JANUARY 2025

Water Innovations

TOP 10 TRENDS FOR 2025

Expert Insights Into Today's Critical Water & Wastewater Issues

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FROM THE EDITOR

By Kevin Westerling
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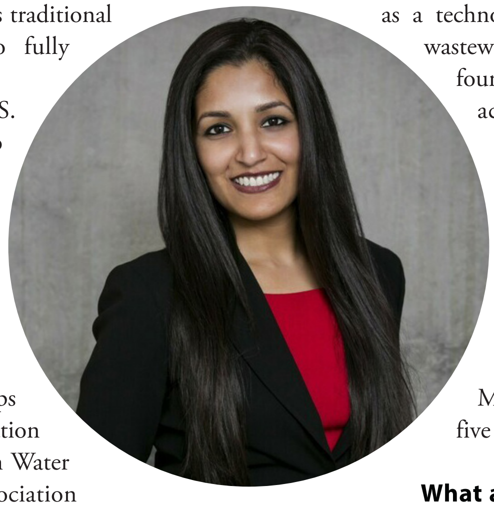
Transition, Changes, And Trends

Hmmm … what's new for 2025? 🤔 That's asked with a hint of knowing sarcasm, as the incoming presidential administration promises to disrupt the status quo. The change in direction for environmental policy, including impacts on regulations as well as traditional and human infrastructure, has yet to fully reveal itself.

What won't change, however, is the U.S. water industry's collective commitment to solving water issues — for the benefit of the environment, consumers, and the industry itself. The professionals behind the scenes who clean and supply our water are the ultimate authorities on the sector's needs and challenges, so their voice should be heeded.

In December, five notable water groups — the American Water Works Association (AWWA), the Association of Metropolitan Water Agencies (AMWA), the National Association of Clean Water Agencies (NACWA), the Water Environment Federation (WEF), and the WateReuse Association — wrote to President Elect Donald Trump calling on his administration to "advance policies that strengthen the nation by recognizing water as a national priority."

The top-line request in the letter was continued financial investment in renewing America's infrastructure, which has been a concern for decades, via State Revolving Funds (SRFs) and other financial assistance programs. Next mentioned were newer concerns, which can also be seen as trends or focus points for water and wastewater professionals in 2025: support of the "polluter pays" principle for PFAS cleanup, regulations based on sound science and fair policies, and action to promote water reuse.



Meena Sankaran
Founder and CEO of KETOS

From Policy To Technology, Forging Ahead

While these water organizations and industry ambassadors appeal for policy progress, we must also seek technological progress. That's the mission of *Water Online's* annual "Top 10 Trends" edition of *Water Innovations*. Themes from above are represented — infrastructure, PFAS, and water reuse — with affordability and regulatory concerns layered into almost every article. Other 2025 trends we cover include advances in GIS for utility management, water quality monitoring methods, desalination, decentralized treatment, smart water programs, and more.

Q&A: An Expert's Analysis

Obvious within the water industry, or most any sector, is that everything is trending toward digital, automated, remote, and "smart" — at its smartest, leveraging machine learning and artificial intelligence.

For an overview of trends on the cutting edge, as well as a technology provider's perspective on the water/wastewater market, I consulted Meena Sankaran, founder and CEO of KETOS. Among her accomplishments, besides leading her company's emergence and innovation in water quality monitoring, Meena was listed among the "awe-inspiring women" named by *Forbes*, ranked among 100 global innovators by Goldman Sachs, and represented at the United Nations for Sustainable Development Goal (SDG) 6.

Meena gave her tech take on the following five questions…

What are the current trends in real-time water analytics and intelligence?

- Focus still largely remains on water usage analytics, more so than water quality, so the need for a breadth of **real-time water quality analytics** still exists as a challenge. It's encouraging to see some startups in Europe, Africa, and Australia pursuing their quest for bacterial/pathogen detection, which is a difficult feat.
- **Satellite image-based water quality monitoring** is picking up steam, but without the onsite sensing systems in place to provide the sensitivity and accuracy needed for decision-making, it has a way to go.
- As a goal to increase the caliber of the water quality data available, **artificial intelligence (AI)** is increasingly being used by companies to predict water demand, detect leaks, and forecast water quality, but the clarity of its use and impact have yet to be uncovered.
- There is a need for **automated and comprehensive remote monitoring for water reuse systems** to provide early detection of any potential health threats. Meanwhile, several commitments to net-zero-water by 2030 are becoming daunting for some private organizations that aren't equipped with the tools or resources for the ambitious, brand-oriented goals they have laid out.
- Aligning to a **PFAS strategy** as a water institution, whether you are a public or private organization, also has to be a top priority for 2025.

What is the role of detection in addressing per- and polyfluoroalkyl substances (PFAS)?

