# tx H$_2$O

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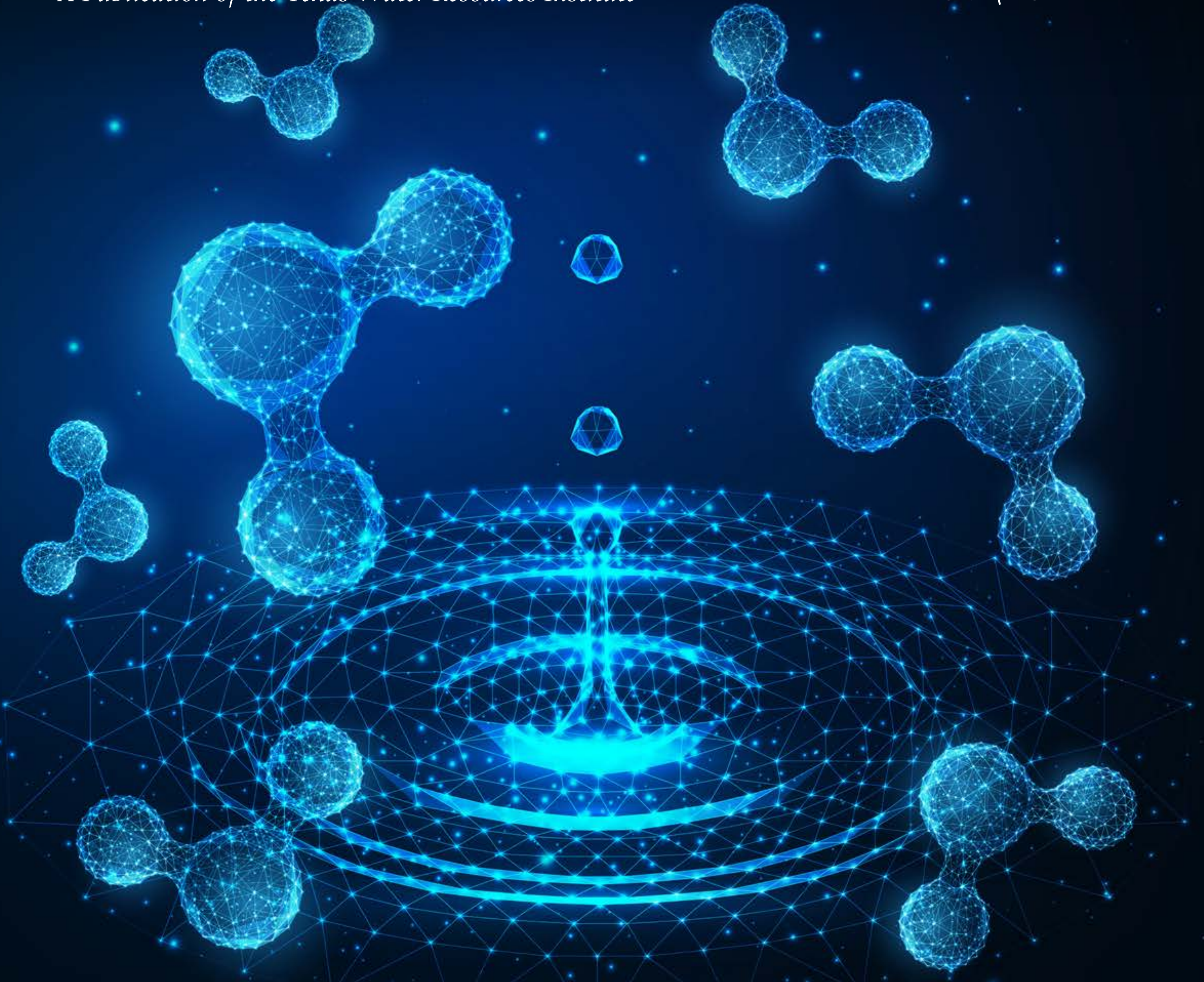

# THE FUTURE OF WATER

Inside: Examining the outlook of water infrastructure, workforce needs and alternative water sources on a changing planet

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

Water infrastructure is old and in urgent need of repair and renewal. Continued climate disruption places many more people at risk of chronic water insecurity. Water infrastructure is increasingly vulnerable to floods, freeze and fires. A water workforce with the needed skills to address these challenges are in short supply due to a wave of retirements and the lack of a pipeline for new talent.

But the future of water is not yet written. In this issue of tx$H_2O$, we learn how researchers, policy makers and water professionals are mapping pathways to navigate a future of secure water. They are adapting existing water systems, introducing new technologies and offering new ways of thinking about water supply and distribution to transform how water flows to the next generation.

This issue reports on advances in data science, or big data, to enhance decision-support tools for leak detection, water quality monitoring and water efficiency management in agricultural and municipal systems. We learn about how nanotechnology improves water quality, and hopefully social acceptance, of critically important alternative sources, like stormwater, wastewater and brackish or marine water.

This issue also highlights the growing recognition that water's future can and needs to be achieved through distributed or decentralized water and wastewater services. But more importantly, decentralized systems offer the greatest chance for positive change in vulnerable communities that still struggle for affordable, safe and adequate water.

Finally, we learn that a secure water future depends on a well-trained, dynamic and diverse water workforce. To that end, this issue describes how students can chart their own path. STEM education paired with industry internships, co-ops and volunteer opportunities help young professional hone communication skills and open opportunities for the continuing education necessary for workforce needs.

New technologies are necessary to change how we clean, manage and distribute water in the future. But these advances alone are not sufficient. Our water future also depends on people — a well-trained workforce, partnerships with decision makers and the general public's engagement to support and guide the implementation of these advances. We need society to innovate how we govern and manage our water resources.

So, let's chart the future of water together, by "making every drop count"…for all.

Wendy Jepson, Ph.D.
Associate Director of Research (Social Science), Texas Water Resources Institute
University Professor and Chancellor's EDGES Fellow, Texas A&M University

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**Published by**
Texas Water Resources Institute

**Editors**
Kerry Halladay
Danielle Kalisek
Chantal Cough-Schulze
Sarah Richardson
Texas Water Resources Institute

**Art Direction**
Sarah Richardson
Texas Water Resources Institute

**Student Writer & Editor**
September Martin
Texas Water Resources Institute

**On the cover:**
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*make every drop count*

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Photo by Erica Martinez.




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Story by Chantal Cough-Schulze

# COLONIAS: THE CANARY IN THE WATER INSECURITY COAL MINE

## Experts are coming together to find water security solutions in Texas

Canary and coal images from Freepik.com, manipulated by Sarah Richardson.

Across the United States, more than two million people lack access to running water and basic indoor plumbing. Those who have access to water may still be without water that is safe, reliable and affordable. Between June 2016 and June 2019, nearly 130 million people's drinking water came from distribution systems in violation of the law.

As climate change leads to increased drought and disrupts water infrastructure systems, it's imperative to understand and address water insecurity, said Wendy Jepson, Ph.D. Jepson is an associate director of research (social science) at the Texas Water Resources Institute and a University Professor in the Texas A&M University Department of Geography.

Jepson described colonias — unincorporated subdivisions along the U.S.–Mexico border — as a "canary in the coal mine" of water insecurity in the United States. She said that addressing the challenge of water insecurity starts with places like colonias.

The colonias are home to roughly 840,000 people, according to a 2015 report from the Rural Community Assistance Partnership. There are more colonias in Texas than in any other state. More than 40% of colonias residents live below the poverty line, and 20% live just above it. At least a third of colonias do not have secure access to water services, wastewater services, or both.

### Shaping water insecurity in the colonias

The development of the colonias in the mid-20th century was "driven by a need for low-cost labor," said Amber Wutich, Ph.D. Wutich is the director of the Center for Global Health at Arizona State University (ASU) and a President's Professor of anthropology in the ASU School of Human Evolution and Social Change.

That "low-cost labor" was often in agriculture and maquiladoras, which are manufacturing plants on the border.

"People who were supplying that labor had to create a standard of living out of very low salaries, salaries that are not probably appropriate to the cost of living in United States," Wutich said. "This meant that people couldn't live in conventionally zoned housing in the United States. So colonias emerged as a kind of informal settlement that offered a solution for people who were working in maquiladoras and farming labor and other low-income professions."

Early land buyers in the colonias were promised water utilities and other infrastructure, which never appeared. Since then, Jepson said that the colonias' continued lack of water security is sometimes explained away as a product of poverty and remoteness. But, she said, that isn't a sufficient explanation.

*As climate change leads to increased drought and disrupts water infrastructure systems, experts say it's imperative to understand and address water insecurity in Texas.*

"This is not a natural evolution of poverty. Poverty doesn't explain this. If it did, water insecurity would be more widespread and common," Jepson said.

Instead, Wutich said the "core issue" driving water insecurity in the colonias is a phenomenon called "municipal underbounding." When municipalities expand to include nearby developments, they are obligated to extend city services — such as water, wastewater and paved roads — to the new communities. If municipalities choose to not include those nearby developments within their official boundaries, that's municipal underbounding.

"If colonias become incorporated as part of cities, then this problem of extending infrastructure would become resolved," Wutich said. "But if you look at city limits in Texas, or in other places, they just will skip around the colonia. It gets very clear on that. It's a very specific set of exclusions with regard to who gets to be part of the city."

That exclusion has in turn shaped the colonias' water access.

"The ways in which people are connected to infrastructure are explicitly connected to the ways in which they are connected socially and culturally and politically to other systems in society," Jepson said.

"There's a long history of racial discrimination in housing and infrastructure access that shaped the social life of South Texas. So emerging out of that — once you have racial segregation, access to infrastructure and access to housing are mapped onto that."

Political mobilization in the colonias in the 1980s led to legislative changes and investment, and many colonias residents have since been connected to community water systems. Colonias that remain unconnected tend to be more isolated and more expensive to connect; therefore, they often rely on expensive hauled water from private providers.

## Water insecurity's human impact

Connection to a water system isn't enough. To be water secure, the water also needs to be affordable, sufficient, reliably available and safe to drink.

Whatever the cause, water insecurity has numerous health, economic and social impacts, said Nayeli Holguin, an environmental engineering master's student at the University of Texas at El Paso (UTEP). Holguin has worked with the former and current directors of UTEP's Center for Environmental Resource Management (CERM) on colonias water research. Her master's thesis focuses on the costs and consequences of having to rely on hauled water in some colonias.

People can be injured in the process of hauling and loading massive tanks of water or can contract waterborne illnesses from contaminated water, Holguin said. They may also have to make impossible decisions about using and getting more water, with far-reaching effects.

"They might have to pick one activity over the other in terms of water usage. They'll have to decide, 'Okay, well, do I want to bathe my kids? Or do I want to wash the dishes or do laundry?'" Holguin said. "There's also lost income and lost wages for people who have to go and haul water at a certain time."

## The paths to water

Getting safe, reliable, affordable access to water would go a long way towards reducing colonias residents' uncertainty, fear and stress, said Bill Hargrove, Ph.D., former director of CERM.

"We all want that. I don't think that's unusual that people would want that," Hargrove said. "It improves overall quality of life."

Generally speaking, Hargrove said there are two paths to water access: the "hard path" and the "soft path."

"The hard path is the typical system of providing water, where you have a centralized source, centralized treatment and then delivery by piping to homes. That's the typical hard engineered system," he said.

"The soft path is kind of the reverse of that: depending as much as you can on local resources, sources and conservation. So it's mainly decentralized sources, decentralized treatment and use on-site," he said. He gave rainwater harvesting and using point-of-use filters as examples of decentralized water strategies.

