become a sponsor, please contact Kathy Wythe, *txH2O* editor, at kwythe@tamu.edu.

We are grateful to be part of a university system that makes water research and outreach a priority. I hope you enjoy the issue. As always, let's continue to make every drop count.

Kevin Wagner

Kevin Wagner
Associate Director

tx H_2O

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TEXAS A&M AGRILIFE RESEARCH | EXTENSION

Texas Water Resources Institute
make every drop count

Inside

Volume 8, number 2, Summer 2013

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Illustration by Jaymast

txH_2O *is published three times a year by the Texas Water Resources Institute (TWRI), which is part of Texas A&M AgriLife Research, the Texas A&M AgriLife Extension Service and the Texas A&M University College of Agriculture and Life Sciences. TWRI is funded in part by the U.S. Geological Survey and authorized by the Water Resources Research Act. To subscribe to* txH_2O *or Conservation Matters, TWRI's monthly e-mail newsletter, visit twri.tamu.edu. Follow us on Twitter at Twitter.com/TxWRI.*

TECHNOLOGY IN WATER CONSERVATION

WATER CONSERVATION & TECHNOLOGY CENTER
Securing Our Water Future

It is not unusual for individuals to describe water conservation as a behavioral exercise and urge for education to be used to change people's behavior. For example, people can be taught to save water by turning off the faucet while brushing their teeth or by operating their lawn sprinkler less. Successful water conservation, however, is just as dependent on technological factors.

The technology does not have to be complex to be important — consider high efficiency toilets and showerheads. These everyday appliances largely rely on simple technologies to increase the impact of rinsing and reduce water use. A homeowner who converts the plumbing in a typical pre-1992-built home to this technology can expect to save 22,000 gallons per year in water use without a drop in productivity. Secure 250,000 of these conversions, as San Antonio has over the last 15 years, and it reduces water needs by approximately 17,000 acre-feet every year.

Drip irrigation technology saves large amounts of water while improving horticultural results. It places water directly on the soil, above the feeder roots, instead of spraying it into the air or over the surface of the ground at high pressures and volumes. Water applied by drip irrigation is less subject to wind, runoff and evaporation. Drip irrigation can increase irrigation efficiency from 70 percent or even 50 percent to 95 percent.

Water reuse systems treat wastewater by various technologies including filtering, bioremediation and ozone exposure. These technologies can involve billions of gallons of wastewater — such as in a municipal recycling effort — or they can be small scale, such as in a self-contained toilet.

Some water distribution systems lose 25 percent of water between their wells or their treatment plant and their customers because of leaks. In a large, aged water distribution system, a leak can exist for years before it becomes visible at the soil surface. Leak detection procedures often rely on sound technology to find leaks so they can be repaired and the volume of water lost can be reduced. Some of these procedures involve walking over pipelines with simple amplification equipment, but the "hearing detection" can also be accomplished with instruments attached to pipelines at manholes. These devices "listen" to the water flow in the pipe; when they detect the characteristic sound of a leak, they report by radio to permanent or mobile collection points. Even a small leak can be detected.

Rainwater catchment may be a good way to replace water from other potable sources. In some situations, this involves using the simple technology of capturing rainfall runoff from a roof or another surface. In a hot, dry climate with erratic rainfall patterns, rainfall collection is impractical or requires a large, expensive storage capability. In such situations, condensate collection from air conditioners may be a more reliable, efficient technology to use. The Alliance for Water Efficiency estimates that the amount of condensate can range from three to 10 gallons per day for each 1,000 square feet of air-conditioned space.

As important as technology is in producing new water resources through water conservation, introduction of new technology does not automatically result in water savings. The new evapotranspiration-based irrigation controllers illustrate the point. A lawn's need for water is dependent on the weather conditions. The new controllers link operation of the sprinkler system to weather conditions collected on site or through an ongoing feed from radio- or web-based data. If businesses and homeowners are over-watering lawns, the technology could result in superior lawn performance with less water.

Unfortunately, this technology in its present state of flexibility and sensitivity does not always save water. In a community with strong drought management rules and a population educated in a lawn's capability to survive deficit irrigation, the controllers apply more water than desired or needed. To meet the needs of such a community, the controller would need to translate the weather data to an irrigation regime that reflects a landscape's drought survival capability rather than the water it needs to be lush. Improvements in irrigation controllers are expected, and then the weather-related automatic controllers will be beneficial as a water conservation technology.

Technology at many levels is a major part of water conservation now, and great opportunities for advances exist that will increase its importance in producing water from conservation activities.

Story by Leslie Lee

UNITED

How one computer model makes Texas surface water management possible

Managing surface water supplies in Texas is complex, to say the least. Multiple state agencies work together to ensure that the thousands of miles of rivers and streams in Texas can meet both human and environmental needs, now and in the future. This daunting task would be exponentially more complicated if all parties involved couldn't speak the same language.

In Texas, that common language is a computer modeling system called WRAP, the Water Rights Analysis Package.

Developed by Dr. Ralph Wurbs, Arthur McFarland professor in the Zachry Department of Civil Engineering at Texas A&M University, WRAP is a set of computer programs that processes hydrology and water rights input files for Texas' 23 river basins and simulates the amount of water in a river and reservoir system under a given set of conditions. WRAP enables surface water managers throughout Texas to allocate water resources, plan for the future and ensure there is enough water for environmental as well as human needs.

A statewide surface water permitting system is born

Prior to the 1950s drought, different types of water rights had evolved over hundreds of years in Texas, and eventually this reached an unmanageable point, Wurbs said. State water authorities realized something had to be done. The Texas Legislature passed the Water Rights Adjudication Act in 1967, consolidating all surface water rights into one coordinated system by transforming previously held Spanish and Mexican riparian water rights and state of Texas appropriative rights into certificates of adjudication.

Of the more than 6,000 water rights in Texas, all water rights outside of the Middle and Lower Rio Grande are determined by seniority, chronologically; older permits have priority access to surface water diversions. The Texas Commission on Environmental Quality (TCEQ) now manages water rights permitting and appropriations.

"In Texas, it's 'first in time, first in right,'" said Dr. Richard Hoffpauir, engineering research associate at the Texas A&M Engineering Experiment Station, who has helped Wurbs with WRAP development for the last decade.

TCEQ is responsible for protecting water rights and ensuring that water is only diverted according to permitted levels, based on the priority date of individual water rights. ⇨

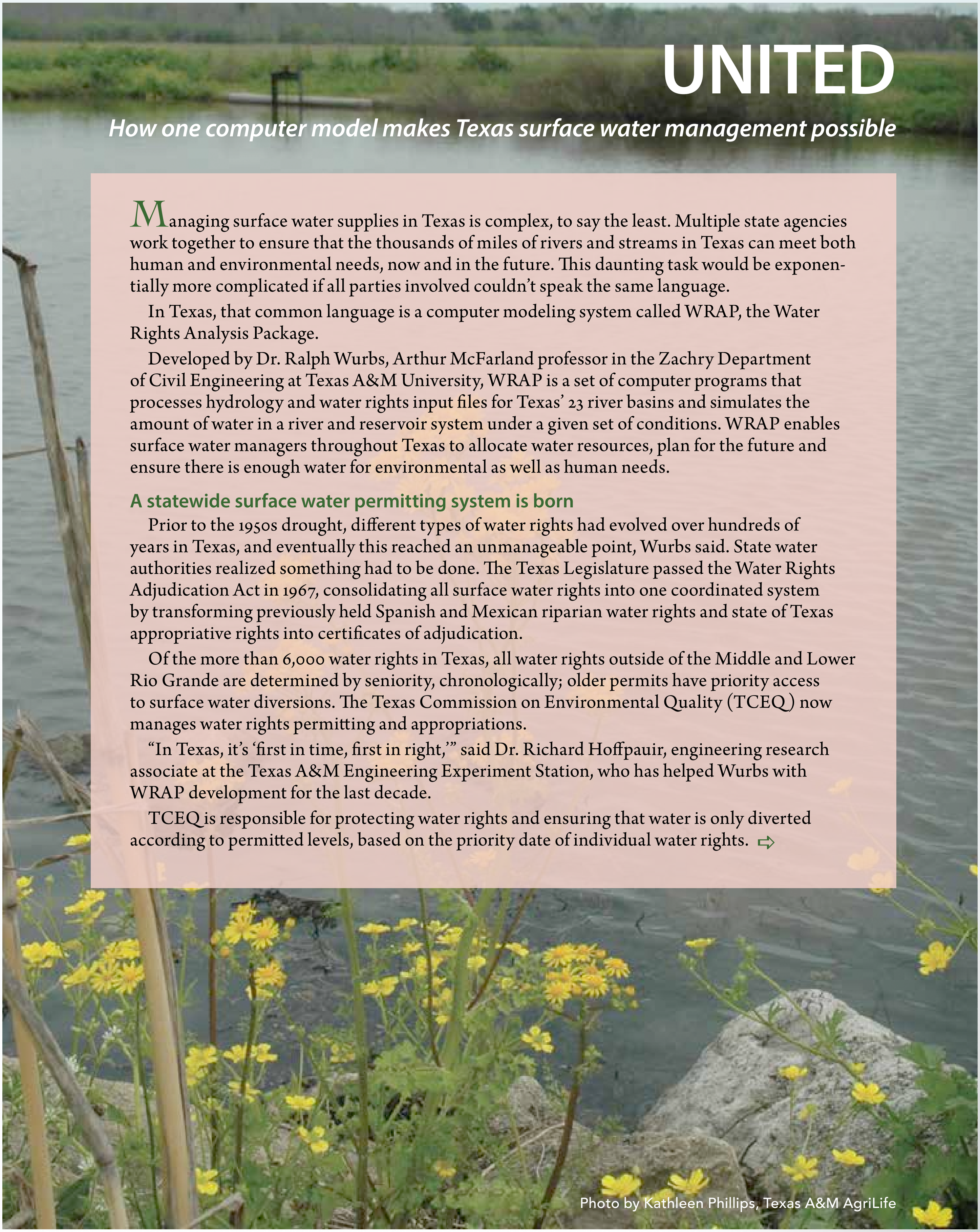

Photo by Kathleen Phillips, Texas A&M AgriLife

Water must be quantified before being allocated

The unified permitting system required an integrated way to quantify and predict surface water supplies.

"The basic premise is this: To manage water resources, you need to know how much water you're managing," Wurbs said. "And when you look at it, you figure out it's not just quantities, it's reliabilities. And so, that led to the modeling system."

"WRAP is about better understanding the water resources that are available," Wurbs said. "If you better understand through the computer modeling system what is available, then you can better manage."

Development of the model, first called TAMUWRAP, began in 1986 as part of a research project led by Wurbs, funded by the U.S. Geological Survey through the Texas Water Resources Institute (TWRI), with the Brazos River Authority serving as the nonfederal sponsor. Over the years, Wurbs and his team would grow WRAP into a robust set of programs able to wholly simulate development, management, control, allocation and use of the water resources of river basins.

After a major drought in the 1990s, the Texas Legislature passed Senate Bill 1 in 1997, which called for a comprehensive water management planning process and a water availability modeling system to make effective management of the surface water permit system possible.

TCEQ and other state agencies began working with Wurbs to develop the Water Availability Modeling (WAM) system, which consists of WRAP and WRAP input datasets for every river basin in Texas. The WRAP-based WAM system is maintained by TCEQ as the state's official surface water modeling platform.