To better understand the problem, the U.S. EPA has initiated nationwide monitoring for 29 PFAS at 10,000+ public water systems, and that aligns with KETOS' motto: "You can't act on what you don't measure."

In addition to real-time measurement, we offer a data-as-a-service (DaaS) platform that sources, cleans, and aggregates publicly available data — from trusted organizations such as the EPA, the United States Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) — to generate actionable insights on PFAS risk and options in just minutes.

It's a start to some much-needed answers.

While municipalities ultimately hold the line for water security and availability, industrial operations are closely tied to the mission. How is industry embracing sustainability and resiliency, and to what effect?

Private and public alignment from a compliance standpoint is what closely intertwines municipalities and industry, as effluent flows from both wastewater treatment plants and industrial operations.

There is no enforcement for climate resilience, but there are key indicators of commitment, such as the appointment — and power assigned to — a chief sustainability officer (CSO). Do they have budget authority? Can they make decisions that force operations to change the status quo? Can they set standards across an organization? Or is the naming of a CSO more a "nice to have" branding announcement?

As someone who wants institutions globally to make water a top priority and take serious action toward gaining intelligence around it for proactive decision-making, it is important to assess how strong organizations are in their sustainability commitments.

What are the water implications brought on by the rise in AI, both good and bad?

While 2024 is widely recognized as the year AI gained significant traction, 2025 will likely witness a rapid expansion of AI-powered technologies, fueled by the growth of new data centers. Much of the focus has been on the electricity and computational power required to support AI-driven data centers, but more attention needs to be given to the downstream impact of water consumption and the subsequent wastewater discharge.

What are some technological advances that could be game-changers for water and wastewater management?

- **Bacterial and pathogen detection in a matter of minutes** — compared to days of waiting — without compromising accuracy, could be massive for utilities.
- **Using AI for sewage monitoring**, in addition to sensing capabilities where opioid concentrations can be understood. This could be science's way of tackling the growing fentanyl epidemic.
- The **removal of pharmaceutical residues** that tend to remain in treated wastewater and advancing toward deeper detection abilities for such parameters.
- **Automated PFAS detection at EPA compliance levels** still remains a large question to be addressed commercially.

Thanks to Meena Sankaran and to you, the reader, for journeying with us into another exciting year of Water Innovations. ■

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A NEW ERA FOR WATER MANAGEMENT: Harnessing GIS Innovations And Collaboration For A Resilient Future

Geographic Information Systems (GIS) are advancing the water sector in expected ways — resource planning and asset management — while also offering exciting, new opportunities.

By Hopeworks, American Water, and Environmental Policy Innovation Center (EPIC)

As the water industry adapts to the current technological revolution, 2025 promises to be a pivotal year for integrating GIS advancements. With rapid developments in high-accuracy global navigation satellite systems (GNSS), indoor mapping, cloud computing, and remote sensing, GIS is poised to transform how water users manage infrastructure and resources. This evolution is about technology and properly equipping the industry with the tools to effectively navigate challenges like climate variability, regulatory compliance, and the impending workforce shift.

Technological Advancements

In 2025, several GIS technological advancements will significantly impact the water industry. High-accuracy GNSS and indoor/vertical mapping will strengthen GIS as the definitive tool for managing infrastructure assets. As infrastructure data's positional accuracy improves, augmented and extended reality technologies are emerging within the sector. Transitioning to cloud computing solutions like Google Earth Engine will revolutionize server-side processing by enabling large-scale watershed analysis, real-time water resource monitoring, and historical pattern analysis on an unprecedented scale. Meanwhile, advancements in remote sensing, utilizing satellite and drone data, will offer water scientists enhanced resolution imagery, more frequent data collection, and superior spectral analysis for water quality assessment.

Leveraging AI And Machine Learning

The integration of AI and machine learning with GIS in water management is progressing, but current results are hindered by limitations in GIS data quality. Addressing these issues will enhance AI's ability to predict pipe failures and optimize maintenance routes, improving fuel efficiency and asset reliability. Key areas for AI/machine learning and GIS integration include predictive analytics — enhancing leak detection, infrastructure failure prediction, and demand forecasting — and automated feature detection, such as mapping pipeline networks and identifying stormwater infrastructure. However, true transformation in water management requires more than technology. Achieving "AI-readiness" involves creating a robust data infrastructure, institutional capacity, stakeholder engagement, and adaptive governance to effectively guide AI use.

Navigating The Lead And Copper Rule With Precision And Insight

GIS is crucial for meeting the Lead and Copper Rule (LCR) requirements, enabling efficient inventory surveys and stakeholder communication. Many utilities use GIS forms and web applications for this purpose. Hopeworks exemplifies how GIS can aid compliance by digitizing lead and copper pipe data for the Environmental Policy Innovation Center (EPIC) and American Water. By training young talent in GIS techniques, Hopeworks empowers utilities to manage infrastructure assets and comply with changing regulations.