Both hard and soft path options have their benefits and drawbacks.

"In a hard-engineered system, the utility takes care of everything. If the pipes break, they fix it; the water is already treated; you don't have to worry about it," Hargrove said. With soft path solutions, "the onus is on the user to both pay for and maintain everything." ⇨

Bilal Abada, a Ph.D. student in Shankar Chellam's lab at Texas A&M University, sets up the water-energy nanogrid in the lab. Photo by Chantal Cough-Schulze.

Still, soft path solutions are more affordable, and the water doesn't have to travel as far. The hard-engineered system is the most well-known and commonly used system in the United States, but Holguin, who coauthored a study on the soft path to water with Hargrove in 2020, said putting in pipes over long distances can be prohibitively expensive.

New technology could stretch the reach of soft path solutions further. A team from Texas A&M and 1898 & Co. has designed a water-energy nanogrid. The truck-mounted system could supply 200 people with 30 liters of clean water per day each over a two-week period, as well as electricity, said Le Xie, Ph.D., and Shankar Chellam, Ph.D., senior authors on the 2020 nanogrid study and professors in the Texas A&M College of Engineering. The next step for the research would be to build a prototype and field test it.

"We did our work in an air-conditioned lab with proper temperature control. We did not evaluate what happens when the truck is bouncing around," Chellam said. "Do these systems actually work in the blazing heat of the summer in the dusty areas of the colonias? That needs to be done before it can be made into a practically implemented product."

## Creating solutions communities want

Moving solutions from the lab to the field will require "boots on the ground who understand the exact scenarios in the colonias," Chellam said. Understanding that starts with asking colonias residents what they think.

"The starting place is to sort of take a step back and engage with the colonias communities," Jepson said. "They are well-organized, vibrant, problem-solving communities. So having a conversation — What would you like? How would you like to solve this? — that to me is the first step."

As with any community, engaging with colonias requires earning trust, said Alex Mayer, Ph.D., who is the current director of CERM and a professor of civil engineering at UTEP.

"Universities are great at doing research, but they may not have the trust in these communities," he said. "Some of the colonias, I think they've been studied to death. They have researchers come in, and they get studied for a year or something, and then the researchers disappear."

Researchers, Wutich said, need to do better. That starts with using good research ethics. Researchers should be clear about their capabilities, share research results with the community and ensure community members know how to opt out if they want to. And above all, researchers should respect community members' time, knowledge and experience. This starts with earning the community's trust by including them in the process.

Earning community trust is both more ethical and makes for better solutions that people will actually want and use, said Alicia Cooperman, Ph.D., assistant professor in the Texas A&M Department of Political Science.

Cooperman, along with Mayer and others, is beginning a study focusing on developing a framework for monitoring decentralized water infrastructure. The framework will be co-developed with colonias near El Paso that rely on hauled and bottled water.

"The goal of the project is essentially to have a back-and-forth dialogue between researchers and residents in the colonias. We will meet with residents and local leaders, share some ideas of different potential water systems and discuss the pros and cons with the broader community," Cooperman said.

One of the questions the research team will be asking is what people need in order to trust that water being delivered is clean.

"There is an often very appropriate distrust of tap water," Cooperman said. "So if we're going to spend a lot of money to put in a new tap water system, is that something that people are going to trust and use?"

Community involvement will therefore be key for ensuring sustainable water security, Wutich said.

"A solution that comes from academic scholars that doesn't involve the perspectives and knowledge and efforts of community members isn't going to last," she said. "It doesn't have legs."

## Many needs require many solutions

Colonias have many different water security needs. Addressing those needs will therefore require many different solutions.

"It's a complex problem; you can't have one solution for everything," Jepson said.

Decentralized solutions such as the water-energy nanogrid, rainwater harvesting and point-of-use filters can support communities in the short term, or longer, if that's what communities prefer. But temporary decentralized solutions alone will not be sufficient. To reach the long-term goal of getting everyone on safe, affordable, reliable community water systems, Jepson said there needs to be a paradigm shift towards a belief in the human right to water security.

"Until, and only until, we are able as a community, as a society, as a state, to commit to a human right to water security and have that inform subsequent policy, technical interventions are simply band-aids, and we're not going to solve the fundamental issues," Jepson said. "We're not there yet. We, as a community, as a state, have not had that conversation."

Two rainwater harvesting systems are connected to the roof of a small structure the owner uses as a bathing room. The owner's house is powered by solar energy and does not have infrastructure for electricity or piped water. Photo by Erica Martinez.

Students install a rainwater harvesting setup on a house near Presidio, Texas. Photo by Bill Hargrove.

Image capture from the video "A&M Colonias Program – Our Mission," courtesy of the Texas A&M College of Architecture Colonias Program.

Tackling those short- and long-term goals will require a multidisciplinary task force. Jepson said meeting those goals will require colonias community members, engineers working on decentralized water treatment, finance whizzes, and community involvement and empowerment advocates. There will need to be researchers developing common definitions and metrics for affordability and other terms, boots on the ground gathering data in communities and political minds pushing for policy that acknowledges the human right to water security.

"It's an all-hands-on-deck situation," Jepson said.

## Canary in a coal mine

The hands already on deck are hard at work. All the research being done — by Jepson, Holguin, Chellam, Mayer, Wutich, Cooperman and more — can be used to develop action plans and funding proposals for implementing solutions. Those solutions will be valuable beyond just the colonias.

"The colonias are a canary in the coal mine," Jepson said.

"When you talk about affordability, reliability and water quality, then the problems faced by colonias residents actually become a more universal problem of water security in the United States. They're facing very similar problems as other lower income communities are throughout the country, such as in Alabama, Flint, Detroit, South Milwaukee or the Central Valley, California."

The number of people in the United States without access to safe, reliable, affordable water — already in the millions — will increase in the future, Jepson said. Climate change is fueling droughts that result in decreased water availability, as well as extreme storms and wildfires that destroy existing water infrastructure.

Addressing water insecurity will require having some hard conversations about what the future looks like, Jepson said. But having those hard conversations — and turning them into action — will lead to a better water future for everyone, Wutich said.

"The reason water insecurity is not solved is not because we don't know how. What's happening now is that people are stepping in and saying — there may not be large-scale political will to address the needs of communities. But we care, and we want to find another way to address these needs, because they have to be met," Wutich said.

"Everybody should be afforded safe, secure, abundant water. There shouldn't be water apartheid."

**Story by** Kerry Halladay

# THE FUTURE OF WATER INFRASTRUCTURE IN THE U.S. AND TEXAS

*Americans have depended on aging centralized water infrastructure, but the impacts of climate change mean the future of water infrastructure might be increasingly decentralized*

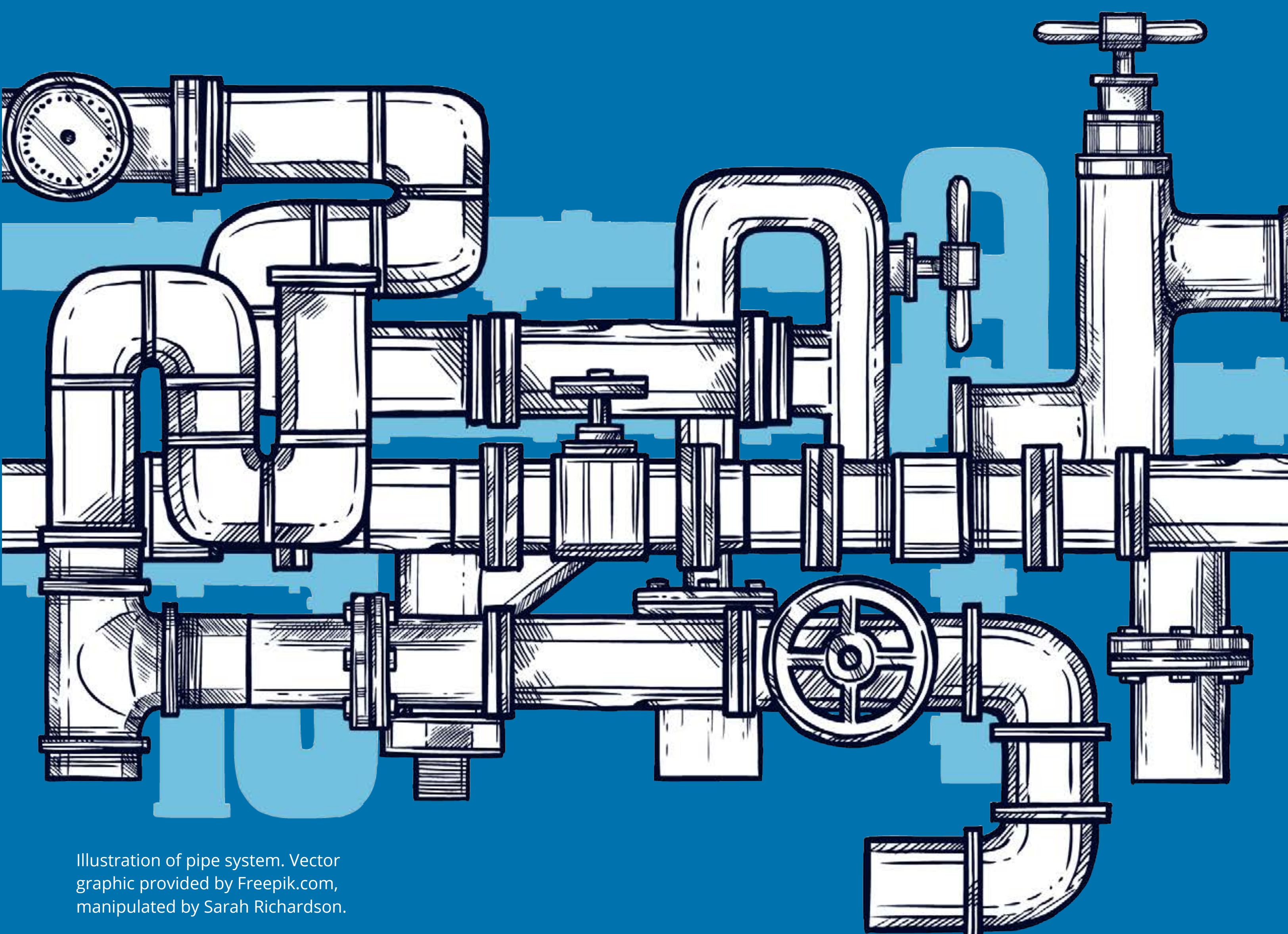


Illustration of pipe system. Vector graphic provided by Freepik.com, manipulated by Sarah Richardson.

The U.S. population is growing and the climate is changing, yet the water systems Americans depend on have remained mostly unchanged for over a century. While big water infrastructure elements have always been built to last — be it the Hoover Dam, the irrigation canals of the Rio Grande or the cast iron pipes of cities everywhere from years gone by — every technology has a lifespan. At a certain point, it needs to be repaired, replaced or reconsidered.

"A lot of infrastructure in this country is aging," said Manny Teodoro, Ph.D., associate professor at the La Follette School of Public Affairs at the University of Wisconsin-Madison and previously professor of political science at Texas A&M University.

"But in the water sector, it's worse than most other sectors of the economy that rely on large, fixed infrastructure," he said.

The problems presented by old water infrastructure, such as lead in the pipes that carry drinking water into people's homes, can be quite costly. This applies both in terms of the human cost if pipes are not maintained and replaced, as the water crisis in Flint, Michigan, famously exposed, but also in terms of financial costs.