"Around 2001, I joined the hydrology team at TCEQ, and in that role, I began working with WRAP model development. The WAM datasets were being developed for river basins around the state," said Dr. Kathy Alexander, technical specialist for the Water Rights Permitting and Availability section of TCEQ.

"In the early development of WRAP, from the early 90s through the point at which TCEQ adopted WRAP as the model that we'd use for the state, there was an incredible amount of background research involved," she said. "That aspect, all of the research involved, Dr. Wurbs was instrumental in making it all happen."

Although WRAP is now used for multiple purposes and at multiple agencies, such as for regional water planning at the Texas Water Development Board (TWDB), at TCEQ it is used to process water rights permit applications. This entails determining how much water is available for a new permit, Alexander said, as well as any possible impacts it might have on existing water rights in the basin.

"If someone applies for a new water right, we have many requirements, one of which is that we have to find that the water is available, after we look at all existing water rights," Alexander said. "A new permit can have what's left over. And so, determining what's left over is what we use WRAP and WAM for. It kind of is that simple, but it's also not. There are multiple levels of complexities to the modeling."

Part of that complex system is the prior appropriations aspect of Texas surface water management policy.

"WRAP and WAM accurately model the prior appropriations system of water rights in Texas, in which the older right gets to go first in its diversion of water," Hoffpauir said. "Water rights created after that right are not to injure the availability of water to the older water rights. So, WRAP is very good in that it precisely models that system."

Helping water planners speak the same language

State agencies aren't the only ones using WRAP. River authorities, private consultants, permit applicants, attorneys — anyone and everyone who deals with water allocations in Texas uses WRAP, creating an agreed-upon, even, reliable playing field for surface water management.

While the state uses the software to permit and plan, water-minded landowners hire engineering firms or consultants to employ the predictive aspects of WRAP.

"Most people want to know about 'what if' scenarios — what if we have a drought, or what if I change my water rights and move them here, or what if I add some other component to my portfolio of water supplies," Hoffpauir said. "So, just as with any modeling system, that's what you're trying to do: ask 'what if' questions and then evaluate how the system responds when you make those changes."

"In my mind, the state of Texas is somewhat unique, somewhat of a leading example for water management nationwide, and that in itself is a contribution — to have a statewide modeling system that's used with consistency," Wurbs said.

"With WRAP, everyone can speak a common language," Hoffpauir said. "It's a common language that the technical people, the engineers and the scientists can all use to get down to the real questions that need to be answered." ⇨

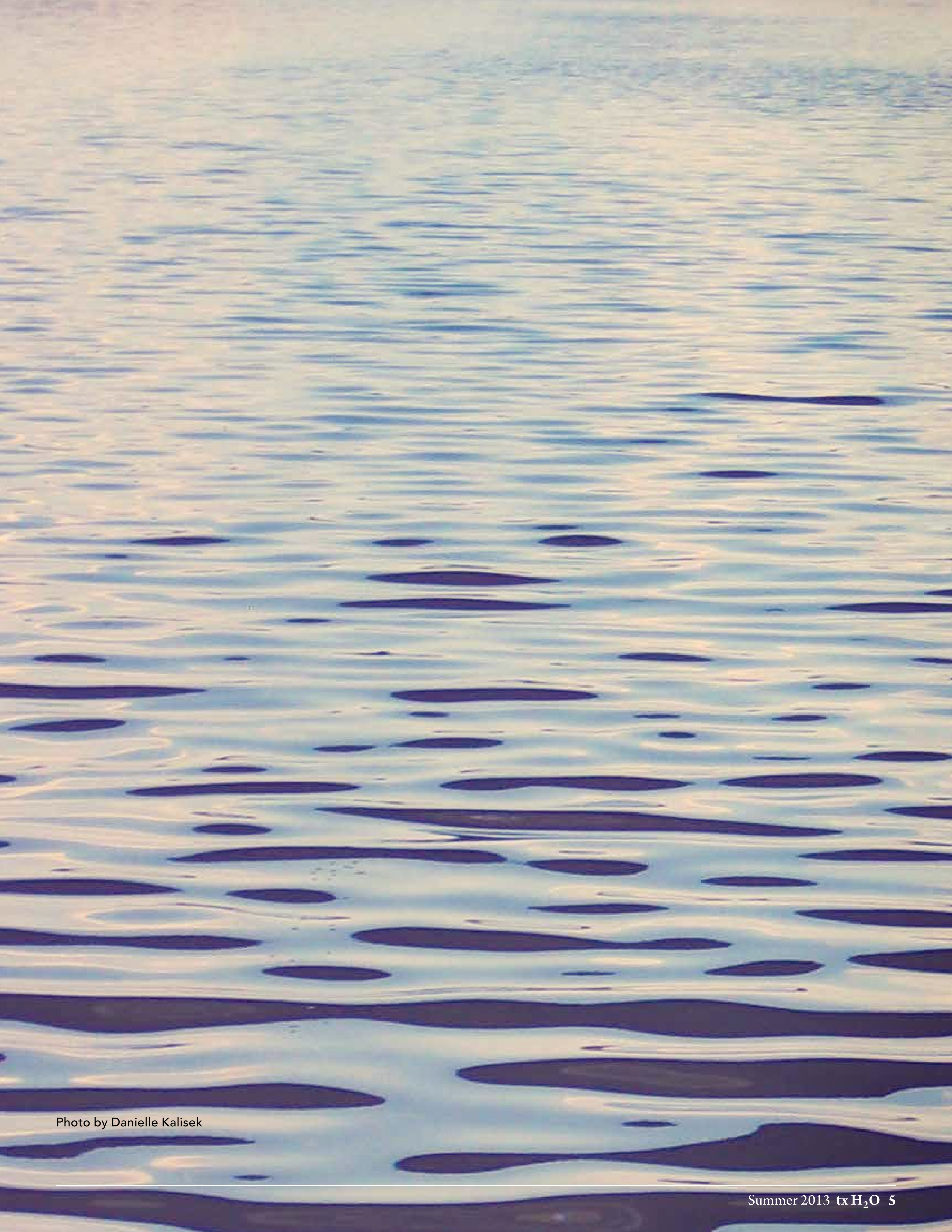

Photo by Danielle Kalisek

To model environmental and instream flow requirements, researchers have developed a version of WRAP that would operate on a daily time step instead of a monthly time step. Photo by Danielle Kalisek.

Uniquely transparent

"There are several aspects of WRAP that are unique," Hoffpauir said. "For one, it is public domain — you don't see that in a lot of other modeling efforts in other places. What you see in a lot of other places is proprietary modeling."

Through TCEQ's, TWRI's and Wurbs' websites, all components of WRAP and WAM can be accessed and downloaded for free — everything from the actual software and input datasets to years of technical reports and user manuals.

The architecture of WRAP, the way the WAM datasets are open-sourced, how anyone can modify them for their purposes, and how simple the system is to use all combine to make the WRAP/WAM system ideal for users, Alexander said.

"With WRAP, everybody is dealing with a publicly available and transparent modeling system. When you get engineers or technical folks all in a room, they don't have to argue about the model — they can just talk about the results," Hoffpauir said.

Collaboration fuels continual improvements

The varied users of WRAP — statewide permitting officials, regional water planning groups and individual water management entities such as river authorities — form a wider water management community in Texas that has seen greater collaboration and consistency because of WRAP.

"There is a consistency, and the advantage of the water modeling system is that it helps tie the water management community together," Wurbs said. "The different water management functions, the coordination, the interconnection of regulatory, planning and operational functions have been tied together perhaps better than they would have been otherwise, because of the modeling system."

Through the years, Texas A&M has housed research development of WRAP, funded in large part by TCEQ. Wurbs' team and TCEQ have consistently listened to public and private groups who use the software, facilitating collaborative progress with WRAP.

"With WRAP, it's a very collaborative effort, and we see the public sector and private sector and academia all coming together to evolve and improve the modeling system over all," Hoffpauir said.

New daily model supports environmental flows efforts

In recent years, WRAP has been instrumental in enabling the state to regulate the surface water flows needed to maintain healthy river and stream ecosystems.

The Texas Instream Flow Program, mandated in 2001 by Senate Bill 2, directed state agencies to conduct scientific studies to determine how much water should flow in each river or stream to ensure a healthy environment. Passed in 2007, Senate Bill 3 created a process for the state to establish environmental flow standards, considering the best available science and future human water needs for Texas' river basin and bay systems.

Based on recommendations from stakeholders and scientists, TCEQ will adopt environmental flow standards for each of the basin and bay systems named in the legislation. TCEQ has adopted environmental flow standards for the Sabine and Neches rivers and Sabine Lake Bay; the Trinity and San Jacinto rivers and Galveston Bay; the Colorado and Lavaca rivers and Matagorda and Lavaca bays; and the Guadalupe, San Antonio, Mission and Aransas rivers and Mission, Copano, Aransas and San Antonio bays.

"Some of the stakeholder teams used WRAP," Hoffpauir said. "And what they were doing was answering those 'what if' questions — what if we adopted this level of environmental flows protection that the science team recommended, what if we adopted that, then how much water would be left over for a new permit?"

WRAP is used in the initial development of environmental flows recommendations, and once TCEQ decides on final regulations, those regulations are incorporated into WAM. Effective modeling of environmental flow requirements has necessitated various additions to the WRAP/WAM system, Wurbs said, including capabilities for modeling at a smaller computational time step.

In recent years, Wurbs' research team has tackled the huge task of developing a version of WRAP that would operate on a daily time step instead of a monthly time step, as the original version had. This meant more data, more programming and more research. Hoffpauir's doctoral dissertation research provided the foundation for the daily modeling system, Wurbs said.

"One of the major reasons for the daily time step is modeling environmental and instream flow requirements," Wurbs said. "The previous version was monthly, and it's not that one version is better than the other — the intent is not to replace the monthly model with a daily model, they're just different. One of the things that the daily model can do quite well is environmental flows."

TCEQ's adopted environmental flow standards include flow regimes consisting of a variety of flows: subsistence flows, base flows and high flow pulses.

"Pulse flows are when there is a rainfall event, so we're talking about hours and days," Wurbs said. "But at a monthly time step you lose this, you really need a daily time step, and the complexities that go along with a daily time step."

"To accommodate the new environmental flows processes, we've done a lot of work within WRAP to be able to model individual pulse flow events on a daily basis," Hoffpauir said. "It's difficult, although not impossible, to model pulse flow events on a monthly basis, primarily because many of the recommendations are for pulse flow events that occur on the order of a few days to less than a few weeks."

"Simplifying assumptions are required to model pulse flow events with a monthly look," he said. "To refine the modeling results, we had to use a daily simulation while preserving all of the capabilities built originally for monthly modeling."

"It is a tremendous amount of work," Alexander said. "Texas is a really big state, so you're looking at daily flows for thousands of points and making sure that you're accurately modeling the complexities of water rights. It's a pretty daunting task, but Dr. Wurbs' team is up to the task."

In August 2012, the new, daily version of WRAP was released to the public, along with extensive new user manuals and technical reports.

WRAP keeps evolving

"The work we've been doing to get these daily time step methodologies worked out, to get the computer programs ready to implement them — it never ends," Wurbs said. "You keep making it better. And that's what was significant about August 2012 — that was when we were close enough to make it available to the water management community."