Additionally, GIS, combined with machine learning, offers powerful solutions for climate variability adaptation in water resource management. These tools predict consumption patterns, identify vulnerabilities, and optimize distribution networks, marking a shift from traditional models reliant on historical data. Hopeworks equips interns with the skills to develop models, analyze data, and create visualizations, supporting the creation of climate-resilient water systems.

Sustainable Water Management Amidst Climate Change

GIS technology is pivotal in asset-hardening analysis, particularly in assessing the vulnerability of point and linear assets to flooding. By integrating FEMA flood maps with modern tools such as lidar-derived local elevation models, hydrology models, and GIS analyses like slope assessments, utilities can produce detailed risk registers to better understand and mitigate flood risks.

Moreover, the integration of machine learning algorithms with GIS marks a transformative shift in water resource management. These advanced tools can predict consumption patterns, identify infrastructure vulnerabilities, and optimize distribution networks in response to evolving climate conditions. Traditionally, models relied heavily on historical data from specific basins or aquifers. However, with climate variability altering hydrological responses, there is a need for models that transcend historical limitations. AI enables the use of diverse climatic data and analogous basins to forecast novel future scenarios, allowing utilities to model various climate impacts on watersheds and develop resilient infrastructure and management strategies.

Forging Collaborative Partnerships

Building strong relationships with municipalities, communities, and nonprofit organizations is essential for understanding local challenges, building trust, and fostering innovation. GIS technology offers significant potential to enhance planning and decision-making regarding infrastructure improvements and replacements for utilities of all sizes and locations. For example, GIS technology enables precise spatial analysis, real-time data visualization, and comprehensive infrastructure mapping, which allow utility managers to identify critical needs, optimize resource allocation, and predict maintenance requirements with unprecedented accuracy and efficiency. However, smaller systems often face resource and capacity constraints, limiting their access to GIS. Nonprofit technical assistance providers play a crucial role in connecting under-resourced, overburdened systems with suitable GIS solutions. These partnerships facilitate valuable opportunities for data sharing, joint projects, and knowledge exchange, enabling a comprehensive approach to managing water resources.

In addition, the water industry faces a demographic challenge with a significant portion of the workforce nearing retirement. This creates an urgent need to recruit, train, and retain a younger workforce, particularly in technical roles. Partnerships between nonprofits like Hopeworks, municipalities, and utility companies will help to attract young talent to the water industry and train the next generation with GIS skills. By investing in the next generation of geospatial professionals, the water sector can ensure a more sustainable and resilient future.

Conclusion

Further integrating GIS into the water sector carries significant upsides, but it is not a panacea. Water defies standard resource management paradigms, resisting conventional technological and economic frameworks. GIS technologies' potential lies in its ability to help diverse stakeholders improve water governance by synthesizing the spatially explicit data that underpin decision-making for common pool resource management — something that to date has been constrained on both technological and social fronts.

By fostering collaborative partnerships and investing in the next generation of geospatial professionals, we help ensure that our water management systems are prepared for the challenges ahead and capable of seizing new opportunities for innovation. Together, we can harness the power of GIS to build a more sustainable and resilient water infrastructure, safeguarding our most precious resource for generations to come.

About Hopeworks

With a focus on skill development, real-world job experience, and trauma-informed care, Hopeworks propels young adults into long-term living wage careers that put them on the path for healing and financial stability. To provide this experience, Hopeworks runs real businesses, providing technology solutions for businesses in GIS, revenue cycle management (RCM), and web design. These businesses help generate over 250 jobs a year, and lead to high-wage, permanent opportunities for young adults in multiple industries.