A 2016 report by the American Water Works Association (AWWA) estimated that 15-22 million people in the United States are served by about 5.5-7.1 million water service lines — the pipes that deliver water from the municipal main or transmission line into individual homes — that are made of or contain lead. The group projected that replacing just those leaded service lines could cost over $30 billion.

The issue of lead in drinking water service pipes is just one small example of the costly problems associated with old water infrastructure.

## Out of sight, out of mind and out in the (funding) cold

Funding the repair and replacement of the big elements of the United States' centralized water infrastructure — water mains, municipal pipes, sewer systems, treatment plants, dams and reservoirs — has its own problems. Chief among these is that those elements are mostly invisible to the public, Teodoro said.

"If people don't see it, historically there's been a tendency to underinvest in the replacement and maintenance of those systems until they fail," he said. "They are beginning to fail, and they have been failing across the country."

Even if the need to invest in big water system infrastructure is not visible to most people, water professionals are acutely aware of the need. In 2001, AWWA announced the "Era of Infrastructure Replacement" had begun. Ten years later, it estimated at least $1 trillion would need to be spent through 2035 to repair or replace the nation's buried drinking water infrastructure alone just to maintain the same level of water service to a growing population. Addressing other big infrastructure elements like dams, reservoirs, treatment plants and pump stations would cost even more.

Today the need for water infrastructure repair and replacement is just as pressing as it was in 2011. And costs have only grown, making the resounding question still: How will we pay for it?

"We have been putting off answering that question for a long time, about 50 years or so," said Robert Greer, Ph.D., associate professor in the Texas A&M Bush School of Government and Public Service and Fellow of the Bush School's Institute for Science Technology and Public Policy. He pointed out that some water pipes have been in the ground for 30 years longer than ever intended and at the very least should be maintained.

## Future federal infrastructure funding

Finding the money to maintain aging water infrastructure, let alone replacing it, has been an issue for most municipalities. In addition to the challenge of being "out of sight, out of mind," water

infrastructure has usually been excluded from federal infrastructure funding projects.

"Infrastructure, for a really long time, was limited to transportation," Greer said. "So, when the feds said, 'infrastructure,' they really meant highways. Sometimes they meant bridges and dams, but it didn't mean local water systems like pipes and pumps and wastewater treatment facilities."

However, the conversation on federal infrastructure funding has recently shifted to include water infrastructure.

The Infrastructure Investment and Jobs Act, H.R. 3684, signed into law on Nov. 15, 2021, allocated $55 billion to water infrastructure and an additional $6.6 billion to western water storage. The $55 billion figure specifically included $11.4 billion each for the Clean Water State Revolving Fund and the Drinking Water State Revolving Fund, plus additional funds for those efforts to specifically address contaminants like per- and polyfluoroalkyl substances (PFAS) and lead.

Despite being signed, the question of how those funds will ultimately be distributed remains. Greer pointed to the differences in how the federal Emergency Rental Assistance program funds related to the COVID-19 pandemic were distributed by different states as an example of uncertainty.

"The devil is always in the details, and policy is all about implementation," he said.

## Shifting perspectives on water infrastructure jurisdiction

Many of those details come down to jurisdiction. Just as lawmakers have shifted their perspectives on what counts as "infrastructure" to include water infrastructure, so too has there been a shift in how water infrastructure jurisdiction is considered.

"Traditionally the way we think about things is that the utility owns everything on one side of the meter, and the customer owns everything on the other side of the meter," Teodoro said.

The utilities' side of the meter includes things like distribution mains, treatment plants, holding tanks and pumping stations. On the other side of the meter are things like water service lines, in-house plumbing and the sewer laterals that take sewage out to the municipal wastewater pipes.

"I think there is a growing recognition that a lot of our public health problems are 'behind the meter,'" said Teodoro. "We maybe need to rethink our paradigm of who is responsible for what. But as soon as you open that box, in addition to the expenses, now we're dealing with a whole host of other social management and legal questions."

Some of those questions specifically apply to water supply infrastructure. Greer noted that the repair and replacement of lead service pipes is not controversial in terms of federal infrastructure funding. But local supply and water diversification efforts, such as more reservoirs, pipelines or brackish desalination plants, very much are.

"It's really difficult trying to talk about some of those projects objectively because there are so many people who have really strong opinions and vested interests," Greer said. "Running out of water is a huge, but regionally specific, problem. There is no one-size-fits-all solution, and we have a real challenge."

## Shifting perspectives on what water infrastructure even means

Along with the other perspective shifts related to water infrastructure, the overall perspective on what counts as water infrastructure needs to shift, said Amber Wutich, Ph.D., President's Professor and director for the Center for Global Health at Arizona State University. She said what most Americans think of as water infrastructure, such as dams, reservoirs, treatment plants, pipes and mains, is a narrow view of a specific form of water system: a centralized one.

The U.S. Centers for Disease Control and Prevention (CDC) estimates that over 90% of Americans get their household water from centralized systems. This means just under 10% — or roughly 33 million people — don't. Of those, the CDC estimates that about half depend on private wells, which are the sole responsibility of owners. Similarly, the U.S. Environmental Protection Agency (EPA) estimates that over 20% of Americans are served by decentralized wastewater treatment systems such as private septic systems, which are also the sole responsibility of their owners.

Other examples of decentralized water and sewage systems include above- or below-ground cisterns, composting toilets, home water filter systems and having water trucked in. Even buying bottled water is a part of the water infrastructure landscape, according to Wutich. She called these and other technologies, strategies and behavior patterns part of a "mosaic water provisioning system."

While these may not be part of what many Americans think of as water infrastructure, decentralized systems are nonetheless ways people get clean water into, and eliminate waste or wastewater from, their homes. ⇨

Illustration of workers inspecting pipline from Freepik.com, manipulated by Sarah Richardson.

"There have been millions of people in these kinds of arrangements in the United States that have not been much attended to," Wutich said. She explained that rural communities, unincorporated communities such as colonias, and other underserved populations around the country have been living with unreliable connections to centralized water and sewage systems or none at all.

"An important starting point when thinking about the future is acknowledging that many more people than we realize are already not part of centralized water distribution systems and probably more will join them," Wutich said.

## Climate change and water infrastructure

Wutich said that climate change and how it is and will impact water infrastructure are the most pressing issues related to water infrastructure, both in the United States and abroad.

"Infrastructure is built with a certain set of assumptions, and increasingly those assumptions are not reflecting reality," Wutich said, speaking specifically of the impacts of climate change. She gave several examples, including the increase in the number and intensity of droughts across the Southwest, flooding in coastal Texas and wildfires in California.

Regarding fire, Wutich gave the example of the 2018 Camp Fire that destroyed the town of Paradise, California. Though that specific fire was sparked by electrical transmission lines, climate change is widely credited with creating the perfect situation for wildfires to become record-setting infernos like the Camp Fire. The chronic drought and increased temperatures of climate change in the West combines to create an abundance of dead, dry trees and plant life that help fuel fires and the weather conditions that help them spread.

The Camp Fire leveled buildings and melted the underground water pipes in Paradise. This largely destroyed the town's centralized water infrastructure. Pipes that didn't melt delivered water so tainted with chemicals that it was unsafe to drink or use. The fire similarly destroyed large portions of the Miocene Canal, which delivered water to local farmers and ranchers.

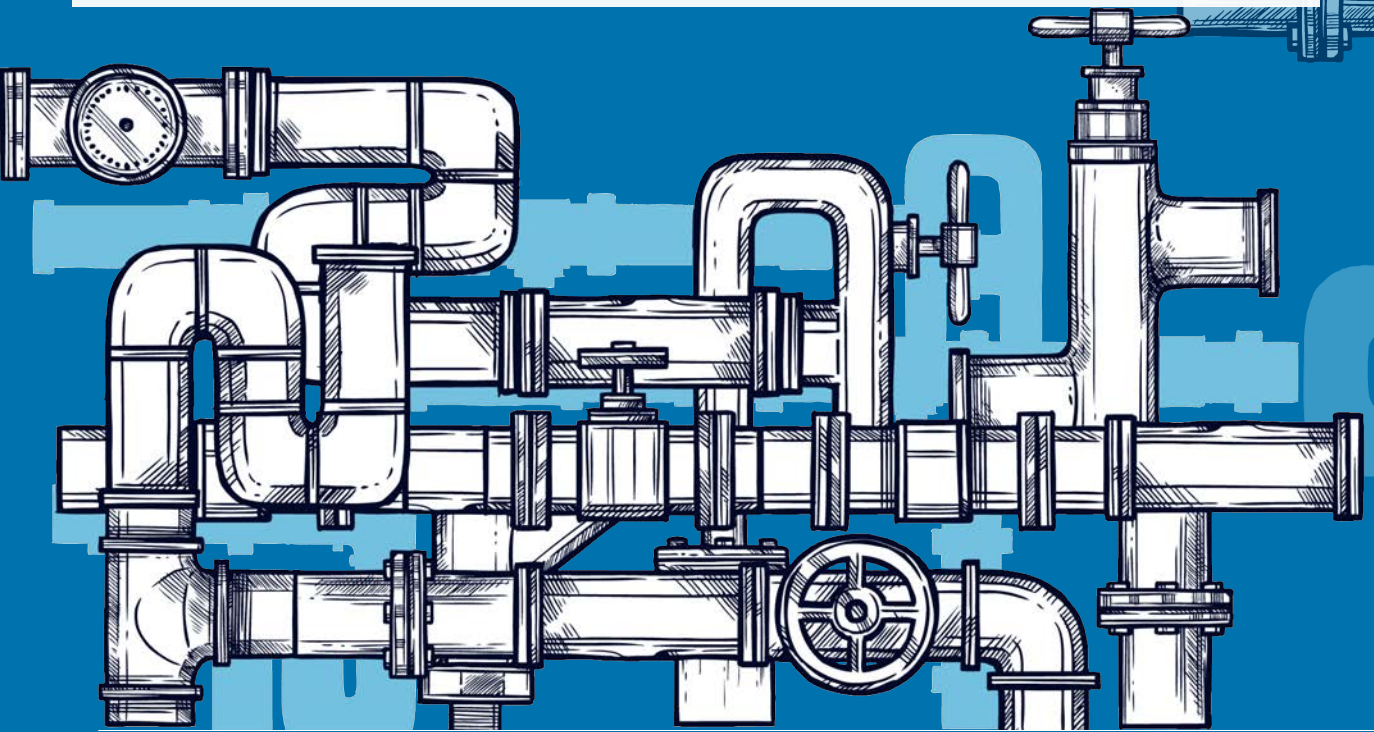
"The result of the Camp Fire is a perfect example of what we expect to see more and more: people who have had stable housing and water infrastructure for decades in the U.S. West who are going to be permanently displaced because of the changes brought by climate change," Wutich said.

"It is also a great example of the fact that it is already happening," she added. "There are people in our communities who are already being affected."

## Asking the right questions for the future

Both Teodoro and Wutich noted that the United States' success with centralized water and sanitation systems might prove to be an Achille's heel for most Americans when it comes to thinking about and preparing for the future.

"There is nothing more important than water, and yet, because people are so accustomed to receiving water service at home, they don't recognize the everyday miracle that it really is," Teodoro said. "That is an ironic result of the success we have had building and maintaining our water infrastructure so far. If you were to ask people 200 years ago, they would be keenly aware of how essential water is."