Wurbs and his team are currently working with TCEQ to develop daily flow datasets incorporating new environmental flow standards for various river basins in Texas. Research efforts for the Brazos River dataset have been completed, and they are now working on the Trinity and Colorado. TCEQ is in the process of reviewing the new daily datasets and will continue to use the monthly model in water rights permitting.

"WRAP keeps evolving," Wurbs said. "Currently the focus is environmental flows. And that's going to continue to be the focus for a while."

"Water is very important to the economic development of the state, and at the political level and the technical level, and at the agencies, people recognize that and work together. The Texas Legislature has supported it. Texas has moved out on it. The Senate Bill 1 planning process is a major step in dealing with water, and the water availability modeling system is a unique system."

For more information, visit *txH2O* online at

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Story by Danielle Kalisek

THE ENDING OF AN ERA

After more than 10 years, the Rio Grande Basin Initiative concludes

The Rio Grande near the river diversion point for the Delta Lake Irrigation District office in Edcouch, Texas. Photo by Danielle Kalisek.

Scientists with the Rio Grande Basin Initiative used aquatic weed control methods and herbicides to control invasive water plants such as water hyacinth, pictured. Photo by Danielle Kalisek.

Editor's Note: Writer Danielle Kalisek has managed the Rio Grande project for the past eight years. The information below is collected from her experiences of working with the project and its participants and includes quotes from project members.

The beginning of the era

The Rio Grande Basin is one of the most productive agricultural areas in the United States, and irrigated agriculture claims more than 85 percent of the basin's water. Persistent drought in the basin and predicted population growth will continue to strain limited water supplies both for agricultural irrigation and urban water consumption.

In 2001 the *Efficient Irrigation for Water Conservation in the Rio Grande Basin initiative*, also known as the *Rio Grande Basin Initiative* (RGBI), began to address these supply problems with a team of researchers, extension specialists and county agents from Texas A&M AgriLife and the New Mexico State University College of Agriculture and Home Economics. After 12 years of continued successful efficient irrigation and water-conserving efforts, the federally funded project ended in July 2013, but much of the water conservation work that was initiated continues.

Over the years, about 145 researchers and extension workers in Texas and New Mexico received grants through RGBI. Project personnel worked with local irrigation districts, agricultural producers, homeowners and others. Efforts focused on nine areas: 1) irrigation district studies; 2) irrigation education and training; 3) institutional incentives for efficient water use; 4) on-farm irrigation system management; 5) urban water conservation; 6) environment, ecology and water quality protection; 7) saline and wastewater management and water reuse; 8) basinwide hydrology, salinity modeling and technology; and 9) communications and accountability.

The RGBI project was funded through the U.S. Department of Agriculture National Institute of Food and Agriculture (NIFA) and administered by the Texas Water Resources Institute and the New Mexico State University Water Task Force.

Expanding impacts

The RGBI project has affected not only those living in the basin — farmers, homeowners, youth — but also the researchers and extension personnel involved in the project. In many cases, RGBI research conducted at Texas A&M AgriLife Research and Extension Centers has been taken to farmers and implemented in their fields for comparison studies. Those involved in the project held educational events to teach homeowners and youth about in-home and landscape water conservation measures they can take to save water and dollars. RGBI funding has helped support numerous students, researchers and extension personnel and has helped add leverage to secure additional funding. All these accomplishments have formed a foundation for future projects. A major contribution of the RGBI project, beyond conserving dramatic quantities of water, is training the next generation of water scientists.

"It has helped us develop great relationships with irrigation districts and New Mexico faculty, and it has facilitated the adoption of water-conserving technologies," said Dr. Ronald Lacewell, RGBI project participant and assistant vice chancellor of federal relations at Texas A&M AgriLife.

"RGBI put minds, talents and experiences to work together in common water conservation goals," said Dr. Daniel Leskovar, professor and center director at the Texas A&M AgriLife Research and Extension Center at Uvalde. "It excelled in engaging groups collectively — multidisciplinary, multicollaborative and multi-institutional — in critical research, education and extension water programs."

Dr. Shad Nelson, associate professor at Texas A&M University–Kingsville, attributes RGBI funding to his start in citrus research. "RGBI helped to solidify my career in Texas as well as provided meaningful impacts to the citrus growers of South Texas. Farmers have been able to showcase water-saving practices to other growers." ⇨

"The RGBI program not only helped to establish a strong foundation for my research programs, but also encouraged me to expand the scope of my research program by [helping me leverage] external funds," said Dr. Zhuping Sheng, associate professor at Texas A&M AgriLife Research and Extension Center at El Paso.

By financially supporting personnel, RGBI projects have also supported students. In particular, Nelson's funds supported six graduate students who have all continued into agriculture-related jobs or at federal agencies such as USDA. Lacewell's funds supported 10 agricultural economics graduate students and three undergraduates working on his projects.

Putting initiative results into action

Technology transfer and implementation continues in the basin as a result of RGBI efforts.

"The RGBI project has helped us begin to understand the complex water interactions of the Rio Grande Basin," said Blair Stringam, assistant professor and RGBI project director at New Mexico State University. "We are beginning to understand groundwater and surface water interaction as well as evapotranspiration and surface water losses. We hope to gain additional understanding in the future."

"The RGBI project has been instrumental in allowing citrus growers in the Lower Rio Grande Valley see that alternative irrigation methods can be implemented now and provides high economic returns while saving 35 percent [irrigation] water," Nelson said.

"Technology adoption certainly has occurred in a major portion of the farming community," Leskovar said. "Farmers and citizens have a better understanding of the value and volume of water used for food production."

These adoptions and efficient technology transfers include center pivot and LEPA irrigation systems, weather data, sensing technologies, drought-tolerant field crops and high-value specialty crops, he said.

Highlighted Findings & Implemented Results

Accountability and communications were high priorities of this project. Starting in 2003, an annual progress and accomplishments report was published, highlighting that year's results and efforts of the project participants. These reports show that project efforts conserved roughly 500,000 acre-feet of water per year, leaving more available for other users, such as municipalities, or for farmers to use in other fields. In addition, farmers, irrigation district managers, homeowners and others saved about $500,000 annually by implementing more efficient methodologies or infrastructure or adopting water-conserving practices. The team produced more than 1,500 publications from these efforts.

Selected accomplishments

Infrastructure evaluations of seepage losses found that linings in irrigation canals saved 47–800 acre-feet per mile or 10–30 percent of water delivered. Lining 10 miles of canal in El Paso would save enough water for 1,000 acres of irrigated crops or 8,000 households.

Economic analysis of 15 federally authorized irrigation district projects with the RGIDECON© model showed estimated savings of 49,392 acre-feet of water per year with cost of saving water ranging from $16 to $119 per acre-foot.

Engineers, working with irrigation districts, completed GIS maps of irrigation delivery systems in the upper and lower Rio Grande basins. These provide an indispensable tool to district personnel for district planning and modernization.

Scientists working with state and federal agencies and commodity groups demonstrated productive and safe use of graywater and brackish water for the production of irrigated vegetables.

The Landscape Irrigation Auditing and Management Program received EPA's WaterSense® certification. Students who complete the course and pass the certification exam become WaterSense Certified Landscape Irrigation Auditors. Training events were conducted, providing certification to licensed irrigators, water utility personnel and other landscape professionals.

Dr. Juan Enciso, associate professor at the Texas A&M AgriLife Research and Extension Center at Weslaco, added that drip irrigation has increased in West Texas due to these project efforts and more farmers have implemented the use of polypipe and leveling on their lands to irrigate more efficiently.

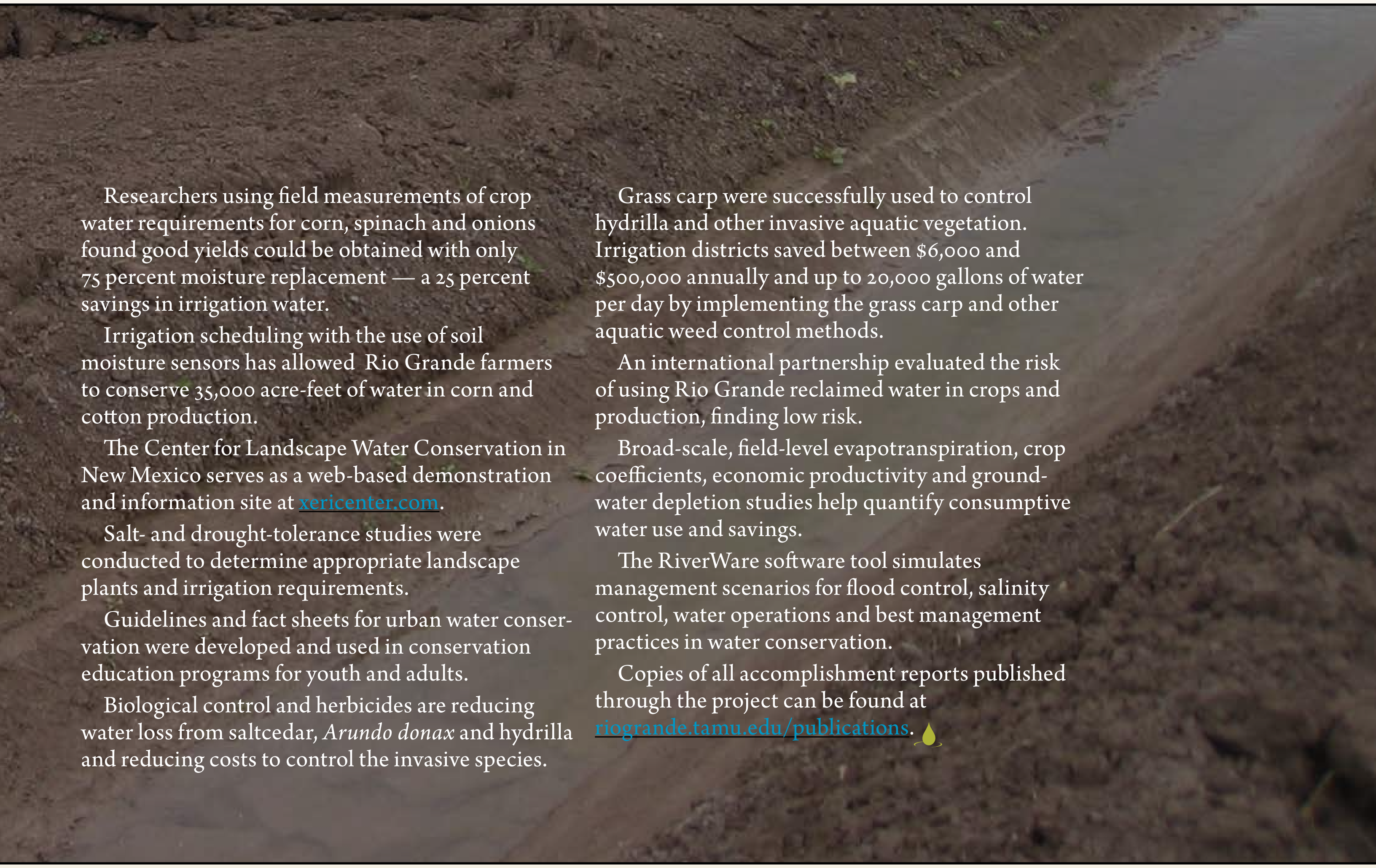
Dr. Sam Fernald, interim director of the New Mexico Water Resources Research Institute and professor in the Department of Animal and Range Sciences at New Mexico State University, said the "RGBI allowed us to respond to a big data need regarding acequias." The project allowed Fernald and other researchers to implement measurement infrastructure that helped gather the needed data to fill in the gaps on acequia effectiveness and use.