About American Water

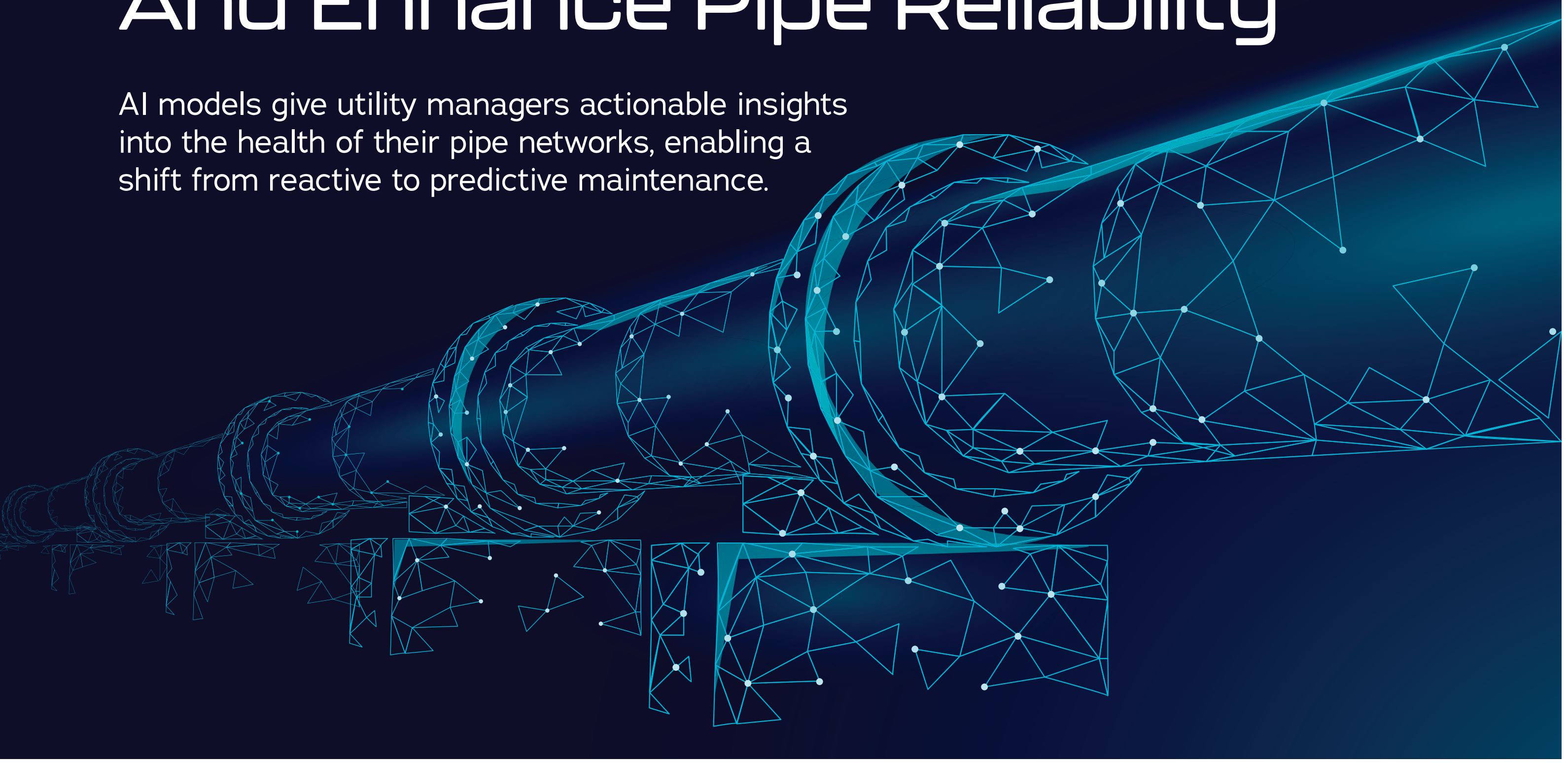
American Water is the largest regulated water and wastewater utility company in the United States. With a history dating back to 1886, We Keep Life Flowing® by providing safe, clean, reliable, and affordable drinking water and wastewater services to more than 14 million people with regulated operations in 14 states and on 18 military installations.

About The Environmental Policy Innovation Center (EPIC)

The Environmental Policy Innovation Center (EPIC) is a nonprofit organization whose mission is to build policies that deliver spectacular improvements in the speed and scale of environmental progress. We deliver data-driven policy analysis, innovation, and technical assistance to eliminate disparities across water systems and ensure that residents across the country have access to safe and accessible drinking water. ■

Using AI To Reduce Water Loss And Enhance Pipe Reliability

AI models give utility managers actionable insights into the health of their pipe networks, enabling a shift from reactive to predictive maintenance.



By David Kushner

Water utilities across the U.S. face a growing infrastructure challenge. The average failure age for a water pipe is 53 years, and 33%[1] of the water mains in the U.S. are over 50 years old. Water utilities find it challenging to identify which pipes are at risk of failure, because they lack the data needed for making informed decisions on pipe replacement. This makes it difficult to prioritize maintenance or replacement, resulting in decision-making based on often costly speculation instead of data-driven insights. However, advancements in artificial intelligence (AI) and machine learning (ML) are transforming how utilities can predict and prevent pipe failures and stay ahead of these infrastructure challenges.

The Growing Problem Of Aging Water Infrastructure

The U.S. alone has over 770,000 miles of aging water mains. The sheer scale of these systems makes it difficult for utilities to stay on top of maintenance and replacement schedules. Historically, utilities have used reactive approaches to managing pipe failures — responding to breaks and leaks after they occur. This method often results in high costs, water loss, and service disruptions, with pipes being replaced only after they fail.