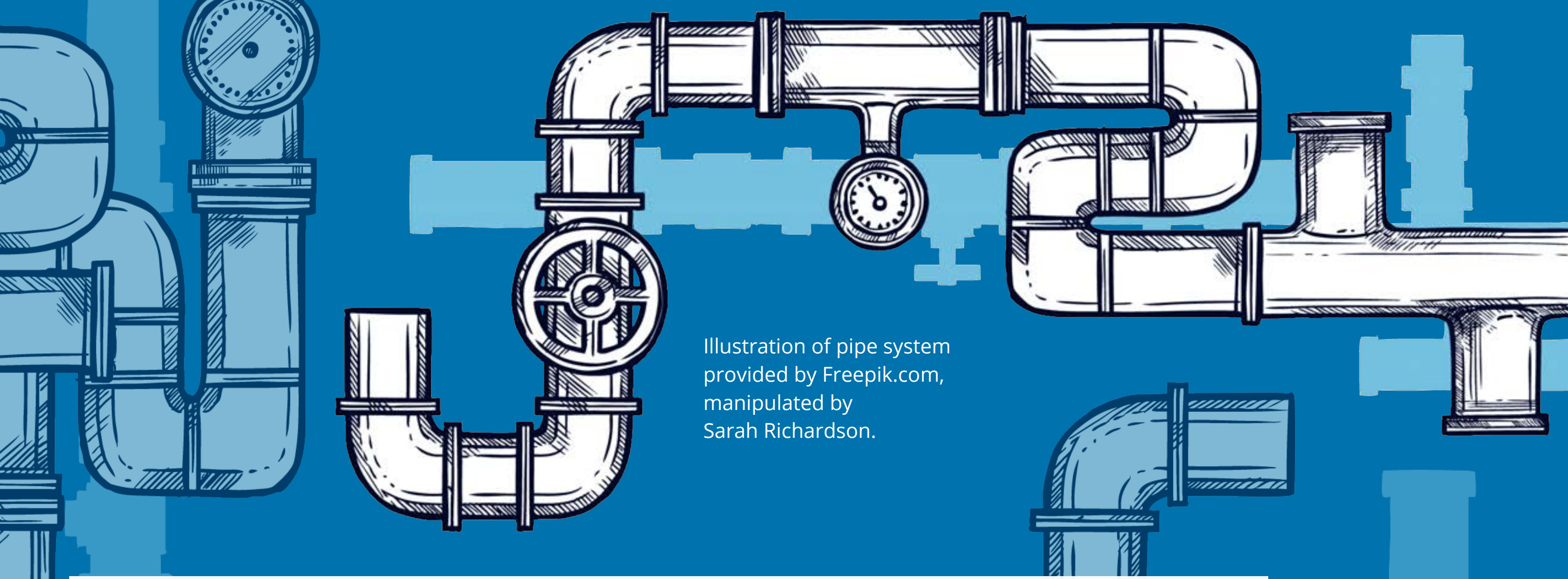


Illustration of pipe system provided by Freepik.com, manipulated by Sarah Richardson.

Wutich also pointed out that a U.S.-based perspective limits the sorts of questions Americans ask and how they think about future solutions.

"The questions we ask are probably too small and are not meeting well enough with what the future will probably look like, even in the U.S.," she said. "There is enormous variability in how people manage water globally, but we in the U.S. have really just had variants on one model for the past 100 years that has worked incredibly well and given us an enormously incredible quality of life."

She suggested a shift of perspectives when asking about the future of water infrastructure.

"The question is, if we assume high variability in people's access to stable, centralized water infrastructure, what will water provisioning need to look like to meet people's basic water needs?" she said. "This is why colonias are so important. They are a perfect example of communities that are in hybrid water systems and give us a model of what many more people might be looking at in the future."

## Funding for the future

While the issue of funding the future of water infrastructure is a complicated one, the recently passed federal infrastructure bill will help alleviate some parts of the issue in the short term. But it won't be a cure-all. Teodoro pointed out that, while federal money can help utilities, it is not "free money," but usually takes the form of revolving loan funds.

"These loans can save utilities significant money, but it's still only at the margins — local ratepayers still have to pay the bills," he said, adding his concern that federal intervention be seen as a solution to the issues. "Running these systems to failure and then waiting for federal bailouts every 50 years or so is not a sustainable funding model."

Greer voiced guarded optimism about the possibilities the infrastructure bill could create for improving the current situation.

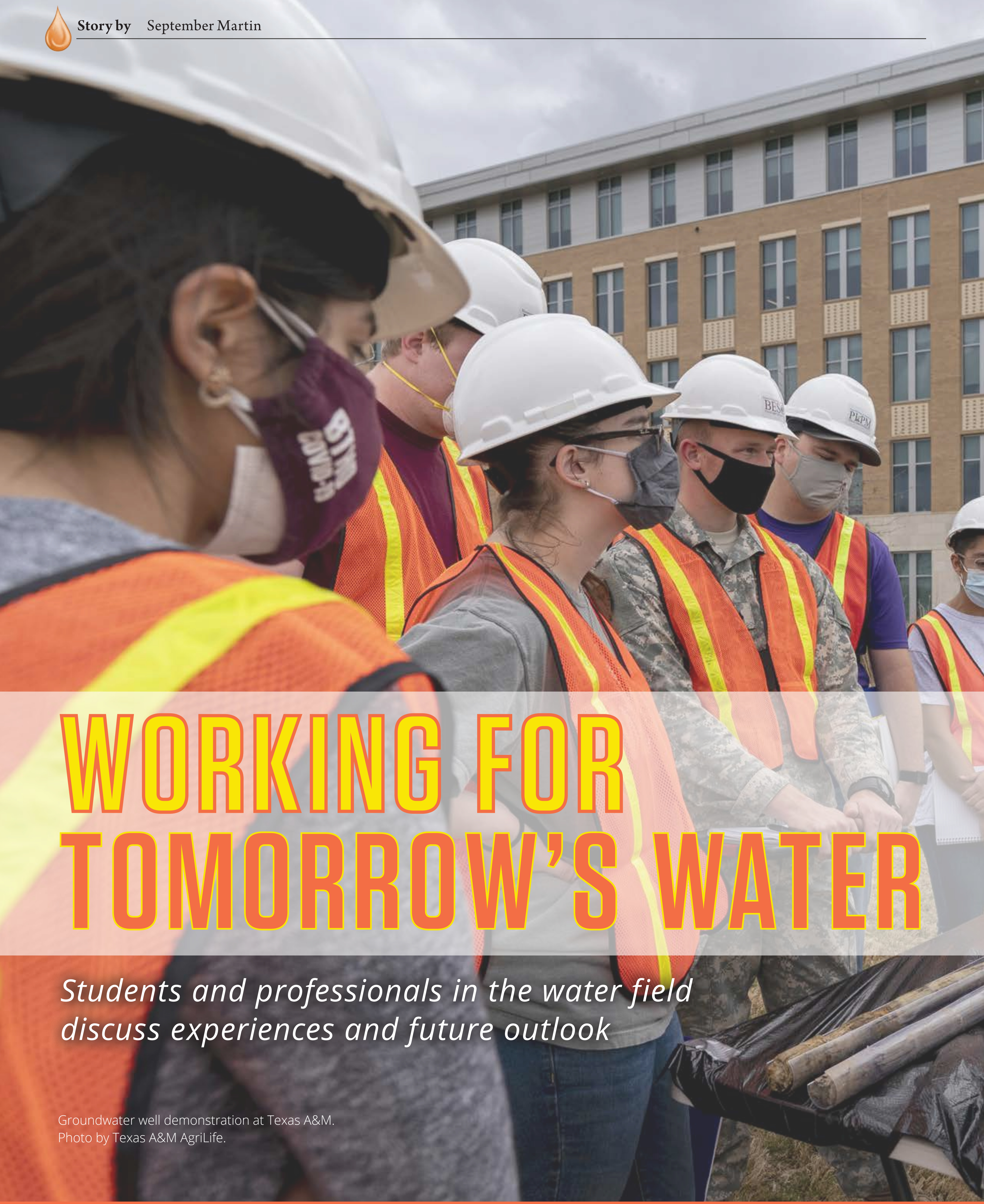
"At this point, I feel confident saying that some of the money for repairing and replacing some of our aging infrastructure is going to come from the federal government," Greer said. He also noted that the current administration recently announced the U.S. Department of Agriculture will also be creating a program for rural water infrastructure.

Speaking before the bill was signed into law, Wutich said the funds, if invested well, could put the country in "an incredible position to address some of the future stressors of climate and our water infrastructure."

She also noted that, while many water researchers' projections paint a foreboding future, the scientific community is ready to help take on the challenges ahead, and that increased funding will help immensely in that effort.

"We are trying to think forward and ask, 'What do we need infrastructure to look like in 20, 50 and 100 years?'" she said. "There are just hordes of people with solutions ready to test and ready to launch. We've all trained to be there to help solve these problems that we know our society is going to face. We are excited and invigorated."

**Story by** September Martin



# WORKING FOR TOMORROW'S WATER

*Students and professionals in the water field discuss experiences and future outlook*

Groundwater well demonstration at Texas A&M.
Photo by Texas A&M AgriLife.


RADNOR

A growing U.S. population means growing demands on the U.S. water system. But keeping the water system running, let alone expanding it to meet future demands, requires a skilled and varied workforce. That means students interested in a career in water need to prepare themselves for the high-tech, data-dependent world of the future water industry.

In addition to the increase of 1.2 million people between 2019 and 2020, the U.S. population is aging. According to the U.S. Census Bureau, 56.1 million people, or 17% of the population, are 65 or older. The changing age demographic of the population is directly linked to the need for workers in the wastewater industry.

The U.S. Bureau of Labor Statistics estimates that "about 10,500 openings for water and wastewater treatment plant and system operators are projected each year, on average, over the decade. All of those openings are expected to result from the need to replace workers who transfer to other occupations or exit the labor force, such as to retire."

The need for wastewater workers is not a new problem. An article called "Water, but No Workers" appeared in the summer 2019 issue of txH2O that discussed the role educational institutions in Texas were filling by providing more water-related education to support those in the workforce and produce graduates ready to fill the growing need for workers in the water industry.

Two years later, there is still a shortage of workers in the water industry, and it is anticipated that the shortage will become greater as water facilities are forced to expand operations in response to population increases.

Shannon Sauceman, human resource manager at North Texas Municipal Water District (NTMWD), said they never had a problem finding people to work, but the COVID-19 pandemic has made recruitment of good quality candidates more difficult. This presents a problem because they are expanding operations in response to the growing population in Texas, according to Galen Roberts, assistant deputy of water resources at NTMWD.

NTMWD serves communities in the north and east Dallas metro areas, one of the country's fastest growing metroplexes. The water district will be unable to meet consumer needs if they do not have enough people to make it happen.

Those water workers increasingly need to make use of instrumentation and data analysis in the changing water landscape, making these important skills for anyone who wants to work in the water sector.

"An instrumentation, data analytics type background is going to continue to be useful as we acquire more data and make more data-driven decisions," said Scott Hoelzle, wastewater conveyance system manager for NTMWD.

Finding enough well-skilled workers for an expanding water system is not the only problem on the horizon. Roberts said finding new water supplies is a growing issue. The water industry is having to get creative about the sources they pursue and the technologies they use to treat and make the water available for people. Understanding changing demography and what it means for future water demands is essential, he said, especially as the changing climate impacts available water and the resiliency of existing supplies.