Other efforts such as controlling *Arundo donax* and saltcedar, invasive water-consuming plants along the river, have helped save water, leaving more available for the people of the basin, Lacewell said. In addition, desalination use in South Texas has grown and become competitive with municipal water production.

Project sponsor NIFA often uses data produced through RGBI because it is broad-based and applicable worldwide. The data is particularly applicable to population issues emerging in the United States, said Dr. James Dobrowolski, national program leader and RGBI project manager at NIFA. "USDA is proud of this project, and I have used a lot of this information, especially the drought information. The West Texas area is at the forefront of drought decision-making and leads the way in adapting irrigation to drought."

"Even though we can't control the natural hydrological process effectively," Sheng said, "we have made a great step forward through the RGBI program in understanding how water can be managed on farms and in urban areas once water is captured for uses."

For more information, visit *txH2O* online at twri.tamu.edu/txH2O/.



Researchers using field measurements of crop water requirements for corn, spinach and onions found good yields could be obtained with only 75 percent moisture replacement — a 25 percent savings in irrigation water.

Irrigation scheduling with the use of soil moisture sensors has allowed Rio Grande farmers to conserve 35,000 acre-feet of water in corn and cotton production.

The Center for Landscape Water Conservation in New Mexico serves as a web-based demonstration and information site at xericenter.com.

Salt- and drought-tolerance studies were conducted to determine appropriate landscape plants and irrigation requirements.

Guidelines and fact sheets for urban water conservation were developed and used in conservation education programs for youth and adults.

Biological control and herbicides are reducing water loss from saltcedar, *Arundo donax* and hydrilla and reducing costs to control the invasive species.

Grass carp were successfully used to control hydrilla and other invasive aquatic vegetation. Irrigation districts saved between $6,000 and $500,000 annually and up to 20,000 gallons of water per day by implementing the grass carp and other aquatic weed control methods.

An international partnership evaluated the risk of using Rio Grande reclaimed water in crops and production, finding low risk.

Broad-scale, field-level evapotranspiration, crop coefficients, economic productivity and groundwater depletion studies help quantify consumptive water use and savings.

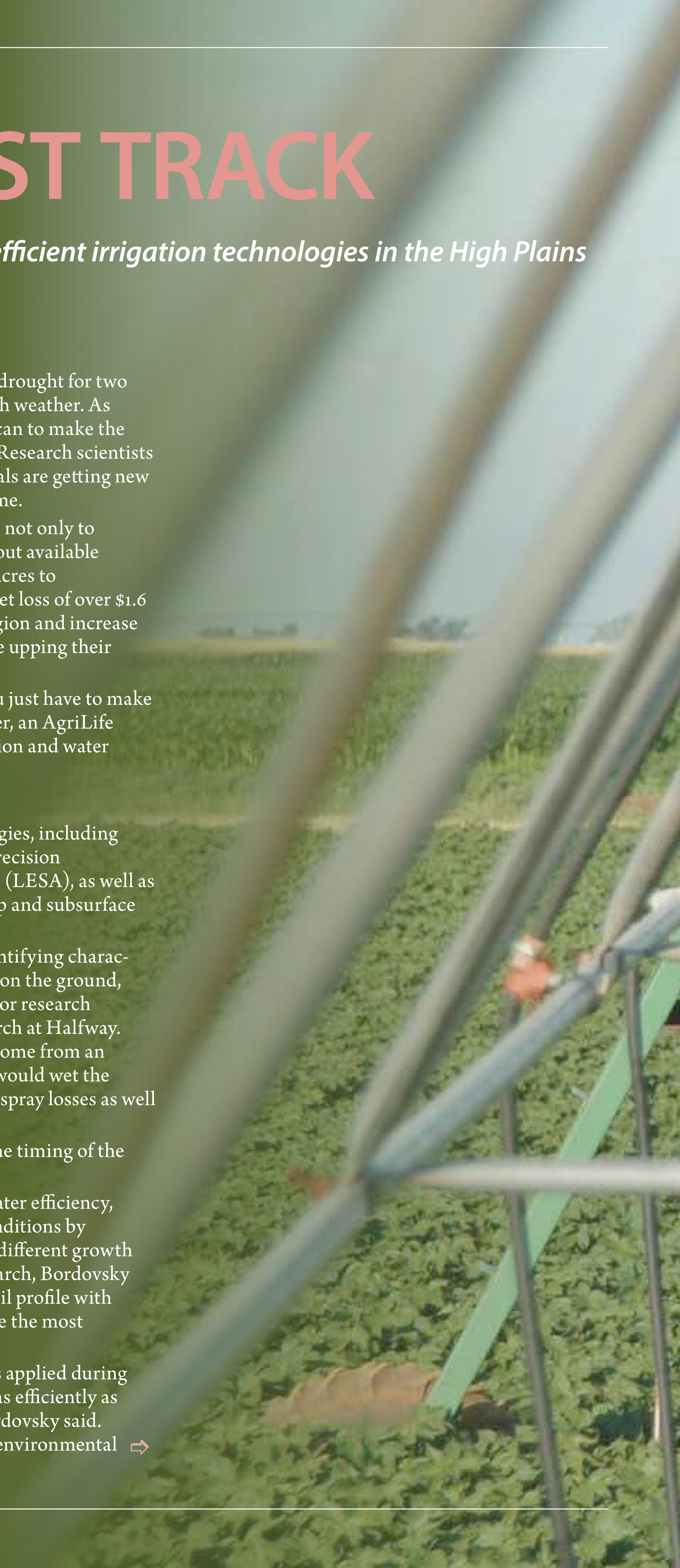
The RiverWare software tool simulates management scenarios for flood control, salinity control, water operations and best management practices in water conservation.

Copies of all accomplishment reports published through the project can be found at riogrande.tamu.edu/publications.

Story by Leslie Lee

ON THE FAST TRACK

Collaboration expedites adoption of efficient irrigation technologies in the High Plains



The High Plains of Texas have been nagged by severe drought for two years straight, with very little rainfall or relief from harsh weather. As agriculture producers in the region use every tool they can to make the most of their available resources, Texas A&M AgriLife Research scientists and Texas A&M AgriLife Extension Service professionals are getting new irrigation technologies into growers' hands in record time.

Irrigation is incredibly valuable in the High Plains — not only to individual producers but to the region as a whole. Without available irrigation water, converting all of the region's irrigated acres to non-irrigated dryland farming would cause an annual net loss of over $1.6 billion.[1] As drought and supply limitations stress the region and increase pressure on producers, Texas A&M AgriLife experts are upping their efforts.

"If you have limited water, like we have here, then you just have to make the best use of it when you apply it," said Dr. Dana Porter, an AgriLife Extension agricultural engineering specialist for irrigation and water management, who is stationed in Lubbock.

Better tools and timing

There is an abundance of efficient irrigation technologies, including low-pressure center pivot systems such as low-energy precision application (LEPA) and low-elevation spray application (LESA), as well as microirrigation systems such as microspray, surface drip and subsurface drip irrigation, Porter said.

"LEPA is a type of center pivot irrigation, and the identifying characteristic of that system is that water is deposited directly on the ground, typically in alternate furrows," said Jim Bordovsky, senior research scientist and agricultural engineer with AgriLife Research at Halfway. "LEPA eliminates spray evaporation losses that would come from an applicator that was higher off the ground and typically would wet the entire surface area. So we're reducing evaporation from spray losses as well as soil surface evaporation losses."

It's not just the irrigation system that is important. The timing of the application is also key.

Bordovsky is leading a four-year study to optimize water efficiency, yield and fiber quality of cotton under limited water conditions by evaluating a combination of irrigation amounts during different growth periods using LEPA irrigation. After three years of research, Bordovsky has found that the conventional wisdom of filling the soil profile with water at the beginning of the growing season may not be the most economical use of water.

"One of the things we saw was that the water that was applied during that first period of the growing season was not utilized as efficiently as water applied during the second and third periods," Bordovsky said. "Part of that is due to the fact that we've got very harsh environmental ⇨

[1] *Texas Water Resources Institute EM-115, 2012.*

Low-energy precision application, or LEPA, irrigation eliminates spray evaporation losses that would come from an applicator that was higher off the ground and typically would wet the entire surface area. An experimental type of LEPA system is pictured. Photo by Jim Bordovsky, Texas A&M AgriLife Extension Service.

conditions — high wind speeds, high temperatures, low relative humidity — during that time period."

The study began in 2010, which was a relatively wet year, Bordovsky said, followed by two very dry years.

"We've also seen that we are enabling that cotton plant to grow too large early with insufficient irrigation capacity to meet the water needs of that plant later in the growing season," Bordovsky said. "We are seeing that our water value, or our water efficiency, is higher toward the end of the growing season."

This research is supported in part by the Texas State Support Committee of Cotton Incorporated and the U.S. Department of Agriculture (USDA) – Agricultural Research Service Ogallala Aquifer Program. Many of the research projects in the High Plains have been funded by the Ogallala program, which was created by Congress in 2003 to find solutions to problems arising from declining water levels in the aquifer. Approximately 80 state and federal scientists from the Agricultural Research Service, Kansas State University, AgriLife Research, AgriLife Extension, Texas Tech University and West Texas A&M University participate in the Ogallala Aquifer Program, and the Texas Water Resources Institute helps facilitate it in Texas.

Not one size fits all

Extension professionals such as Porter help producers decide which irrigation system will be ideal for their individual operation.

"We have all of those great technologies — LEPA, microirrigation, including subsurface drip — and they are great tools, but they are not one-size-fits-all," Porter said. "They've got to be managed well to get the good results."

When producers are choosing irrigation systems, there are many factors to consider: available irrigation supplies, field topography and size, weather conditions, management style, labor force and economics.

"We can't take all the pivots in the High Plains and turn them into LEPA systems, because the typography of many fields is such that you would have too much runoff with a LEPA system," said Bordovsky, who has extensively researched LEPA systems. "We cannot say, across the board, convert everything to LEPA and save all this water; there are areas where it is not a good fit."

Porter and Bordovsky said that each technology has its limitations, and producers should seek the best solution for their operation.

"For instance, subsurface drip is a really good tool, but it's not going to work for everybody," Porter said. "There's an economy of scale to consider. If

Low-energy precision application, or LEPA, irrigation is being used to irrigate approximately 20 to 30 percent of High Plains cotton for at least a portion of the growing season. An experimental type of LEPA system is pictured. Photo by Jim Bordovsky, Texas A&M AgriLife Extension Service..

you have more water and a bigger field, it is cheaper per acre to put in a low-pressure center pivot than it is a subsurface drip system. With LEPA, if I've got too much field slope, then I run too much risk of losing water to runoff. So, none of these work everywhere."

She said that it's also important for her and her peers to be realistic about new technologies.

"When we talk about new research, it's so important to spell-out clearly the details, the specific conditions under which the results were achieved," Porter said. "A new technology isn't a magic fix."