Complicating matters further, the data available to most utilities making these decisions are incomplete. Utilities often rely on pipe age and material type when prioritizing which pipes to replace or repair, but these factors alone don't provide actionable insight into whether the pipe is at the end of its useful life and whether other pipes should be prioritized for replacement. Environmental

By continuously learning and refining predictions over time, AI models help utilities make better decisions about where to allocate resources and when to intervene.

conditions such as soil type, temperature variations, and pressure loads, as well as historical failure patterns, are critical in determining which pipes are most at risk. Without accurate data across these variables, utilities are left to rely on institutional knowledge and gut feelings, potentially missing critical early warning signs of failure.

Enter AI And ML

AI and ML advancements are revolutionizing various industries, and water utilities are also experiencing this transformation. By leveraging these technologies, utilities are now able to combine historical data, real-time sensor readings, and environmental factors to gain deeper insights into the health of their pipe networks.

AI and ML models are adept at analyzing extensive data sets to identify patterns and connections that may be challenging, if not impossible, for humans to detect. For example, an AI model can analyze a combination of factors such as pipe age, material, historical failure rates, water pressure, and even weather patterns to predict which pipes are most likely to fail in the near future. These insights allow utilities to prioritize replacements and repairs based on actual risk rather than age alone.

In many cases, these AI-driven models rely on both structured and unstructured data. Structured data, such as pipe material and installation date, can be combined with unstructured data like maintenance records and work orders to create a comprehensive view of each pipe's condition. By continuously learning and refining predictions over time, AI models help utilities make better decisions about where to allocate resources and when to intervene.

Moving From Reactive To Predictive Maintenance

The transition from reactive to predictive maintenance is one of the most significant benefits AI offers water utilities. Rather than waiting for a pipe to burst or leak, predictive maintenance strategies allow utilities to forecast problems before they become emergencies. This proactive shift can reduce water loss, lower repair costs, and improve service reliability.

Predictive maintenance depends on data analytics to continuously monitor the state of infrastructure in real time. For instance, pressure sensors installed throughout a distribution network can detect minute changes in water pressure that may indicate a developing leak. When combined with AI algorithms that analyze historical failure patterns, these real-time data inputs provide a powerful tool for identifying potential issues before they escalate.

Furthermore, predictive maintenance can extend the life of aging infrastructure. Instead of replacing pipes on a set schedule based on age alone, utilities can focus on preventive measures for pipes identified as high-risk by AI models. This approach not only reduces unnecessary replacements but also maximizes the lifespan of pipes that are still in good condition.

Reducing Costs And Enhancing Efficiency

Cost savings are one of the most immediate benefits of predictive maintenance. Repairing a pipe before it fails is generally much less expensive than dealing with the aftermath of a major burst. The cost of water loss, service interruptions, and emergency repairs can add up quickly, particularly in urban areas where large-scale infrastructure failures can disrupt entire neighborhoods.

AI can also help utilities optimize their maintenance budgets by enabling precise planning. Instead of allocating resources on pipes that may or may not need replacement, utilities can focus their efforts on high-risk areas, ensuring that repairs and replacements are carried out where they are needed most. This targeted approach reduces waste and helps utilities operate more efficiently.

In addition to lowering costs, predictive maintenance can improve the overall quality of service to customers. By preventing unexpected outages and reducing water loss, utilities can ensure a more consistent supply of clean water to their customers. This not only benefits consumers but also helps utilities meet regulatory requirements for water quality and conservation.

Improving Decision-Making With Data-Driven Insights

One of the key advantages of AI is its ability to provide data-driven insights that enhance decision-making at all levels of an organization. For water utilities, this means moving away from intuition-based decisions toward evidence-based strategies that maximize infrastructure performance and minimize risk.

AI models can offer utility managers clear, actionable insights on the pipes most susceptible to failure and the expected timing of these failures. With this information, decision-makers can better prioritize projects, ensuring timely completion of critical repairs and replacements. In addition, the transparency provided by AI models allows utilities to justify their decisions to regulators and stakeholders, helping to build trust and confidence in their infrastructure management strategies.

Water utilities that embrace AI-based predictive maintenance strategies stand to benefit from reduced water loss, lower repair costs, and improved service reliability — all of which contribute to greater sustainability and operational efficiency.