Roberts explained that the water industry will need people with the skills to address these needs.

"There are the needs of today and the needs coming in the next five to 10 years as we're trying to meet growing demands," he said. "But there's also a changing landscape in the water industry, and I'd say the wastewater industry as well, that will require continued technical skills and perhaps new skills that aren't as prevalent in the water industry today."

So, how well prepared are students from water programs for their work in the water industry?

## What employers are looking for

There are a variety of jobs in the water industry, everything from operators to researchers to administrative staff to lawyers. All positions require some type of technical skills, such as working in a lab and electrical and mechanical knowledge, as well as a basic understanding of geographic information systems (GIS). Understanding of GIS was a technical skill that several of the industry professionals identified as important.

Zeke Campbell, assistant deputy of water treatment and conveyance for NTMWD, said an aptitude in math is also useful across many positions.

"Mathematical skills are good to have," he said. "You will use those skills if you're doing some budgeting or trying to figure out some chemical dosages or tank volumes. If you're good at math, in general, it's going to be a lot easier for you."

Aside from technical skills, there are some soft skills that are valued regardless of the position. Rachel Ickert, water resources engineering director for the Tarrant Regional Water District (TRWD) said that TRWD, as with most employers, want applicants with the right attitude who are a good fit for the position and the team. They also want people who are willing to work and learn. Hoelzle of NTMWD had much the same to say.


TWRI staff prepare to collect data at the Angelina River. Photo by Ed Rhodes.

"Almost even a bigger part than having a technical skill coming in is having the right attitude and personality, willing to learn and wanting to learn and wanting to do the best that you can do," he said. "That can set you apart in a heartbeat."

Good communication skills are also overwhelmingly valuable for employees at all levels. Both verbal and written communication are needed for collaborating, working in teams and maintaining relationships with stakeholders. Good communication is especially valuable for working with elected boards, said Jason Gehrig, infrastructure engineering director at TRWD.

Roberts of NTMWD said that flexibility and critical thinking are especially important skills for future water workers.

"Technical skills are requisite for a lot of these positions, but applying the knowledge that's learned in school to the real-world setting is also necessary," he said.

"Industries like ours are dynamic," Roberts continued. "You're constantly dealing with issues that may not fall squarely within what's included in the textbook, or you need to respond to things like regulatory changes all the time. And being able to react to and adapt to some of those dynamic things is a really important skill that I look for in anyone that I'm looking to hire."

## Former and current water students explain

Six current water students or recent graduates from the Texas A&M University Water Management and Hydrological Sciences (WMHS) program currently work with water systems through the Texas Water Resources Institute (TWRI). All offered their advice and shared their experiences on what has best prepared them and what they wished they had studied.

Preparation for water work started in the classroom for these working students. Half of the WMHS group identified a specific class (CVEN 664: Water Resources Engineering, Planning Management) as an important experience from the program.

Nathan Glavy, a former extension specialist with TWRI, said the class was useful because the professor provided a systemic overview of water, with an income-outcome, logic-based approach to problem solving within that system. ⇨

Jacqueline Rambo, a former graduate research assistant with TWRI, also noted the systemic nature of how the class is taught. She explained that the professor emphasized working with a variety of stakeholders, "to make sure that the best solutions happen. And I think that is the most important thing that I learned from that class, because I think that concept is applicable to so many fields."

Half of the WMHS group also mentioned classes in GIS as being especially important in their current work. Stephanie deVilleneuve, a research specialist at TWRI, said she took one GIS class while she was working on her master's degree. At the time she was not sure she would ever use the information. Her opinion has changed since then.

"I wish I had taken more GIS classes," she said.

The majority of the WMHS group also stressed the high value of the interdisciplinary nature of the program. Luna Yang, a research specialist with TWRI, explained how the flexibility in the program allowed her to take classes from many different departments. One class she has found particularly helpful was the statistics class she took in the Texas A&M Department of Statistics. There she learned about algorithms in a more in-depth way than she would have in an applied statistic class, a skill she is finding very valuable in her work today.

Anna Gitter, Ph.D., a former research specialist at TWRI, summarized these experiences well:

"There's not one single issue that you ever encounter that's in a narrow, specific discipline. There's always going to be an interdisciplinary nature to it. I would probably just say that was what has been most viable coming from this program."

## Workplace challenges and continued learning

Many of these non-technical skills needed in the professional water world are fostered in the Texas A&M WMHS program through the interdisciplinary nature of the program. While the program promotes written and verbal communication, there is one aspect that posed a challenge for the six TWRI working students in their professional lives: communicating with stakeholders.

"Not everyone is a scientist, so you have to portray information in a way that everyone can understand," said Ryan Marrero-Villa, a graduate research assistant at TWRI. "So when I have to make presentations for stakeholder meetings, I have to present in a way that is not overwhelming, is not confusing, and they get the main points."

Yang suggested that it might be helpful to have a seminar on communicating science for the public as part of the WMHS program.


Anna Gitter collecting a water sample during a water quality monitoring trip along the Navasota River. Photo by Leslie Lee.

In addition to the challenge of communicating with a variety of stakeholders, the WMHS group also identified some individual challenges they were not prepared for. Examples include new and unfamiliar content, work habits and organization, and time management. Despite the few challenges they identified, they all felt prepared to deal with new challenges.

As Gitter explained, "one thing you learn in grad school is you have to be able to teach yourself how to do things and how to learn things."

## Preparing for the future

Though the changing landscape of the water industry and the current difficulty finding good workers provide challenges, water professionals are energized for the future. The industry itself is adapting to the changing needs of the people it serves.

Water professionals are increasingly recognizing the issues of equity and social justice as important in what they do today, Ickert said. She has experienced these issues from the perspective of flooding, but she said it is important to understand what it means to water organizations and how they need to respond.

Gehrig explained that one way TRWD is responding to social equity issues in the water industry is by participating in a high school

internship program for disadvantaged students. The water district is partnering with Cristo Rey Fort Worth College Prep to show students the variety of careers available at TRWD, especially so students will see what is possible and that not everyone who works in water is an engineer.

Kathleen Vaught, public relations specialist for NTMWD, said that the water sector is a great one for students to pursue.

"This is a very rewarding career," she said. "The salary and benefits are wonderful; it's a well-paying industry. You can really make a career here."

To prepare for a career in the water industry, deVilleneuve recommended that students in a water program be as focused as possible from the very beginning.

"Really focus on where you want to be, the kinds of people that you want to interact with, with your research, and learn as much as you can about them," she said. She added that students may want to take as many GIS classes as possible.

Yang's advice for students entering the WMHS program was to take advantage of the interdisciplinary aspect of the program and take as many different classes as possible during the first year or year and a half. She also said to sign up for, and actually attend, the seminars because they are really helpful.

Both Marrero-Villa and Rambo recommended anyone interested in the water industry should experiment with jobs and volunteer to try new things. They also recommended not shying away from things outside of one's field, because not everyone takes a straight path to their career.

Glavy and Gitter both emphasized the importance of networking and getting to know people, because who you know can often be even more powerful than what you know when it comes to finding a job.

Professionals from the water industry also have some great advice for future water industry workers. They recommend building a good knowledge base by taking STEM classes, taking advantage of different professional organizations and visiting the local water treatment center. It is also possible to learn a lot from talking to people in the industry and pursuing internships, co-ops and volunteer opportunities. Finally, take advantage of training and educational opportunities at local colleges and universities.

Ickert neatly summarized all of the good advice:

"Go for it! Learn as much as you can, and get as much real-world experience as you can. It is important work."

(Left) Nathan Glavy and assistant demonstrating a cross-section survey at an Urban Riparian Restoration workshop. (Right) Nathan Glavy and Clare Escamilla recording data in Seguin, Texas at an Urban Riparian demonstration site. Photos by Ed Rhodes.

Story by Kerry Halladay

# DECIPHERING BIG DATA AND WATER

*Making the flood of information work for water management in a changing future*


Infographic elements by Freepik.com, manipulated by Sarah Richardson.

Before 2011, the U.S. National Library of Medicine's PubMed Central had only seven articles and one grant recorded on the field of big data and water. Ten years later, that number has grown to over 8,249 articles and over 1,190 National Institutes of Health (NIH) grants in that field. The volume of articles has almost doubled every year since 2014, and the growth of NIH grants has similarly grown over the years, making it a dominant academic paradigm in the water space.

The rapidly growing interest around big data in water is not surprising; the possibilities big data has for water-related work and research could make U.S. water systems more sustainable both in agriculture and at home. For example, big data is being used to identify leaks in metropolitan water systems, track water quality problems in rivers and help farmers use less water more effectively for their crops. Some researchers hope that big data will soon be able to help people — both in agriculture and in metropolitan areas — better use water in the face of climate change.

Big data is used as the proverbial raw material that water researchers and water managers use to derive models, look for trends and train artificial intelligence (AI). It is necessary for making predictive tools about water.

In short, big data is the grease that makes digital farming, adaptive resource management and smart water systems run.

## Defining big data

Despite the growing interest in big data in water, there are some challenges related to the field, one of the most fundamental being its definition.

Very simply, big data is what its name suggests: a lot of data. However, exactly how much data it takes for a body of data to count as "big" is a moving target because it has traditionally been a conditional definition.

"I tend to say that if you can manage it on your laptop and work with it, that's not big data," said Saurav Kumar, Ph.D., Texas A&M AgriLife Research assistant professor at the El Paso AgriLife Research and Extension Center, echoing a common definition of big data being a data set too big to work with on standard computing devices. Because the processing power of available computing devices continually expands, what counts as "big" also expands.

Robert Mace, Ph.D., executive director of the Meadows Center for Water and the Environment at Texas State University, also described big data in terms of the specialized tools needed to manage and work with it.

"When I hear the words, 'big data,' what I see is large databases and tools that are used to extract actionable information out of those large databases," Mace said. He additionally explained that those tools can be anything from visualizing programs to custom-written algorithms to already-trained AIs.

Despite the fluidity of the definition of the "big" part of big data, it has some specific characteristics that differentiate it from data. Though sources vary on what the core definition of big data is, most agree on three main features: volume, variety and velocity.

Big data comes in large volumes, from a wide variety of sources, rapidly or semi-constantly. For example, Kumar explained that one of his drones equipped with sensors can collect terabytes of data about evapotranspiration over an agricultural field. Sensing equipment can also collect a wide variety of data. For example, a network of water sensors set up in a river might collect information on flow rate, water pH, dissolved solids and oxygen, and temperature. In terms of velocity, some sensing tools used in smart metering in large cities can collect water usage data at rates of every few seconds, resulting in an almost constant flow of data.

## Challenges of working with big data

All that volume, variety and velocity makes gathering, cleaning and managing big data challenging. Mace described working with big data as being "messy" a lot of the time.

"There are warts in there," he said. "There can be errors. Somebody without a lot of experience might assume it is correct and not realize that there's a healthy error bar around it. Some of it might be flat out inaccurate, because, for example, a driller made something up."

So-called “dirty data” requires data cleaning on a big scale. That involves correcting or removing incomplete, corrupted, incorrect or improperly formatted data. At the scale of big data, specialized tools — usually in the form of software and special skills — are needed.

Once cleaned, big data must also be structured to be useful to researchers or end users. Structuring can turn a “data lake” — a large collection of usually unstructured data from a variety of sources and likely different formats — into a “data warehouse” that is easy to navigate to find what is needed rapidly.