Working together

In the High Plains, AgriLife Extension focuses on helping producers maximize the benefits from those new technologies, Porter said.

"We help producers by applying soil physics knowledge, soil moisture characteristics, soil storage, and helping folks understand the root zone and how to manage that for maximum efficiency," Porter said.

She said that with all of the different factors to consider — weather conditions, soil moisture data and plant stress indicators — AgriLife Extension can help producers interpret data to choose their best irrigation system option.

At the same time, the research team Bordovsky leads is working to give producers better tools for efficient irrigation.

"The high rate of adoption of advanced irrigation technologies — including low-pressure center pivot and subsurface drip — I will accredit much of it to his work," Porter said, on Bordovsky's research. "He's done so much, just leading the way in developing, first of all, and then refining LEPA and subsurface drip. Because of his research program and research programs like it, such as the USDA's Conservation and Production Research Laboratory at Bushland, and because these technologies are really well-suited to growing conditions and the climate conditions in the Texas High Plains, [the technologies] just fit here. They are working here."

LEPA has been around for a number of years, said Bordovsky, and approximately 20 to 30 percent of High Plains cotton is grown using LEPA for at least a portion of the growing season.

"The producers out here are very proactive in adopting new technology, and they will do that as quickly as they can, of course as a function of economics," Bordovsky said. "So if they can convert from furrow to drip irrigation, and they can see that they can produce as much or more, and get as much production to result in payback for that investment, they will do that. They will jump through hoops to learn that technology."

Porter also credits the Ogallala Aquifer Program for helping facilitate improvements in the High Plains.

"The fact that research and extension folks here have a good collaborative relationship is so important, and the Ogallala Aquifer Program has made it even easier for us to work with other states and agencies, too," Porter said. "We share information so much better, and it's easy for me to get the information into producers' hands faster."

The past two years of drought have also increased producers' receptiveness to "anything that can help them save water and prolong the life of the water they've got available," Bordovsky said. Although Bordovsky is mainly a research scientist, he also participates in field days and producer meetings, he said.

"The growers trust the research that comes from here, and it works for the growers," Porter said. "We have some really progressive producers here in the High Plains who are willing to grab onto these new technologies and incorporate them into their operations."

The combination of well-researched and thoroughly developed technologies, open-minded producers, and the adaptability and applicability of the technologies to High Plains conditions has made the region an example of the land grant mission in action: high quality research and experimentation resulting in relevant knowledge that is disseminated to the public through extension education.

"We've got the education, the research, the industry involvement and the technology development in a kind of critical mass, all in one location — so we just have this huge rate of adoption of efficient technologies such as LEPA and subsurface drip," Porter said. "In other places where any of those pieces are missing, adoption may lag because it's more of a struggle for the producers to get the information, expertise and equipment that they need. But here, they have relatively good access to these resources."

The researchers' ultimate goal is increasing the economic value of the irrigation water applied, Bordovsky said. As limited supplies and the possibility of continued drought looms, innovative research and relevant extension education will continue to help make High Plains agriculture increasingly efficient.

For more information, visit *txH2O* online at twri.tamu.edu/txH2O/.

Story by Katie Heinrich

Making wastewater environmentally sustainable

Innovative technology offers new possibilities for wastewater treatment

Municipal wastewater treatment plants may soon become more sustainable in their treatment of wastewater by pursuing new electron beam (e-beam) technology being researched at a Texas A&M AgriLife Research center in College Station.

To help these plants in their move to increased sustainability in wastewater treatment, the National Center for Electron Beam Research (NCEBR) is focused on bringing e-beam technology to the wastewater industry, said Dr. Suresh Pillai, director of the center, professor of microbiology at Texas A&M University and a Texas A&M AgriLife Research Faculty Fellow.

E-beam technology can remove pathogens and chemical contaminants normally found in wastewater in one step. The technology also retains valuable plant nutrients and other compounds in wastewater. Using this technology, municipalities would be able to generate biosolids, which can be applied to agricultural lands and landscaping without any concerns of potential pathogens, Pillai said.

Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge, which is the name for the solid, semisolid or liquid untreated residue generated during the wastewater treatment.

By partnering with wastewater industry groups such as the Water Environment Research Foundation (WERF) and industry leaders such as Headworks BIO Inc., a wastewater screening equipment engineering company in Houston, the NCEBR is attempting to accelerate the move of e-beam technology commercialization from the research laboratory to the marketplace, Pillai said.

E-beam processing or electronic irradiation is a process that uses electrons, usually of high energy, for various purposes. E-beam technology and processing are currently used commercially in the medical industry to sterilize medical products, in the food industry to pasteurize food against pathogens and protect it from contamination, and in the agricultural industry to prevent the introduction of invasive pests into unprocessed bulk crops that may be sent across national borders.

"The NCEBR has been at the core of research and commercialization of this technology for over a decade," Pillai said. "Now we are actively working with our research partners to develop commercially relevant information to help promote adoption of this technology into the wastewater industry. It is imperative that we collect realistic metrics and economics of the technology.

"When tested on wastewater, this technology has worked beautifully," he said.

Pillai said the technology can be used for both the liquid and solid wastes present in municipal waste streams. Besides killing all viruses, parasites and bacteria, e-beam can degrade certain pharmaceutical and personal care products.

Proximity to adoption

No wastewater treatment plant currently uses the e-beam technology; only pilot-scale field tests have been done. In the 1980s a study was done in an e-beam pilot plant in Florida. The study showed promising, positive data; however, the linear accelerator energy needed for high volume applications was not available at the time, Pillai said.

Pillai hopes that within the next one to four years, there will be at least one pilot scale installation of the e-beam technology in a wastewater treatment plant and that this installation will show that this technology is robust and sustainable, leading to wider adoption of e-beams in wastewater treatment.

Theoretically speaking, this technology could find immediate application in many cities if it were to become commercially feasible, Pillai said.

Funding from WERF has allowed the center to pursue advancements in the e-beam technology that would make the technology highly suitable for the wastewater industry. Based on these findings, the center has filed a U.S. patent for the application of e-beam technology in wastewater treatment.

Pillai hopes the commercialization of the patented technology will bring in additional research funding, allowing the center to further improve and develop the technology for wastewater treatment.

E-beam and cities

By working with e-beam technology companies, Pillai said they are taking steps to customize the technology into operational units for cities and water municipalities. The United States has many sizes of wastewater treatment plants, so the installation of the e-beam technology needs to be suitable for the size of the plant, Pillai said.

"We are configuring the technology to meet different-sized cities and preparing design specifications for cities of different sizes," Pillai said. "The wastewater industry could lose faith in the technology if we erroneously put an e-beam into a small city that does not have the capacity to use it or have the means for the capital investment in the technology."

Pillai said it is increasingly common to see public-private partnerships in which a consulting or engineering firm builds and operates a treatment facility and then receives revenue from the city for the volume of wastewater treated. This helps cities that may not have the funding capacity to incorporate new industry technology into their treatment plants.

Multiple advantages

The e-beam technology will improve the quality of the sewage sludge from the wastewater. E-beam technology, when used at appropriate doses, disinfects the sludge and transforms it into a pathogen-free biosolids fertilizer, making it a valuable product of this technology. The product is environmentally stable and meets federal standards for fertilizer, allowing it to be applied to agricultural lands, he said.

"By adopting this technology, a municipality does not have to pay for [sludge] to be taken to a landfill," Pillai said. "Rather, the sludge is marketable and the city utility can actually sell the sludge."

Pillai partnered with Dr. Bob Reimers, a wastewater treatment process chemist at Tulane University, to conduct a cost benefit analysis, learning what the cost would be to use this technology in sludge processing.

"There are a lot of ways this technology can be used," Pillai said. "You have to be careful that you are recommending this technology to the appropriate municipality. That's why we are working with wastewater engineering companies who do know the industry well."

Pillai and his team at the NCEBR have also worked with environmental consulting companies such as BCR Environmental in Florida and the International Atomic Energy Agency in Vienna, Austria, a global agency that promotes e-beam technology for wastewater treatment.

"Harnessing e-beam technologies to clean, heal and feed the world is part of the NCEBR's mission," Pillai said. "We are hopeful our efforts to commercialize e-beam treatment of wastewater will help us deliver on that mission."

(left photo) Wastewater treatment plants may soon become more efficient and more sustainable, thanks to electron-beam technology. Photo courtesy of Texas A&M AgriLife Extension Service.

(right photo) Mickey Speakmon, electron beam facility manager, works in the e-beam center. Photo by Leslie Lee.

Herdsmen in Africa are using a decision support tool, Waterhole Monitoring for Livestock Early Warning System, to make decisions on where to move their livestock for water. Photo by Dr. Jay Angerer, Texas A&M AgriLife Research.

FROM CENTRAL TEXAS TO AFRICA

Texas A&M AgriLife Research technology is changing natural resource management

In a remote part of southern Ethiopia, a local herdsman checks the Internet using his cell phone to make a decision critical to his family's livelihood: what direction he should move his livestock to find water.

The herdsman locates available water by accessing online maps generated from a computer-modeling tool developed, in part, by researchers at Texas A&M AgriLife Research and Extension Center at Temple, widely known as the Blackland Center.

With funding from NASA, the AgriLife researchers in Temple worked with the U.S. Geological Survey (USGS) to develop the Waterhole Monitoring for Livestock Early Warning System (watermon.tamu.edu) in southern Ethiopia and northern Kenya. Using climate and satellite images from NASA, the system provides near-real-time monitoring and changes in the water levels at waterholes throughout these countries, said Dr. Jay Angerer, assistant professor at the Temple center.

NASA satellite images identify the waterholes and stream networks from imagery, and climate data streams provide relative humidity, temperature, rainfall and wind. A hydrologic water balance model uses this information to estimate daily waterhole depth variations, he said. Field teams collect data from the waterholes to verify the model.

This decision support tool, which was expanded to the western African country of Mali, is proving invaluable to the nomadic communities, providing them with information for planning livestock movements. When the herdsmen start moving their animals to the next destination, "they don't know whether there is water and whether they might get stranded," Angerer said. "Cattle can't go more than about two days without water."

Now the herdsmen can access color-coded maps from the Internet with their smart phones or consult nongovernment organizations that assist herders in planning. The maps show the condition of the waterholes, ranging from green for good conditions to red for near dry conditions.

"A map really communicates if it has the right landmarks in it," he said. "It doesn't have to be in the local language."

The waterhole monitoring program is one of numerous tools based in computer technology that AgriLife Research scientists at Temple have helped develop since the center's establishment in 1910.

Recognized for their expertise in computer modeling, the AgriLife researchers, often working with USDA's Agricultural Research Service (ARS) and Natural Resources Conservation Service (NRCS) scientists, have used computer technology to develop models to simulate agricultural and watershed information, among other projects.

"Our focus is trying to find solutions to problems that affect land and water," said Dr. Tom Gerik, the center's resident director.

The waterhole monitoring program is an outgrowth of another program first created for Africa — the Livestock Early Warning System (LEWS) — which was developed by scientists at Temple and the Texas A&M Ecosystem Science and Management Department (then Department of Range Science) through the Center for Natural Resource Information Technology (CNRIT). AgriLife Research established CNRIT in 1991 for collaborative research among various departments to develop decision support systems for management of natural resources.