Looking Ahead: The Future Of AI In Water Utilities

The shift from reactive to predictive maintenance represents a critical opportunity for water utilities to improve their operations and serve their communities more effectively. Water utilities that embrace AI-based predictive maintenance strategies stand to benefit from reduced water loss, lower repair costs, and improved service reliability — all of which contribute to greater sustainability and operational efficiency. As the challenges of aging infrastructure continue to grow, adopting proactive solutions powered by AI will be essential for maintaining safe and reliable water systems for the future. ■

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About The Author

David Kushner has been with Itron for more than 20 years. Currently, in his role as director of global data management for water, electricity and gas, Kushner is committed to working with utilities and municipalities to reach resourcefulness and sustainability goals.

Assessing The Reliability Of Current Water Quality Monitoring Practices

High-quality water — and public trust — flows downstream from high-quality monitoring.

By Ellie Gabel

The validity of current water quality monitoring practices varies based on the criteria used and conditions testers perform under. Questioning these strategies' reliability and consistency demands an analysis of these variables. Here are the most critical factors in the industry and what testers can do to improve them.

Sampling Methods

Many methods are straightforward, allowing experts to collect a sample in its typical environment without contaminating it to see the water in its most natural state. Sometimes, delayed testing or unintentional cross-contamination provides inaccurate results. There are no ways to reverse these changes, even when using the most analytical methods with sensitivity considerations.

Experts are designing enhanced techniques to make them less susceptible to changes. Composite sampling considers them over time by acquiring variations of the water's quality to represent a wide array of conditions. Event-driven sampling is another attentive way to verify how water reacts after specific weather events or contamination.

New technologies, like mass spectrometry, can pinpoint contaminants in lower quantities than conventional measures. Many entities are trying to tackle the growing problem of PFAS, which this method finds in less than three minutes.

Monitored Parameters

Parameters must be comprehensive yet focus-driven. Limiting measurable metrics saves on research labor and hones in on the most critical points of the water's quality. They should incorporate staples, like pH and dissolved oxygen. Most of these are embedded into most assessment programs. However, many do not consider relevant novel pollutants.

Identifying what is relevant now will make water testing more meaningful for treatment professionals trying to keep the public and environment safe. The parameters should first be context-specific, identifying what is essential to analyze for drinking versus agriculture. There may be some crossover.

Then, observing current events and biological indicators could reveal previously unmonitored criteria. These may include microplastics, bacteria, or pharmaceuticals. Researchers should expand the indicators they focus on by creating a different list for biomonitoring. For example, tracking the health of fish populations could signify what needs to be assessed in water tests.

Citizen Science

Citizen science is public water quality testing. Its input is vital for expanding data collection[1] and determining the effectiveness of testing and treatment strategies. Some utility companies and plants may have limited citizen science initiatives. Expanding these efforts increases water dependability.

Organizations should amplify the number of sites from which they collect data. They may monitor a watershed, but other regions nearby, such as city parks, could be affected by altered water. Working with community boards, like Parks and Recreation, city councils, or nonprofits, will improve data density and engage the public in water quality literacy.

Testing Frequency

Some agencies test frequently but not in enough circumstances, while others may execute minimal tests. Improving the public's perception of water quality requires corporations to test often and in as many situations as possible.

For example, a case study that analyzed snowmelt and ground snow in the Pacific Northwest proved the quality was on par with grocery store-available water[2], regardless of elevation and the recency of the snow's accumulation. Understanding these figures is important to inform nearby companies how to tend to each water source.

Temporal variability may skew data from one sample to the next in the same location, and these data points are as valuable as results from years prior. Comparative analysis with context visualizes how many influences cause local waters to degrade in quality.

Regulatory Compliance

After investigations from the U.S. EPA, around 70% of water systems in the U.S. failed to comply with the Safe Drinking Water Act[3]. When corporations ignore industry-leading recommendations, communities bear the brunt of this negligence through scarcity and health concerns. This impact leads to societal distrust in water treatment and utility systems.

Improving public perception requires multiple measures. First is improved data integrity and reporting. Water stakeholders must send testing and quality reports to compliance agencies to inform their frameworks. Additionally, it can force companies to engage in better quality assurance and control.

Water quality businesses should boost commitments to regulation abidance and create proprietary compliance for emerging contaminants as industry leaders establish new standards. For example, dyes and hormones are growing concerns[4] but require more research to inform rule-setting. Companies must get ahead and still focus on how to remove these problems to preserve quality. Enterprises may even engage in pilot studies to contribute to broader bodies of research.

Putting Trust In Water

Many regions experience water scarcity because of questionable quality and inaccessibility. Improving water quality testing worldwide would make affected communities struggle less. Sustainable development and global equity rely on experts dedicating as many resources and as much time as possible to make it the best it can be. Therefore, every stakeholder in the industry must engage with these strategies as soon as possible to enhance testing accuracy and water clarity. ■

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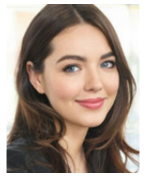

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The Benefits *And Challenges* Of Desalination

Leaning on a wealth of experience, an engineer lays the groundwork for successful, cost-effective desalination projects.