“These datasets are coming as a large volume of complex data in different formats, different velocities and heterogeneities of veracity,” said Binayak Mohanty, Ph.D. — Texas A&M University Regents Professor and College of Agriculture and Life Sciences Chair in Hydrologic Engineering and Sciences — speaking of the big data created by water sensing technologies.

“All of this together makes the challenge more complex and the issues more demanding, but at the same time, maybe there are more opportunities for the future. How can we organize all the data, bring it together so people can have a platform to find it, access it, interpret it and use it?”

## Using big data in agriculture

Big data is both an outcome of other tools — usually sensing technologies like water monitors, flow meters, drones equipped sensing tools, soil moisture monitors and so on — and a tool in and of itself. Most fundamentally, big data is necessary for making informed, reliable predictions about the future that can translate into real-world actions and improve how water is used and managed.

In agriculture, big data is necessary for digital agriculture, which is the use of data and data-based tools like AI, the internet of things and model-based predictive tools to optimize agricultural operations. The more familiar phrase “precision agriculture” is part of the wider concept of digital agriculture.

Scientific irrigation scheduling tools are among the examples of water-related irrigation strategies that depend on big data, according to Ali Ajaz, Ph.D., Texas A&M AgriLife Extension program specialist at the Texas Water Resources Institute (TWRI), who has been studying the adoption of such technologies along the Rio Grande. These tools usually combine data derived from soil moisture sensors and weather data and then process them using AI to help farmers make targeted irrigation decisions for their crops and make better use of their water resources.

“Irrigation scheduling is a science where we are trying to find out how much water is required at what time to achieve a certain crop yield goal,” Ajaz explained. He added that for the majority of the Rio Grande growers who have adopted scientific irrigation scheduling technology, the biggest factor that pushed them to do so is to maintain the quality of their land.

“Being informed about the water application on your farm has been a link in the chain of sustainable ag.”

Even if growers aren’t yet using all scientific irrigation scheduling tools, Kumar said some use parts of the suite of tools, like soil moisture sensors. Kumar described one pecan farmer he worked with who had created a large data processing hub for himself where he collected data from his moisture sensors and generated graphs to better visualize the data to inform his irrigation plans.

Though not all irrigators have quite the big data do-it-yourself drive as Kumar’s example pecan farmer, Kumar said in his experience many farmers use information from soil moisture sensors.

“My impression was that he was an outlier, but no! He’s not that unique. There are other growers who have soil moisture sensors, at least, and use that data to time their irrigation very well.”

Other examples of using big data related to water in agriculture include the use of field imaging and similar remote sensing technologies. These efforts usually involve drones to determine what portions need to be irrigated either visually or through the rate of evapotranspiration over a field. Such tools generate massive amounts of data that can then be used to identify patterns. Apps and other services can use that data to produce useable tools for irrigators. Work was ongoing on such an app and funded in part through a TWRI-administered Water Seed Grant. ⇨

Blue digital mesh wave from Freepik.com, manipulated by Sarah Richardson.

## Using big data in water resources management

When it comes to big data in water management, Kumar gave the example of El Paso Water, El Paso's water utility, having an issue with the taste and smell of the water coming into the city.

"They spend a lot of money just to improve those characteristics because people often complain," he said.

The taste and odor issues with El Paso water often stem from algae blooms in New Mexican reservoirs along the Rio Grande, the source of the city's water. These algae blooms can result from warm water temperatures in summer coupled with high levels of nutrients in the water. While the water's musty taste and smell is a nuisance, it is not a safety issue.

Using big data could give El Paso Water enough advance notice to address the issue before it becomes a nuisance.

"What they are planning to do is install sensors near the Elephant Butte reservoir, which is several hundred miles away," Kumar said. He explained that the data from the sensors could show the patterns of water conditions upstream that can result in an algae bloom.

"That way El Paso Water can know when they are likely to have issues with taste and smell about three days in advance and can plan their mitigation efforts," Kumar said.

## Using big data in municipal water use

As growers are using digital agriculture, municipalities have also been tapping into the growing potentials of smart water metering. Smart water metering — part of the advanced meter infrastructure concept — allows water utilities and municipal water users to better monitor overall water system efficiency and identify problems with the system. In early stages, smart water metering allowed utilities to more closely monitor water use for billing purposes and more easily read water meters at the household level. More recent advances in smart metering have extended near-real time information to water users on their household level usage.

Not only does smart metering like this generate big data, that data is required for current and future tools to help utilities and users alike to better understand and manage their usage.

Mace gave his participation in Pecan Street as an example. Pecan Street is a non-profit research and development organization originally founded in 2009 through seed funding from the University of Texas-Austin.

"They do detailed monitoring of energy use and water consumption," he explained. "It's difficult to measure water use at, say, the individual sink level, but there's long-standing research that the whole-house signal can be decomposed into what's irrigation, what's a shower, what's a washing machine and so on. Different uses have different volume and duration profiles that can be identified with this level of monitoring."

Mace and his wife use Pecan Street's water monitoring technologies at their home and keep track of their water usage with the organization's tracking app. The smart meter sends usage data every 4-10 seconds. They were able to use this information to identify when a pipe burst under their house. They were also able to use the information to solve a water mystery.

"I was able to use that meter to show that I was having a mysterious use sometimes during the day when my wife and I were at work," he said. "We realized that the neighbor was using our outdoor faucet to wash his car."

Some utilities are rolling out similar big data-creating smart water meters and big data-dependent tools for residents. The City of Fort Worth started offering the MyH2O program in 2019, which includes smart meters that collect data every hour. An online portal allows municipal water users to track their water usage from the day before. Users can also set automated alerts on their account so that they are notified by text if their water use has not stopped running, suggesting a leak, or if their water bill is approaching a set amount. Austin's My ATX Water program, launched in 2020, is very similar, and other Texas cities like Allen, Abilene and Mesquite have recently announced smart water metering projects.

Abstract data particles from Freepik.com.

## Climate change and the future of water's big data

Big data can also help water users of all kinds adapt to the uncertain future of climate change. However, climate change can make it hard to understand big data.

"Based on climate change, our future is going to be even more nonstationary," Mohanty said, explaining that "nonstationary" in this context means that what we know from the past may not hold true for the future.

"Basically what is happening here is the data is generated as the water is moving; it is a continuous cycle," Mohanty added. "As soon as water hits the ground in the form of rain, it moves through the soil water systems, then it joins the groundwater. Or surface runoff goes to the rivers and eventually goes to the ocean and is recycled back through evaporation and clouds and begins the cycle again.

"But these processes are continuously changing because of climate change. So we need to understand these physical processes are happening and also how the parameters that are driving the physics are changing with time."

He said that researchers need to figure out how to link knowledge of the physical with the data. He described the physical side of water issues as things like hydrology, engineering, the understanding of how contaminants or nutrients move in a water system, biology of plants and plant physiology and atmospheric science. The data side includes disciplines like mathematics, statistics, computer and data science, and electrical engineering. This transdisciplinary approach will allow researchers to go deeper and understand the systems better to better predict things in the future, he said.

"When you have these datasets that are coming from different space and time resolutions and they are evolving and changing because of climate change, you need to have a very good understanding of how to fuse them," Mohanty said.

"This means you have to have a fusion of the laws of nature — the physics, the chemistry, the biology — and bring them into the realm of computer science, big data, AI and machine learning," he added.

"The different pieces of the puzzle are available, but how to connect them together and how to massage them to get the right answers to the right questions is the future for us to look into. We have to sit together and try to answer the questions in a transdisciplinary way."

**Story by** September Martin

# Bigger Is Not Always Better: Decentralizing Texas' Wastewater Infrastructure

*The future of wastewater treatment: wastewater treatment plants versus on-site septic systems*


Urban wastewater treatment plant illustration from Freepik.com, manipulated by Sarah Richardson.

Aerobic septic system and sprayfield illustration by Sarah Richardson with resources from Freepik.com.

Washing and sanitizing bodies, hands, surfaces and clothing are all normal parts of life. When people flush the toilet, take showers and clean the dishes, the resulting wastewater miraculously disappears without much thought. These activities are only possible with a safe and adequate wastewater treatment system.

An effective wastewater infrastructure system is just as important to public and environmental health as it is to personal hygiene. Having an effective, efficient sewage system keeps people safe from polluted water that can transmit waterborne diseases such as cholera, cryptosporidiosis and giardiasis. It can even keep food safe, as contaminated water can lead to contamination of agricultural crops and seafood.

However, there is a growing problem with wastewater infrastructure in the United States. As the population increases, more people are relying on aging wastewater systems and moving into new residential areas. The increased wastewater load taxes existing wastewater systems that need upgrading. Also, as residential areas spread into new geographic areas, people are often turning to decentralized, on-site systems, which also have challenges of their own. However, education, regular maintenance and necessary system upgrades can keep wastewater systems running effectively.

## Centralized systems: wastewater treatment plants

Centralized systems or wastewater treatment plants (WWTPs) are the most common type of wastewater treatment. According to the American Society of Civil Engineers (ASCE), there are more than 16,000 WWTPs in the country. On average, these facilities operate at 81% of their designed capacity. They treat about 62.5 billion gallons of wastewater per day.

An average American produces about 100 gallons of wastewater per day, or 36,500 gallons per year. With the population increasing approximately 1.8 million people per year, already 15% of the WWTPs in the country exceed their threshold capacity. This situation raises the question of how well these systems will be able to keep up.

Another issue with the wastewater infrastructure in the United States is its age. The ASCE states that WWTPs have a typical lifespan of 40-50 years; however, the average age for WWTPs in the country is 45 years. These aging systems require maintenance and upgrades to continue to perform effectively.

According to the ASCE, "as collection systems age and decline in condition, groundwater and stormwater enter the network through cracks, joints or illicit connections as inflow and infiltration," which overtaxes the collection systems, causing sanitary sewer overflows (SSOs). ⇨

SSOs are when untreated or partially treated water is released from a municipal sanitary sewer, according to the U.S. Environmental Protection Agency (EPA). SSOs pose a public health risk because they contain raw sewage that can carry bacteria, viruses, parasites, molds and fungi. These contaminants can cause health problems, from digestive discomfort to life-threatening conditions such as cholera, dysentery and hepatitis. People can be exposed through contaminated drinking water, direct contact with contaminated water and consuming the shellfish collected from them.

The ASCE reported that between 2012 and 2016, improvements were made to more than 180 of the nation's large sanitary sewer systems, which are prone to frequent SSOs. There are thousands of miles of sewage pipes buried under increasingly urbanized cities, and maintenance of these pipes will require interagency collaboration and data sharing. In 2019, as much as 62% of wastewater pipeline maintenance was performed proactively by collaborating utilities, and the remaining 38% was completed as a response to failures. However, since 2017, replacement rates for wastewater collection pipes have stagnated.

Additionally, the ASCE estimated that maintenance costs for WWTPs increased 4% each year from 1993 to 2017. The 2020 estimate for maintenance and operation costs throughout the country is more than $3 billion for wastewater pipe repairs and replacements. This translates to more than $18 per person for wastewater customers relying on centralized systems. The cost is projected to increase by an average of 5% annually.

## Decentralized systems: on-site sewage facilities

The second type of wastewater treatment is an on-site sewage facility (OSSF), commonly referred to as septic systems. OSSFs operate like WWTPs, but on a smaller scale, to treat wastewater from a single building or buildings from a small community.

According to the ASCE, approximately 20% of Americans rely on OSSFs for wastewater treatment, and that percentage is rising. However, exact numbers for OSSFs are difficult to come by because most states do not collect data on OSSFs. In fact, 1990 was the last year that the U.S. Census Bureau collected OSSF data.