After severe droughts in Africa from the late-1980s through the mid-1990s caused famines, the U.S. Agency for International Development (USAID) provided funding to set up an early warning technology program in four African countries — Tanzania, Uganda, Kenya and Ethiopia — which was later expanded to Dijbouti and parts of Somalia. This early warning system provides near-real-time predictions of forage conditions over the landscape in these countries, Angerer said. Knowledge of forage conditions over the wide area is important, ⇨

he said, because most lands are communal. Management of the land cannot be by just one person, he said.

"The goal is to provide trends of forage conditions to see when forage starts declining and to provide this early warning that there may be conditions conducive to drought, and there is a need to start planning for drought," Angerer said.

Using a hydrologically based plant growth model called PHYGROW, which was developed at Texas A&M, the researchers are able to produce maps showing where forage is declining and what areas appear to be moving into drought. PHYGROW estimates the amount of available forage based on the forage preference of the livestock and the known composition of forage on the landscape. Angerer said statistical tools predict what the likely conditions might be in 60 to 90 days.

Without adequate information, herdsmen can end up in severe poverty because they run out of forage and options, Angerer said. "They did not sell the animals when they had an opportunity and the animals died, or they waited too long and the market prices collapsed," he said.

"They can use the early warning information as a decision tool to say: 'Do I need to move my animals? Do I need to sell the animals? Do I need to buy feed? Do I need to wait?'" he said.

As the researchers and their collaborators considered these situations, they realized the herdsmen lacked information on the market prices for livestock in different areas and on the locations of available water. Such information could complement the forage monitoring and make a better decision tool.

For the market prices, Angerer said, the project developed a market information system that has people at different markets collect data on prices and send it by cell phone text messaging to servers. The system extracts the information and puts it into a database. Herdsmen can send a query to the system with a text message to get information on prices for their local market.

"It makes the price information more timely and transparent in the sense that the herdsmen know the same numbers that the livestock traders know," he said. "They now have the power to negotiate."

More than 12 nongovernment organizations, or NGOs, have been involved in the LEWS project with hundreds of herdsmen associated with each organization. The LEWS is also used in Mali, Mongolia and Afghanistan.

Not only are the LEWS and waterhole monitoring projects allowing the herdsmen to better maintain their herds but by using the technology, conflicts between neighbors are being reduced, Angerer said.

"The information has been useful for assisting NGOs and local agencies in providing herders with information to reduce risk and the potential for conflict over water and forage resources," he said.

Becoming the modeling hub of AgriLife

Gerik said Temple's research focus on land and water that later translated to computer modeling started in 1929 when the USDA's Soil Conservation Service (now NRCS) moved to Temple to try to solve soil erosion problems, mainly with cotton.

In 1937 the USDA established the USDA ARS Experimental Watershed at Riesel, an 840-acre research site northeast of Temple. Hydrologists began collecting hydrologic data such as rainfall, evaporation, runoff and soil erosion.

Once the center had access to mainframe computers in the late-1960s and early-1970s, hydrologic models were developed to predict where water runoff from agricultural fields was going and how much erosion and nutrients were lost through the runoff, Gerik said.

"Those hydrologic models were the genesis of our modeling programs here," Gerik said.

In the early-1980s, the USDA wanted to determine the impact of soil erosion on crop productivity and that started agricultural system modeling at Temple, Gerik said. "That is when we took the hydrologic models and married them with the plant and agronomic models and started looking at these agricultural systems," he said.

Through the years, AgriLife, ARS and NRCS researchers have added models and components of models to simulate different ecosystems in Texas, the United States and around the world.

Today, Gerik said, most of Temple's projects center on the computer models. "It's what we do," he said.

"We use these models to answer questions that we can't answer directly experimentally. It would take years and years and years to do experimental studies and then they would only be confined to relatively small windows of weather, time, etc.," he said. "With models we can change different scenarios and can look at them not for just short periods of time but over decades and hundreds of years," he said. "That is the beauty of the models."

Using these models to quantify the environmental benefits of conservation practices associated with agricultural lands throughout the United States is what AgriLife Research's involvement in the NRCS's Conservation Effects Assessment Project (CEAP) is all about.

(left photo) AgriLife researchers along with ARS and NRCS scientists assessed the impact of cropland conservation practices on the soil and water quality of cultivated croplands as well as watersheds across the United States. Photo by Lucas Gregory, Texas Water Resources Institute.

(right photo) A market information system that collects data on livestock prices at different markets enables herdsmen to send a query to the system with a text message to get prices for their local market. Photo by Dr. Jay Angerer, Texas A&M AgriLife Research.

Gerik said AgriLife researchers along with ARS and NRCS scientists have just finished assessing the impact of cropland conservation practices, such as the use of terraces, grassed waterways and conservation tillage, on the soil and water quality of cultivated croplands as well as watersheds across the United States.

Using the farm-scale model Agricultural Policy/Environmental eXtender (APEX) and the watershed-scale model Soil and Water Assessment Tool (SWAT), both developed largely at Temple, they simulated the current cropping practices and conservation practices, Gerik said.

"We took the APEX model, and we looked at just the impacts of these practices on the fields, then we took output from the field data generated by APEX and incorporated that into the SWAT model, which looked at the whole watershed," Gerik said. "So we could determine the effects of cropland conservation practices on the whole watershed."

By using these models, Gerik said, they can see what current conditions would be "if we didn't have those practices, and we can look into the future to see if we changed the way we managed the land, what the benefits would be."

The CEAP program is also linking the benefits of the conservation practices to financial benefits.

Gerik said that Congress and the USDA initiated CEAP in 2004 to determine whether the money spent on conservation programs was money well spent. "The OMB (Office of Management and Budget) has seen the value of using models to look at the benefit of government programs," he said.

NRCS has seen the benefit of using APEX as one of its planning tools. The tool can comprehensively design management practices that are the most effective in respect to natural resources conservation and cost on the landscape on a particular farm, Gerik said.

"What we learned is that the existing conservation practices are doing a really, really good job in controlling erosion, reducing nutrient losses and runoff and increasing soil organic matter," Gerik said. "But there are still areas where problems with nutrients and erosion exist, so NRCS is working to focus their resources and energy on those areas and issues."

Finding new uses for technology

Uniquely combining several technologies initially developed for different purposes, an AgriLife research team at Temple is using bathymetry mapping, which merges GPS, GIS and sonar technologies, to calculate a reservoir's water capacity and track deposits of sediment in the reservoir. By using these readily available technologies and a boat, the team can calculate the reservoir's depth and sediment quickly and easily, said Dr. William Fox, assistant professor at the Temple center.

The team recently surveyed a 17,000-acre lake in Oklahoma. "We generated over a million data points, of which 600,000 data points were used to develop a model of the reservoir," Fox said.

The team also has used bathymetry mapping to evaluate the flood control structures at Fort Hood and in the Lampasas River watershed to determine ⇨

the capacities and projected longevity of these structures. Thousands of sedimentation-flood control earthen dams were built during the 1950s to 1970s in rural areas to protect agricultural lands and property, rural roads and small towns from flood damage.

If sedimentation is found to be a problem, then the focus will need to be upstream, working to identify and implement conservation practices to slow the process, Fox said.

Gerik said ultimately this information may get into the hands of policy makers where it can be used by local, state and federal officials in developing and maintaining their water quality and flood control plans.

"With bathymetry mapping we are taking advantage of readily available technologies and applying them to the agricultural and natural resource fields," Fox said. "The technology is very accurate, quick and capable of getting a good understanding of what is out there."

Direct measurements gained from the mapping can also help validate and improve models for future use.

"Reservoirs are the archives of what has happened in the watershed," Fox said. By using bathymetry mapping, "we can see how much sediment is in the reservoir and where the likely contributing areas of runoff, erosion and ultimately sedimentation are in the watershed. We hope to tie that information back to how land management in the past has influenced the possibility of this phenomenon taking place."

For example, Fox believes that this mapping can be used in future conservation programs. "Through the CEAP program, NRCS is able to look at the effects of past conservation practices. I would say another question to ask is: How could we more efficiently target our conservation practices within the watershed? To do that you have to understand where in the watershed sedimentation is taking place."

Future developments

"What is very satisfying and rewarding for our group," Gerik said, "is the impact that the models and the collective research being done by the AgriLife, USDA ARS and USDA NRCS team in Temple is having in this country and around the world."

The SWAT model is being used worldwide, and an international SWAT conference is held annually, attracting more than 400 researchers each year.

With the cropland CEAP finished, Gerik said the team is moving on to tackle grazing land and aquatic wildlife CEAP projects. "With the wildlife CEAP, we are tying our models in with aquatic wildlife models," he said. "So instead of just looking at how we are affecting water quality, we are also looking at simulating the impact that conservation practices and water quality are having on fish populations.

"We are very much engaged to continue to develop the tools and the application of these tools," Gerik said. "It never ends."

For more information, visit *txH2O* online at twri.tamu.edu/txH2O/.

NRCS and Texas A&M AgriLife Research scientists prepare to perform bathymetry mapping on a reservoir in Central Texas. Photo courtesy of AgriLife Research.

MARKER-ASSISTED BREEDING

Accelerating the results of 21ST century technology to growers

Historically, it has taken years or decades to improve crops for such traits as disease tolerance or drought and heat-stress resistance. Today, plant breeders at Texas A&M AgriLife can screen for these complex yet critically important traits in significantly less time, thanks to technology at the Texas A&M AgriLife Genomics and Bioinformatics Service.

The unit, established in 2010, provides next-generation sequencing and bioinformatics services to plant and animal breeders, physiologists and life scientists across The Texas A&M University System. Next-generation sequencing is a technology allowing scientists to decipher the blueprints of all life, which are encoded in DNA. Bioinformatics analysis involves analyzing the enormous amount of data and turning it into usable information.

Since opening, the facility has collaborated with more than 400 scientists and has been involved in more than 190 grant applications, according to Dr. Charles Johnson, director of the service.

Johnson said AgriLife scientists are now able to connect the genotypic, or genetic, information from large numbers of breeding populations to a wealth of phenotypic information, meaning variations in the plant's physical traits and function. This allows them to make the connection between genes and resistance to drought, disease and insects, as well as other high-value traits, which leads to increased yields over a broad range of conditions.

Both phenotypic and genotypic information is needed to understand crop traits.

When working with plant breeders, Johnson said, instead of looking at one or two genetic markers at a time, "we can look at hundreds of thousands of markers at one time. Rather than having to expose a plant to a given stress, we can measure the DNA marker and in a systematic way link that marker to a given trait and use that information to select those plants that carry our traits of interest."

Dr. John Mullet, professor in the Department of Biochemistry and Biophysics at Texas A&M University, said that before advanced technology, acquiring genotypic information was the limiting factor to understanding crop traits. He said getting that information was both very costly and labor intensive.

Mullet said that what one of the first high-throughput sequencing platforms (the Illumina GAII machine) allowed them to do, starting in 2005, was to switch from indirect methods of genotyping to sequence-based genotyping.

"The technology we developed we called digital genotyping because of the AC-GT digital nature of the information," Mullet said.

AC-GT stands for adenine, cytosine, guanine and thymine, key components of DNA.