By Rubén Muñoz

Communities are expanding their water supply portfolios to address water scarcity driven by population growth, extreme weather, droughts, and urbanization. As freshwater limitations increase, the demand for brackish and seawater desalination is expected to rise. However, significant hurdles — such as high costs due to energy demands and environmental concerns — hinder the widespread adoption of desalination.

A Road Map To Successful Projects

Based on lessons learned from desalination projects over the last decade, including the Aqaba-Amman Water Desalination and Conveyance Project in Jordan, CDM Smith has developed a road map from concept through procurement.

We identified five major steps in this road map:

1. **Diagnosis.** This initial phase involves performing a water balance to identify the water deficit and generating emergency plans and water usage restrictions.

2. **Planning and development.** We establish a clear definition of the water deficit and impacted areas. This phase also includes addressing brine management solutions, understanding permitting needs, and coordination with local energy providers.

3. **Pre-feasibility study.** This phase focuses on selecting a location for the desalination plant. To develop this task, we determine the capacity of the plant as well as a phasing strategy based on a water demands study, then produce a conceptual process solution to generate inputs used to perform the trade-off for the optimum project location. We use multicriteria analysis (MCA) supported by geographic information systems (GIS) tools incorporating variables such as land use, right of way, local communities, intake and outfall solution, marine environment, power supply, product distribution, and connection points. In this stage, we screen various project locations and rank them using MCA to select a preferred location.

Factors that influence the construction cost of desalination plants include the seawater intake and outfall, location of the plant, power supply connection, brine management and disposal, environmental regulations, and water quality.

4. **Procurement strategy.** This step outlines project delivery options such as progressive design-build (PDB), public-private partnerships (P3), build-own-operate-transfer (BOOT), or build-operate-transfer (BOT) methodologies, and strategies to select the best collaborative delivery approach for the owner and funding partners.

5. **Site and environmental evaluation.** Discharge permitting is one of the most critical activities in seawater desalination projects, which requires a marine baseline study including seawater characterization, marine current, winds, and bathymetry. Best practices include treating the chemicals and waste utilized in the pretreatment process, such as filter backwash. Post-construction testing is typically required to demonstrate compliance with a brine monitoring plan that is submitted during permit application. Typical parameters include flow rate, conductivity, temperature, pH, oxygen, and chlorine. After approval, this process allows the construction of the desalination plant to begin.

Cost Considerations

Factors that influence the construction cost of desalination plants include the seawater intake and outfall, location of the plant, power supply connection, brine management and disposal, environmental regulations, and water quality. The intake and outfall are a substantial portion of the cost of desalination projects. The best location for intake and outfall can be determined by studying various construction methods for the intake capacity, specific site conditions, and environmental permitting restrictions.

In small to midsized capacity plants, it is feasible to install a sub-surface solution using beach wells and slant wells, which are the most sustainable way to extract seawater. We designed a new facility for California American Water's Monterey Peninsula Water Supply Project that includes a slant well for seawater intake.

Large international desalination projects, like the Spence Growth Options project, use various delivery, financing, and operation models. For example, BOT is a concession model whereby a private entity or special purpose company assumes the responsibility for project execution, project finance, and long-term operations. At the end of the concession contract, it can be renewed with the special purpose company, or the asset can be transferred to the owner. Additional desalination initiatives using BOT and P3 are currently under evaluation. There are also several projects in the design phase being implemented as PDB and receiving state and federal funding that do not involve private entities.

Renewable Energy

Desalination plants require substantial energy to operate, and renewable energy would normally be preferred for environmental-impact considerations. The main challenges of implementing renewable energy, such as wind or solar, at desalination facilities is that the generation is not constant, and the best locations for generation are not necessarily close to the desalination plant. This means that renewable energy cannot supply the desalination plant continuously, unless costly energy storage solutions are employed.

When renewable energy cannot be implemented as part of a desalination project, many plants are connected to local power grids. To offset emissions and environmental impacts, projects can incorporate energy recovery devices; solar panels; LED lighting; higher efficiency motors; carbon offset credits; high-efficiency, high-pressure pumps; efficient membrane configurations; and load-shifting strategies to reduce the strain on local power supply.

Brine Management

The seawater desalination process creates a brine that has approximately two times the salinity of raw seawater. The most cost-effective solution is to discharge it back to the sea using brine diffusers, with criteria defined during permitting application using a brine dilution model. For example, the most restrictive standards require compliance with a 2% increase in salinity compared to ambient at 100 meters from the diffuser, which is feasible to achieve during operation and compatible with the ambient salinity tolerance of marine species. We have applied this approach successfully at facilities in the Middle East, Australia, and Latin America.