The lifespan of a conventional OSSF (septic tank drain field) is 20-30 years, but due to the lack of data, it is nearly impossible to accurately assess the remaining lifespan or current condition of existing OSSFs. However, one potential way to estimate the age of OSSFs is by the age of houses that might have them. In 2015, the National Association of Home Builders estimated that the average owner-occupied home is 37 years old. This suggests many systems may be past their usual lifespan and may require replacement, particularly if the property owners did not invest in regular proactive maintenance.

The ASCE estimates that regular maintenance totals approximately $250-500 every three to five years for OSSF property owners. Also, according to the OSSF team at the Texas A&M University AgriLife Extension Service, an aerobic system typically has maintenance contracts costing $300 a year, plus they have electrical components that eventually need to be rebuilt or replaced. However, replacing a failing system would cost $6,000-10,000 or more depending on the type of system.

While the financial responsibility for upkeep and replacement tends to fall on the property owner, some states, such as Texas, offer funding to help with system replacement.

## All about the money

Solving the aging, overtaxed wastewater systems' problems in the United States comes down to one issue:

"Money," said Anish Jantrania, Ph.D., P.E., associate professor and Extension specialist with AgriLife Extension's OSSF team. "Who wants to pay money on wastewater systems?"

Jantrania explained that funding for proactive maintenance on centralized wastewater systems is a low priority for governments and utilities. Additionally, organized funding to help property owners fix and upgrade OSSFs is either very low or nonexistent because OSSFs are handled differently from sewer systems.

## OSSFs in Texas

"One of the big differences between sewer and septic is sewers are a national program; they are regulated under a National Pollutant Discharge Elimination System by EPA," Jantrania said. However, he explained that OSSFs are regulated at a state level. EPA offers guidelines and recommendations, but there are no national level standards or regulations.

In Texas, OSSFs are regulated by the Texas Commission on Environmental Quality (TCEQ). TCEQ keeps track of permits, limits, related state regulations and more. This permit tracking is a way to help determine how many OSSFs are in use in Texas, where they are and when they were installed. TCEQ also ensures that new OSSFs are meeting the necessary standards.

"We believe septics are as good or better than sewer systems," said Jantrania.

Jantrania explained that when he uses the terms "septic systems" or "septics," he is referring to any wastewater treatment system that is not a centralized WWTP-type system. Septic systems are widely used in Texas, with an estimated 5.8 million Texans relying on these decentralized wastewater treatment strategies.

A traditional septic system, or an anaerobic system, consists of an underground tank to receive and hold the wastewater and a drain field, which filters the water and allows the clean water to return to the ground. The septic tank is air-tight and relies on bacteria that thrives without oxygen to process the wastewater. This type of system also requires a specific soil type; thus it does not work well in many parts of Texas. However, there are other options for OSSFs today, such as aerobic systems, which use a different process for wastewater treatment that relies on oxygen-loving bacteria.

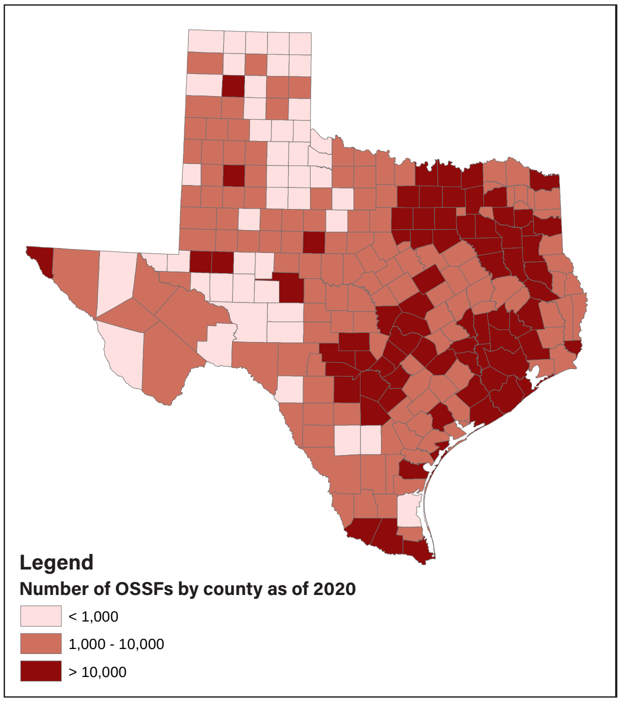
Gabriele Bonaiti, Ph.D., Extension program specialist with the AgriLife Extension OSSF team, estimated the number of properties in Texas that rely on septic systems by using the U.S. Census data from 1990 and the number of OSSF permits issued by TCEQ since 1992. U.S. Census Bureau data reports houses not connected to sewer, summarized by county. TCEQ data is also summarized by county and also identifies the system type.

"Now, of course, there are probably a lot of little errors in doing this, but this is what we found was the best approach," Bonaiti said. "So we have a number, updated to December 2020, which is the last available OSSF permits from TCEQ. And we are at 2.38 million systems."

## OSSF regulations and research at Texas A&M RELLIS campus

"Before 1989, there was no statewide guidance for OSSFs in Texas," said Ryan Gerlich, Extension program specialist with the AgriLife Extension OSSF team. "There were a select number of counties that did have rules before then for installing systems, but not very many."

A critical rule revision in 1997 mandated that OSSF installers and regulators perform soil and site condition evaluations to determine what type of system to install. The rules have been updated multiple times since, and current rules are available on the TCEQ website.




This map was created by the Texas A&M AgriLife Extension OSSF team using and processing data from the 1990 U.S. Census and the TCEQ OARS (On-Site Activity Reporting System) OSSF permits public dataset.

The OSSF research facility and training center at the Texas A&M RELLIS campus in Bryan, Texas played a key role in the preparation for that 1997 rule change. Gerlich explained that the training center was created in part to meet the new requirements, which mandated that a thorough soil and site evaluation be performed before determining what type of system to install.

"The training center was built in 1995 to get ahead of that 1997 rule change," Gerlich said. "There were several different aerobic systems installed at our training center in a manner that they're easily visible. It was really to show the installers what was coming up next as far as the aerobic treatment units and so on."

Much of the research done on OSSFs at the RELLIS campus are funded through a TCEQ grant program that is focused on OSSF research. June Wolfe, Ph.D., associate research scientist with the AgriLife Extension OSSF team, explained that TCEQ funds research so that they can understand how the systems are meeting the state mandates. In addition to research, educating and training OSSF installers, regulators and end users has been a main activity for the AgriLife Extension OSSF team at the RELLIS campus.

"Where they can't solve a problem with a sewer, then we advise them to use septic," Jantrania said. "Or, whenever there are problems with a septic, and if they try to connect to the sewer in that area and they cannot, then we help them. A&M is just one of many players in Texas. We help people to solve what's called failing septic system problems. Our primary business is to educate people on the advances and the new subjects and all that kind of thing. So there are alternatives and a lot of good things in the septic industry." ➯

OSSF Research, Training, and Education Center located on the RELLIS campus in Bryan, Texas. Photo by the OSSF team.

## Growing population in Texas

Like many other parts of the country, Texas' population is growing quickly, which impacts the wastewater infrastructure across the state.

"Texas makes up almost 9% of the total U.S. population," Wolfe stated. "Five of the largest 15 cities in the U.S. are in Texas. That's Houston, San Antonio, Dallas, Austin and Fort Worth. So we've got a large demographic here and a fifth, or about 20%, of that population will rely upon on-site treatment systems."

Wolfe explained that the need for more OSSFs translates to needing a larger future workforce to design, install and service those systems. He also explained that in order to build that workforce, education and training will be necessary. Providing education and training is what they are doing at the Texas A&M RELLIS campus OSSF research facility.

"We'll be able to deal with the population increase through improved engineering solutions and improved design efficiencies. And that's why I point to the Texas A&M OSSF research facility here at the RELLIS campus," Wolfe said.

The Texas A&M OSSF team is looking at ways to advance OSSF science through the modification and testing of current designs. "In order to increase system efficiencies, test new ideas and develop improvements, we need research," he said.

Wolfe shared that the research on aerobic treatment systems looks promising.

"We've got some on-site treatment systems that we're studying here on the RELLIS campus called ATUs, or aerobic treatment units. These designs have a smaller installation footprint than a traditional septic system, and they are more efficient because they add oxygen to the system, which speeds and improves the wastewater treatment process."

Gerlich echoed Wolfe about the promising technology, adding that the aerobic systems work particularly well with Texas soil varieties.

"The aerobic treatment unit is probably the number one thing that is installed," he said. "If we don't have the area for a large drainage field or suitable soil conditions, that's usually the go-to the technology. Space is as, or maybe more, important than soil type."

Gerlich explained that people across the state would have access to OSSFs, regardless of the soil conditions in their location, using aerobic systems and other developing septic technologies.

"There are a variety of technologies out there to meet all the different variations in soil types. When we talk about soil types for a regular septic tank and drain field to operate, we want a coarser textured soil and the sandier soil or loamy soil. Also, we want unsaturated soil, so we don't want seasonal water tables within two feet from the bottom of the drain field," he explained.

In areas of Texas with a lot of clay, such as the Brazos Valley or along the Gulf Coast, the high water table makes the conditions unsuitable for a traditional septic system. However, Gerlich said with the continuously advancing technologies, it is possible to come up with a solution for almost every soil condition.

Not all OSSF technologies are expensive or cost-prohibitive. However, when OSSF owners are in a situation where they cannot afford to fix or replace a failing system, Jantrania explained that there is funding available to help pay for those projects in Texas. Gerlich has even worked on some government-subsidized OSSF installation and repair projects, including the Coastal Zone Act Reauthorization Amendments, Tres Palacios Creek and Lampasas River Watershed.

"A lot of the ones that we replaced were on the coast. And they were old homes, most of them were homes from the '50s and '60s that were originally built as a weekend fishing cabin. So when it was originally built, they put in a 200 gallon septic tank and 50 feet of drain field," Gerlich said. "But there were only a couple people there a weekend or two a month, and that was about it. And now people have moved into those houses full time, so they are overloading that really old system."

As the population increases, technologies advance and change, and the OSSF training facility continues to provide education for installers, regulators, designers and end users. Gerlich explained that professionals in the industry are required to have 24 hours of continuing education every three years to renew their licenses, allowing them to learn about new technologies.

## Looking to the future

Jantrania explained that one of those new technologies, aerobic systems, was the biggest environmental advancement made in the 1990s. Researchers at the RELLIS campus continue to focus on improving these systems.

Disinfection systems are another new aspect of the OSSF process that researchers are investigating. So far, adding a liquid chlorinator or an ultraviolet light to aerobic systems has shown promise for improving system disinfection.

"We are actually looking at ozone at our center, so we can have some new concepts for disinfection," Jantrania said. "And the biggest research that we are guiding now is reuse. Texas is big on reuse of wastewater on the municipal scale, and our goal is to make sure some of those advancements in reuse technologies are also available to on-site folks."

Another future advancement in sewage treatment that Jantrania anticipates is nutrient reduction. He explained that Texas has some nutrient-sensitive areas, specifically groundwater with nitrate contaminants.

"Nitrogen and phosphorus are the nutrients in wastewater, and if they get into groundwater or surface water, they become a pollutant rather than a beneficial thing," Jantrania explained. "So, what we try to do is either remove it before discharge or try to reuse it by growing vegetables or whatever else you can grow so that the nutrients become a resource rather than a pollutant."