In addition to genotyping, the center conducts bioinformatics analysis, leading to the selection of molecular markers that become a DNA road map for desirable traits. He compared the bioinformatics analysis to a giant puzzle. A team of bioinformaticians, geneticists, statisticians, mathematicians and computer scientists put the DNA information pieces together to make a complete picture.

Mullet said the bioinformatics analysis is quite intensive. In the past, generating a genetic map consisting of 500 to 1,000 DNA markers took a year. With the first high-throughput sequencing platform, it only took a few months to produce five or six maps, he said. Comparing old maps to new ones showed that accuracy had also increased.

Last year the Genomics and Bioinformatics Service acquired the latest in a series of increasingly fast and powerful DNA sequencing machines: the Illumina HiSeq 2500®.

Johnson said that the top-notch DNA sequencer can complete the equivalent of the human genome project in just 24 hours. The human genome project, which provided the first blueprint for human DNA, took 13 years and cost more than $2.8 billion by the time it was completed in 2003. Now this same feat can be accomplished for less than $5,000. ⇨

The Genomics and Bioinformatics Service recently acquired the latest in a series of increasingly fast and powerful DNA sequencing machines: the Illumina HiSeq 2500®. Photo by Danielle Kalisek.

The new sequencer may allow that price to drop to as low as $1,000, according to Johnson.

"This new technology has been a driving focus in expanding genomic research across Texas A&M," Johnson said, "and we look forward to expanding the use of this technology across an even wider group of scientists in the future."

Dr. Bill McCutchen, executive associate director of Texas A&M AgriLife Research, said AgriLife is building an unprecedented understanding of gene content and genome organization. "Quite simply, future discoveries will be all about our ability to measure phenotype in a reproducible and sensitive way and then reduce this information to a description at the molecular level," he said "Investments in genome science technologies will help move research programs beyond simple information gathering to knowledge generation."

Details of the methodology

The researchers' methodology begins with creating populations that they later segregate according to important traits such as drought tolerance, Mullet said. "Then we score or phenotype those traits under optimum conditions, sometimes in growth chambers and sometimes in the field depending on the trait we're trying to assay," Mullet said.

Next, the team identifies the parts of the genome and genes that control the traits. That information enables the team to do marker-assisted breeding and gene discovery, he said, and this methodology streamlines the research process.

"We sort of get right into the nexus there, and we do both gene discovery and marker-assisted breeding," Mullet said. "What this technology does for our breeding program is it allows us to get rid of things that we know will not work because of past history and lets us focus on things that have the potential to work so we can evaluate more of those. It's those things then we take to the field and go through our traditional breeding and evaluation."

Sorghum sequencing

Dr. Trish Klein, associate professor in the Department of Horticultural Sciences and the Institute for Plant Genomics and Biotechnology at Texas A&M, works with Johnson and with sorghum breeders to develop genetic markers for particular traits, including disease resistance and height, she said.

She agreed that using the gene sequencing technology is tremendously beneficial for the breeding program, saving money and time.

"Using the Illumina HiSeq 2500 platform, we can identify molecular markers linked to traits of interest and then screen sorghum germplasm for these markers," Klein said. This screening identifies plant lines that contain certain molecular markers and thus are more likely to have a desired trait, for instance resistance to fungal disease.

"This has a tremendous impact on the efficiency of our breeding program," Klein said.

Sorghum researcher Dr. Bill Rooney, professor in the Department of Soil and Crop Sciences at Texas A&M, said his research group provides the plant tissue. "The Klein and Mullet labs process the plant samples and then the Genomics and Bioinformatics Service runs all the sequencing," he said. "After Klein's lab processes the sequence data, she provides information in the form of what sequences are present in which plants."

Rooney receives a color-coded Excel spreadsheet listing the plant lines with the various markers of interest. Once he receives this information, he selects the best lines to advance in the program based on phenotypic and marker data. Rooney and his group use those genetic associations to shorten the time it takes to do the breeding.

"We can do it faster and eliminate some generations and secondly, maximize the efficiency of our evaluation process," he said.

For example, Rooney said, if his team has more than 3,000 lines to phenotype, the sequence data allow Rooney and his group to eliminate the genotypes that do not possess the trait instead of having to grow them all in the field.

This process reduces the number of plants being tested in the field about ten-fold. Having already selected for genotype, the team can focus on planting sorghum that has the right phenotypic characteristics for the trait of interest.

Starting with the material Rooney or other breeders bring to Klein's group, the group extracts DNA from leaf tissue for each plant sample and prepares it for the HiSeq 2500 machine, Klein said. In the end they may have more than 100 DNA samples in a given tube, each DNA with its own specific barcode. These samples are given to Johnson's group for sequencing. Once the data is returned to Klein, she has a bioinformatics pipeline that can process all the data to identify markers in each of the individual plant DNA samples that were sequenced.

Due to the massive amounts of data, Klein has developed bioinformatic scripts that can find sequence differences among the lines in a largely automated fashion. Her team can correlate those sequence differences to phenotypic differences that have been measured in the field, she said.

"Basically, we use those marker trait associations or genetic mapping studies to identify regions in the sorghum genome that are linked to our traits of interest, and because they are DNA sequence differences, we can turn those into marker assays for rapid screening," Klein said.

The technology Klein's lab uses to make those libraries is called digital genotyping. The particular methodology they use was developed in Mullet's lab.

"Dr. Mullet's group developed the digital genotyping, and my lab developed the pipeline for handling the downstream data," she said.

Traditional versus sequencing technologies in wheat

While sorghum sequencing is fairly advanced, wheat breeders are just starting to break into the new sequencing technologies.

"I am a very traditional plant breeder, so most of what we do is based on field evaluations," said Dr. Jackie Rudd, AgriLife Research wheat breeder in Amarillo. "Our program develops wheat varieties for producers. Most of what we do is plant yield trials across the state, see which ones come out on top and advance the 'winners.'"

"We're in a natural drought area, and things that survive in multiple field trials here have drought tolerance, no question about it," he said. "Can we improve that? We think so. Can we save time on it and move that drought tolerance a lot quicker than we have in the past? Absolutely, and that's where the whole genome selection is going to be valuable."

Marker-assisted selection is something Rudd has been doing in his program one gene at a time, he said.

"We developed markers for some wheat rust resistance, green bug resistance and wheat streak mosaic virus resistance; we only have markers for a few specific resistance genes, so our progress is limited," Rudd said. "What really intrigues me is that we can now do whole genome selection. We are just beginning to conceive what the benefit of that is going to be; theoretically it makes a lot of sense and I believe it will change how we do breeding."

Currently genome selection is at the very early stages for the wheat breeder. Particular wheat lines are known to be drought- or disease-resistant or to have bread-baking qualities. Breeders have made multiple crosses with other wheat lines to bring in other useful traits, he said.

"We will use whole genome selection to combine variety A with the best part of variety B," Rudd said. "It is a trial-and-error process through traditional breeding; but this new technology is extremely promising. I'm a little apprehensive since this is our first time to use digital genotyping in wheat, but I'm ready to jump in with both feet."

Technological advancement

Mullet said he often asks his students, "What technology has been developing the fastest in the last 10 years?" The usual answer is computing technology. But actually, Mullet said, "sequencing technology is improving at a rate faster than computing technology" and is "revolutionizing what we can do."

"This technology is groundbreaking because it's giving biologists a look into DNA in a way that even six years ago was impossible," Johnson said. "It's allowing the biologists and scientists to conduct research that would have been in the realm of science fiction only a few years ago. We are truly part of a new era of life science research."

Rudd is looking forward to the advancements that this new technology could bring to the wheat breeders.

"New technology is talked about all the time," Rudd said. "Every year someone is saying how much better their technique is, but this possibility of whole genome selection really fascinates me. It's based on good science and I'm more excited about it than any other new technology ever in my career, except maybe my first computer."

Read more about the program at twri.tamu.edu.

Story by Kathy Wythe

Reclaiming a valuable, clean resource

Texas cities increasingly embracing potable reuse

In May 2013, the Colorado River Municipal Water District opened a $14 million advanced water treatment plant to apply additional treatment to reclaimed wastewater in Big Spring. The geodesic dome-roofed water storage tank (pictured) holds wastewater before it is treated at the plant. Photo courtesy of Texas Water Development Board.

A Texas water supplier has become the closest to date in the United States to use what is commonly referred to as "toilet to tap" technology. In May 2013, the Colorado River Municipal Water District opened a $14 million advanced water treatment plant to apply additional treatment to reclaimed wastewater to supplement Big Spring's drinking water supply.

Although many experts call the Big Spring system direct potable reuse technology, the water district calls it indirect potable reuse because it blends the reclaimed water with raw surface water before sending the water to a conventional drinking water treatment system.

The small village of Cloudcroft, New Mexico, also blends highly treated wastewater with natural waters and then places the mixed water in a storage reservoir for about two weeks before sending it through the drinking water treatment plant. New Mexico health authorities classified this project as indirect potable reuse because of the blending part of the process.

Close behind Big Spring is possibly Brownwood, which has received funding approval to construct a proposed direct potable reuse plant. Once constructed, the city must conduct a study that demonstrates the plant can produce water that meets federal and state drinking water standards, according to the Texas Commission on Environmental Quality (TCEQ). If approved, the plant will pump reclaimed wastewater treated to drinking water standards directly into the drinking water distribution system without first blending it with any other water. The only currently operated reuse system in the world in which the treated water is fed directly into the distribution system is in Windhoek, Namibia.

In the world of water reuse, distinctions are important when it comes to definitions. Reclaimed water is domestic or municipal wastewater treated to a quality suitable for a beneficial use. Potable reuse refers to the use of reclaimed water to supplement drinking water supplies. Indirect potable reuse usually includes water entering an environmental buffer such as a river, lake or aquifer before it is delivered to the drinking water treatment plant. Direct potable reuse, however, uses engineered treatment processes instead of an environmental buffer to purify the reclaimed water before introducing the reclaimed water either into the drinking water treatment plant or directly into the drinking water distribution system.

Using reclaimed water for nonpotable uses is a strategy that has been around for years. Farmers have used reclaimed water to irrigate their crops; industries have used it for fire protection; and cities have used it to water golf courses or public parks, among other uses.

As the state's population continues to grow and unused surface water and groundwater supplies diminish, reuse is becoming an even more popular and widely used method to increase water supplies. In the 2012 state water plan, more than 10 percent of the water management strategies for the year 2060 are water reuse strategies.

"Most regional water plans include reuse strategies to meet nonpotable demands — such as golf course irrigation, for example," said Jorge Arroyo, former director of innovative water technologies at Texas Water Development Board (TWDB), "or indirect potable reuse, which entails reclaiming and treating wastewater and recycling it to surface water reservoirs or aquifers used as drinking water sources."

El Paso Water Utilities, North Texas Municipal Water District and Tarrant Regional Water District all use indirect potable reuse to supplement their drinking water. Now, direct potable reuse is gaining attention.

According to Arroyo, three regional water plans have specifically identified direct potable reuse as either recommended water management strategies or alternative strategies if strategies recommended in the 2012 water plan prove unfeasible.

Why now?

Dr. Bill Batchelor, professor and holder of the R.P. Gregory '32 Chair in the Zachry Department of Civil Engineering at Texas A&M University, said water suppliers are looking at using direct potable reuse now because of necessity.

"We are doing reuse because we need to, because alternative water sources are not available," Batchelor said.