## The bottom line

Despite the challenges of population growth and aging water infrastructure systems across the country, wastewater treatment in Texas has a bright outlook. OSSFs provide a solution to growing wastewater treatment needs based on a growing population, as they can be installed in new residential areas with no sewer access and can be more economical than connecting to existing sewer systems. The OSSF Center at the Texas A&M RELLIS campus provides Texans a unique and proactive resource for OSSF education and solutions.

To address the issue of cost, there is financial help available for Texans in need of assistance for OSSF replacement. Additionally, since OSSF technology is continuing to adapt and improve due to the work done at the RELLIS campus, OSSF systems are becoming more efficient and economical.

Through the education and research, the AgriLife Extension OSSF team is there to help Texans navigate the world of OSSFs and step into the future of wastewater treatment.

"You find water, and you find energy; we take care of sewage," Jantrania said. "That should be our slogan."

(Left) The Texas A&M AgriLife OSSF team inspecting an aerobic treatment system. Left to right: Mesut Özdmir, Ryan Gerlich, and Anish Jantrania. (Right) Ryan Gerlich, an AgriLife Extension OSSF team member, demonstrating how to take a sample from an ATU using a sludge judge device for a routine inspection. Photos by J. Wolfe.

Photo by iStock.

# STORMS, SALTWATER, SEWAGE AND AIR: FINDING FRESHWATER IN A CHANGING WORLD

*Researchers are looking to unexpected sources to solve the problem of not having enough freshwater where and when it's needed.*

All the water that has ever been on Earth — except what's gone to the International Space Station — is still here in some form. But only 3% of that is freshwater, and only 0.5% of the planet's freshwater is easily accessible. If all the world's water fit into a gallon jug, then the easily accessible freshwater would be roughly one tenth of a teaspoon.

The growing global population is using more freshwater, and climate change is causing more extreme droughts and flooding, said Bridget Scanlon, Ph.D., senior research scientist in the Bureau of Economic Geology at the University of Texas (UT) at Austin.

"We are running out of water in some places, and we have more water in other places," she said.

At a conference of the Stockholm International Water Institute, Scanlon heard the water crisis described as being one of "too much, too little or too polluted."

Finding more freshwater is therefore "a key scientific challenge" for humanity, said Guihua Yu, Ph.D., professor of materials science at the UT Austin Walker Department of Mechanical Engineering and the Texas Materials Institute.

"As the population grows, and as climate change becomes really concerning, how can we accommodate these growing droughts?" he asked.

To meet that challenge, researchers are looking for freshwater in unexpected places.

## Stormwater

Scanlon explained the first place to find freshwater is by looking at the "too much" part of the water crisis: capturing water from storms and floods.

"Texas has always been subjected to either floods or droughts," she said. "If you have a problem with a supply-demand disconnect — either a spatial or temporal disconnect — you could try to resolve that by storing water or transporting it. The flood water in much of central and eastern Texas is a great resource."

Captured stormwater can be used to recharge aquifers in a process called managed aquifer recharge. Aquifers supply much of the drinking and irrigation water for the state, but they have been used faster than they are naturally replenished. Current managed aquifer recharge technologies using stormwater could bolster the stores of aquifers.

There's been interest in taking advantage of stormwater in Texas. In 2019, Scanlon coauthored a study with Qian Yang, Ph.D., Bureau of Economic Geology research associate, quantifying how much stormwater could be captured from high water events in Texas rivers from 2015 through 2017.

Scanlon and Yang found that the amount of water flowing in 10 major Texas rivers during high-flow events was nearly as much as the capacity of Lake Mead, the United States' largest reservoir.

"That water represented more than the state was using in a particular year, you know, the average water use, if we could capture the water from those three years," Scanlon said.

## Saltwater

The second unexpected place to find freshwater is saltwater. Some countries in more arid parts of the world have already turned to desalination to meet demand for freshwater.

Desalination is done in one of two ways. In thermal desalination, saltwater is heated up, and the resulting water vapor is condensed and collected. In reverse osmosis desalination, saltwater is pushed through a series of membranes at high pressure to remove salt and other contaminants.

Desalinated water can be used for drinking water, as it is in Israel, where desalination is expected to provide 85-90% of the country's municipal and industrial water by the time its next two desalination plants are completed. Scanlon said that desalinated water can also be used for agricultural purposes, even if it's not treated up to drinking water standards. Even without desalination, brackish water can be used for industrial purposes, which in turn leaves more freshwater for other uses.

Desalination accounts for roughly 1% of the world's freshwater, but its use is growing. In Texas, there are more than 50 desalination plants that treat brackish groundwater and surface water. This can produce over 150 million gallons of water per day for municipal use. There are no operational seawater desalination plants in Texas, but several projects are in progress on the Gulf Coast.

## Sewage

A third source of freshwater is sewage, or municipal wastewater.

Over 75% of usable water can be recovered from wastewater, in contrast to 20-50% water recovery from seawater, said Qilin Li, Ph.D., professor at Rice University and co-director of the Nanosystems Engineering Research Center for Nanotechnology Enabled Water Treatment. And unlike stormwater, wastewater is essentially always available, so it can be harvested at a steady rate.

Typically, wastewater is treated up to a level that the effluent — treated wastewater — is safe enough to be discharged into waterways. ⇨

Bathtub, clothes washing machine, sink and toilet icons by Freepik.com.

"What you do in wastewater reuse is you take the effluent from the existing municipal wastewater treatment plant, and you further treat it to a much higher quality," Li said.

That fully treated water can then be distributed through the same water system as conventional water sources, such as surface water and groundwater. When the water goes straight from the wastewater treatment system to the drinking water treatment system, that's called direct potable reuse. Li said that direct potable reuse is the simplest and most affordable method for reusing wastewater.

In a 2020 study, Li and others used Houston, Texas, as a model to test how reused wastewater could supplement existing water sources. They found that reusing wastewater could decrease the need for existing water sources by nearly a third. Though it would increase short term costs, it would save money and energy in the long term.

"In the long term, you can reduce the uncertainty in your water supply, and you can reduce discharge of waste streams into your natural aquatic system. And overall, you can potentially save some energy, which will help reduce the carbon footprint of the water system for the city as well," Li said.

## Air

Another source of water is all around us, said Xianming Dai, Ph.D., assistant professor of mechanical engineering at UT Dallas.

"Air is everywhere," he said. "Researchers show that there is over six times the amount of water in vapor around our planet than in all the rivers. Six times. That's enough for many purposes, if we can have good technology to harvest water from air."

Dai, who studies the surfaces used for harvesting water from air, said researchers' inspiration for harvesting water from the air came from seeing what already was happening in nature.

"They found that in the desert, a beetle collects water from fog for survival. Nature is smart," he said. "We wanted to get inspiration from nature."

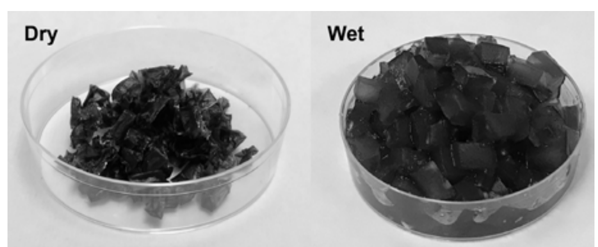
Water can be harvested from the air by condensation: Water vapor condenses into water droplets on a cooled surface and drips into a collection reservoir. The water condensed from the air is clean, as long as the condensing surface is clean, and the water can be used for drinking or irrigation.

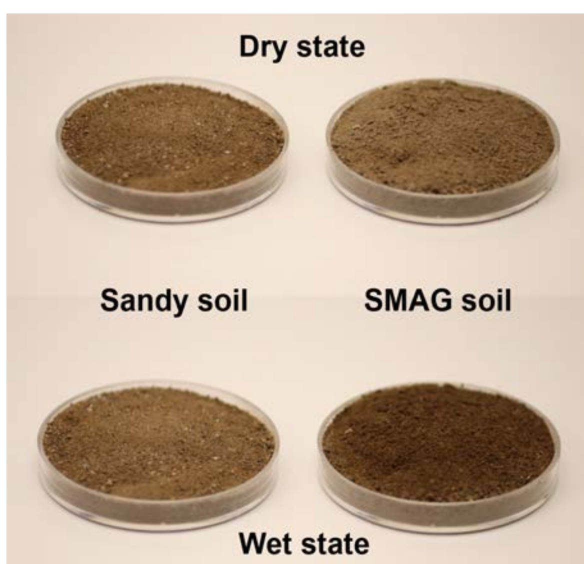
Water harvested from the air can also be used more directly for irrigation using "self-watering soil," Yu said.

Self-watering soil is soil that has been coated in super moisture absorbing gels, which Yu and his research team described in a 2020 study. One component of the gel absorbs moisture from the air, while the other is thermoresponsive, meaning that it absorbs water when the temperature is cooler and releases water when the temperature is higher.

"You can think about the gel kind of like a slowly absorbing sponge," he said. "The gel-coated soil harvests the moisture from the air and stores the water, particularly in the humid and cold night. Then when the sun rises and it heats up, they can release water slowly. So it's very efficient."

Because the gel is coated onto soil, the water collected by the gels is released into the soil. Each kilogram of self-watering soil can absorb roughly 3-4 kilograms of water, "so it's actually more than




(Top) Super moisture absorbing gels in dry and wet states. (Bottom) The difference between self-watering soil (SMAG soil) and normal soil in wet and dry states. Photos by Guihua Yu.

Radishes grown in self-watering soil on a rooftop at the University of Texas at Austin. Photo by Guihua Yu.

enough for many of the common kinds of crops to grow," Yu said.

## Getting ahead of the curve

Cost, public opinion and the limitations of materials have always complicated the use of alternative water sources, but barriers are coming down slowly but surely.

For example, in 2020, researchers found that if the membranes used in desalination have more uniform density — down to the nanometer scale — they are far more energy efficient and therefore more cost-effective. Dai and his research team also recently discovered a phenomenon called the coarsening effect, which helps tiny water droplets coalesce, solving a major problem for harvesting water from air.

Both discoveries are useful across multiple freshwater sources. Dai's discovery can be used to improve thermal desalination as well as harvesting water from air, and the desalination membrane discoveries can also benefit stormwater and wastewater treatment.

Still, each source of freshwater has more work ahead to make it broadly usable.

Scanlon said that Texas-specific pilot studies are needed to demonstrate that stormwater can be used effectively as a water source in Texas, and both wastewater and stormwater reuse will require building more infrastructure. Li said that implementing wastewater reuse will require helping the public get over the "yuck factor," as well as overcoming communication barriers.

"There is still a huge gap between what we think can be done and what municipalities are willing to do or think they're ready to do," she said. Researchers need to connect with decision makers and the general public so that everyone is on the same page about the problems and the solutions, she said.

Having more freshwater solutions is necessary now, Li said, because more change is coming.

"There are many places in this world that don't have enough freshwater resources that are nearby and accessible and at a low cost," she said. In those places, water reuse is already needed. Elsewhere, climate change and population projections show that water reuse will be needed in the future.

Being prepared for that uncertain future will depend on "whether we've done our homework," Scanlon said. But, Li said, there's an opportunity to get ahead of the curve.

"This is why we are thinking about how we can prepare," Li said. "Cities that are already using alternative freshwater sources, they're doing it out of necessity. But many other cities, they have a chance to do this right, to design a system we can optimize in multiple different ways."

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