Arroyo agreed. "Direct potable reuse projects are considered in cases where conventional water sources are insufficient or economically inaccessible," he said.

TWDB provided a loan for the Big Spring project and has committed to funding the Brownwood project, Arroyo said.

While diminished available water supplies are definitely the main driver in this increased interest, Dr. Ellen McDonald, a principal at Alan Plummer Associates, Inc., said because of research conducted over the last 10 to 15 years, the research and professional community has become more comfortable with the fact that the available treatment technologies can produce high quality purified water.

"The big focus now is on making sure we understand how to operate these treatment systems in a way that ensures that the treatment processes perform properly and the system has appropriate redundant processes and safeguards," she said. "As we bring the pipes closer and closer together between the wastewater and water systems, there is less time to react if there is a problem. Operationally figuring out how to control these systems and determining what to monitor, where to monitor and how to monitor is the real challenge with direct potable reuse."

Although the risk of a potential breach of the treatment process is not unique to direct potable reuse projects, Arroyo said the design of direct potable reuse projects requires redundancy in the treatment process and close monitoring of all treatment phases.

The technology used

Batchelor stressed that the treatment processes or technologies for direct potable reuse are not new; they have existed for years. "The technology has been there but the cost and need were not," he said. "The technology has definitely improved, the costs have decreased and the reliability has increased. The developments in treatment technology have made it easier to do direct potable reuse."

"The Big Spring plant is new in the sense that it is direct, but the idea of using a water supply that is partly made of wastewater is very old," Batchelor said. "We have been doing that for a very long time."

At the Big Spring operation, wastewater is first treated at a conventional wastewater treatment plant. Then, instead of being discharged into a creek, ⇨

The Big Spring advanced water treatment plant uses a three step process to treat the wastewater: microfiltration, reverse osmosis and advanced oxidation. This photo shows the reverse osmosis equipment. Photo courtesy of Texas Water Development Board.

Definitions

Direct potable reuse: Reclaimed water is transported directly from a wastewater treatment facility to a drinking water treatment and distribution system without being released to the natural environment.

Indirect potable reuse: Reclaimed water is released to the natural environment from which it is subsequently taken and treated for potable consumption.

Direct nonpotable reuse: Reclaimed water is transported directly from a wastewater treatment facility to a site for nonpotable beneficial uses such as landscape irrigation, power plant cooling and manufacturing without being released to the natural environment.

Indirect nonpotable reuse: Reclaimed water is released to the natural environment and then taken and used for nonpotable uses, such as golf course irrigation.

the reclaimed water is treated a second time at the advanced treatment plant. This facility adds three advanced processes to the conventional treatment method. About 5 to 20 percent of this twice-treated water is then blended with surface water from one of the district's reservoirs and treated again at Big Spring's drinking water treatment plant. The blended water may also go to surface water treatment plants in Snyder, Odessa, Stanton and Midland, according to TCEQ.

"The water is really going through three treatment plants before people drink the water," Batchelor said.

Big Spring's new advanced treatment plant uses microfiltration, reverse osmosis and advanced oxidation, Batchelor said. In the first two steps, membranes filter out particles in the water. Microfiltration removes essentially all bacteria and other large organisms that cause disease. Reverse osmosis removes dissolved materials and even smaller organisms, such as viruses that could potentially be pathogenic.

"Those two steps give barriers to transmission of pathogens," Batchelor said.

The final step, Batchelor said, is advanced oxidation. In this step, chemicals are added and ultraviolet light is used to destroy very low concentrations of potentially toxic organic compounds that could get through reverse osmosis.

"This process has multiple barriers to remove organisms that might cause disease and to remove organic and inorganic compounds that might be toxic," he said.

The treatment processes used at the Big Spring plant "have been tested and used elsewhere and shown to be effective," McDonald said.

As interest in direct potable reuse increases in Texas, TWDB is taking a leadership role in helping to advance potable reuse so it can be implemented in a safe and practical manner. Alan Plummer Associates, Inc., through a project partially funded by the TWDB, is developing a resource document that will assist water providers as they plan and consider the viability of a direct potable reuse project for their systems, McDonald said.

"One of the things we are looking at in our TWDB study is technologies that don't involve reverse osmosis, because reverse osmosis has the challenge of producing concentrated brine that has to be disposed of somewhere," she said.

Dealing with brine disposal can be challenging and expensive, she said. "Big Spring has a place to dispose of its brine relatively inexpensively. Not all utilities will have this luxury."

Cleaner than drinking water

Batchelor pointed out that Big Spring will actually be using a smaller percentage of treated wastewater in its drinking water than the city of Houston, which uses indirect potable reuse by acquiring its drinking water from Lake Livingston.

Much of the water that flows into Lake Livingston originates from wastewater treatment plants in the Dallas area. Time and natural processes in the Trinity River further "treat" the water before it reaches the lake. Once Houston draws the water from the lake, it goes through the normal treatment for drinking water.

"From the statistics I have seen, water coming from Lake Livingston has a higher fraction of wastewater than Big Spring will have," he said.

The Big Spring reclamation plant replaces natural processes that take place in a river, Batchelor said.

"The water that is being produced in the Big Spring plant is extremely high quality water," McDonald said.

A report issued by the National Research Council in 2012, *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater*, substantiates the idea that reclaimed water is safe. A council news release stated: "The concentrations of chemicals and microbial contaminants in reuse projects designed to augment drinking water supplies can be comparable to or lower than those commonly present in many drinking water supplies."

Although technology and safety are no longer barriers to direct potable reuse, public acceptance is.

"The yuck factor that people have with direct reuse is really not related to what the concentrations of any particular contaminants are, it is related to the general idea," Batchelor said.

Arroyo said the public needs more information about the benefits, risks and risk-management approaches of potable reuse through increased educational outreach and that is one reason for the Alan Plummer study.

McDonald agreed that getting beyond public perceptions is difficult. She cautioned, however, that direct potable reuse isn't always the best answer for a water supplier.

"We need to be careful about getting so excited about it that we don't consider all the other options," she said.

For more information, visit *txH2O* online at twri.tamu.edu/txH2O/.

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Partnership wins environmental award

The Texas Water Resources Institute (TWRI) and the Buck Creek Watershed Partnership recently won the Texas Environmental Excellence Award in the agriculture category. The partnership, including landowners in the Buck Creek watershed, worked for more than 10 years to restore Buck Creek and have it removed from the Texas Commission on Environmental Quality's (TCEQ) impaired water bodies list.

Created by the Texas Legislature in 1993, the Texas Environmental Excellence Awards honor individuals, organizations and businesses that protect the state's human and natural resources while ensuring clean air, clean water and the safe management of waste.

Research efforts, education and workshops were provided by TWRI, Texas A&M AgriLife Research, Texas State Soil and Water Conservation Board (TSSWCB), Texas A&M AgriLife Extension Service, Red River Authority of Texas, Texas Parks and Wildlife Department, U.S. Department of Agriculture and local soil and water conservation districts that, along with local stakeholders, form the Buck Creek Watershed Partnership. Funding for the projects of the partnership was provided through a Clean Water Act nonpoint source pollution grant provided by TSSWCB and U.S. Environmental Protection Agency.

Members of the partnership received the award at a banquet in May. Shown left to right are: Dr. Paul DeLaune, Texas A&M AgriLife Research environmental soil scientist; Dr. John Sij, retired AgriLife Research agronomist; Phyllis Dyer, AgriLife Research watershed coordinator; Lucas Gregory, TWRI project specialist; Dr. Kevin Wagner, TWRI associate director; and Mitch Conine, project management coordinator of the TSSWCB Nonpoint Source Management Program.

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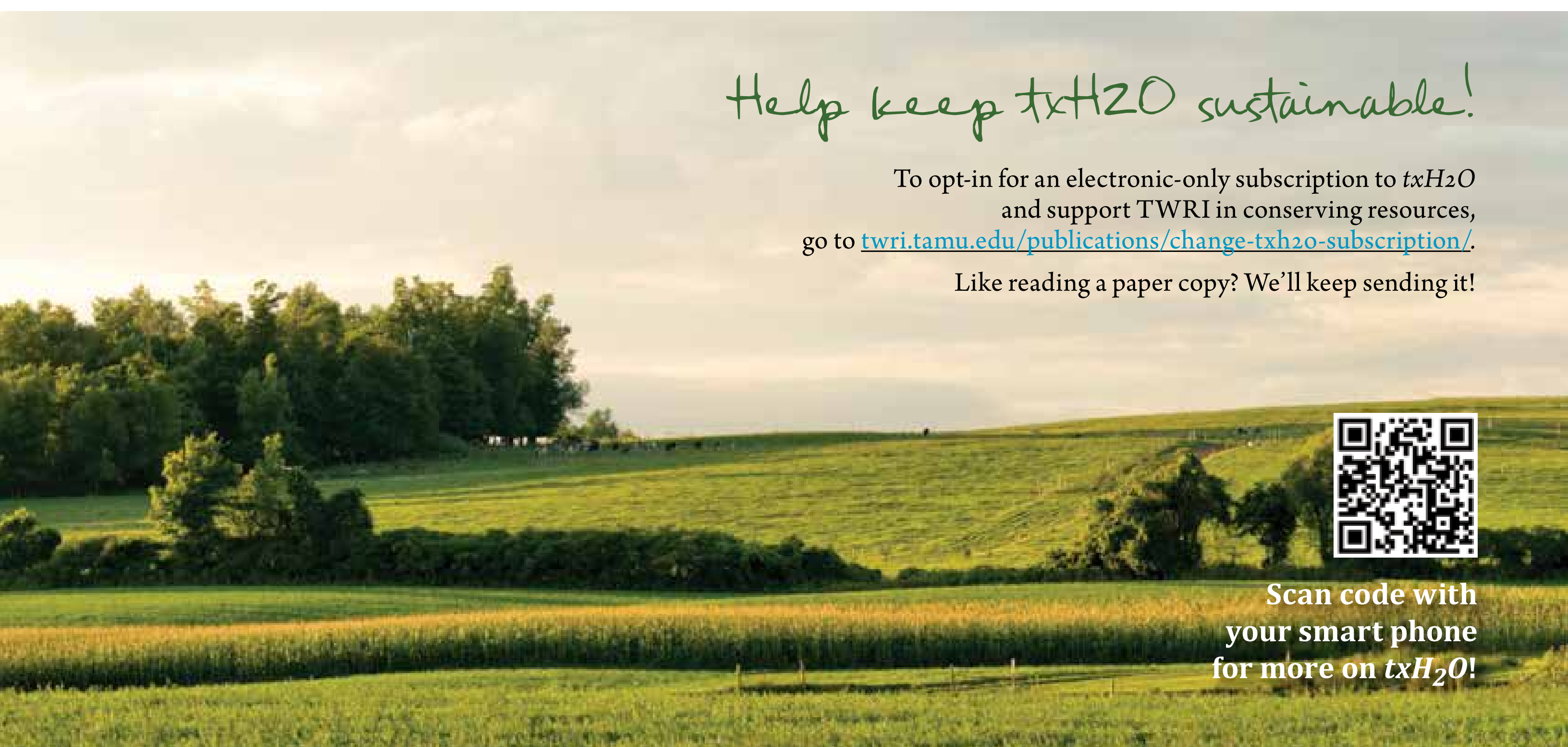

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