RO technologies are rapidly progressing with new developments and innovations that decrease costs and increase efficiency.

For brackish desalination applications that require inland disposal, we have used deep infiltration wells or evaporation ponds. We have also implemented minimal liquid discharge (MLD) using higher recovery technology like closed circuit reverse osmosis (CCRO) to reduce brine volume and produce more permeate.

In seawater applications, a brine mining process using combinations of nanofiltration membranes, reverse osmosis (RO), and high-pressure RO (HPRO) and counter-flow RO (CFRO) for concentrate streams has been tested and can achieve recovery of 65% and concentrate up to 200,000 mg/L of total dissolved solids. This application has great potential for economic feasibility depending on the market value of the minerals extracted from brine; currently, the technology is proven at pilot scale but not yet implemented at full-scale plants.

Pretreatment

Large existing desalination projects producing more than 200 MGD with open intakes and relatively good water quality, i.e., total suspended solids (TSS) of under 5 mg/L, utilize one stage of pressurized multimedia filter to reduce footprint and optimize cost. Midsize existing desalination plants of 5 to 30 MGD use an ultrafiltration process to further reduce footprint and civil works, but along with that come greater operational costs. Of course, the pretreatment selection needs to be based on specific raw water quality in terms of TSS, turbidity, total organic carbon (TOC), algae-bloom risk, and estimation of lifecycle water cost. Open intake with water quality challenges will require intensive pretreatment with coagulation/flocculation, dissolved air flotation,

or clarification, which increases capital cost significantly. One way to optimize this is to assess various treatment configurations and leverage pilot plant data to determine actual operational performance in specific locations.

Leveraging Reverse Osmosis Solutions

RO technologies are rapidly progressing with new developments and innovations that decrease costs and increase efficiency. Recent technological advancements include:

- **Modular solutions.** One way to reduce costs is to apply modular preassembly solutions for RO skids. Main components can be prefabricated offsite in a controlled environment, ensuring high-quality products. This reduces the risk of project delays, because prefabrication activities can be done in parallel with civil works and reduce installation costs onsite.
- **RO configurations.** Special optimized configuration includes a pressure center with a dedicated common set of large, high-pressure pumps to feed several RO skids. Large pump capacity can achieve higher efficiency.
- **Decreased energy consumption.** Development of new membranes with higher productivity allows us to optimize the flux distribution by utilizing various membranes in the pressure vessel, with high rejection in front and high productivity in the rear positions, thereby decreasing energy consumption. Restricted limits for boron and bromide require a certain technology trade-off to select the optimum configuration by analyzing one-pass configuration with high-rejection membrane versus partial, second pass with variable permeate split. The permeate split application with a second pass allows us to optimize the size of the second pass and adapt the process to variations in salinity and temperature.
- **New development of energy recovery devices with higher capacity.** The increase of 30% in energy recovery devices allows a compact design with fewer pressure exchange elements and less mixing, which reduces energy consumption compared to previous models.
- **Dry membranes.** Usually, membranes come with a solution to preserve them during transport and storage, but newer membranes can be shipped "dry," which allows a longer storage time and reduces installation time during commissioning phase.

Desalination presents a viable solution to address water scarcity from freshwater sources. While desalination provides substantial benefits, it also presents challenges, such as high costs driven by significant energy demands as well as environmental impacts. However, advancements in RO technology and effective brine management practices can help control costs and improve efficiency. By leveraging these practices, communities can navigate the complexities of desalination and contribute to sustainable water management. ■

About The Author

Rubén Muñoz is a civil engineer with 17 years of experience in engineering water supply infrastructure and desalination projects. As the discipline leader for desalination at CDM Smith, Rubén focuses on the planning and design of marine works, desalination plants, hydraulic conveyance for pipelines and pumping stations, and RO plants.

Modern Solutions For Aging Water Systems: **AMI And Beyond**

Lessons from two communities on the benefits of advanced metering infrastructure.

By Trey Overman

Water utilities in North America are grappling with aging infrastructure that is increasingly prone to leaks, inefficiencies, and costly repairs. Many systems, built decades ago, were not designed to meet today's operational demands or population needs. Fortunately, digital technologies such as smart metering, advanced metering infrastructure (AMI), and software platforms help utilities modernize operations, regardless of the age of their pipelines. These solutions provide near-real-time insights, enable proactive maintenance, and help reduce non-revenue water (NRW). Digital tools allow utilities to manage their existing infrastructure while also future-proofing against additional strain, such as an increase in population.

Leverage Advanced Metering Infrastructure To Optimize Water Management

There are many ways to employ digital solutions to manage aging infrastructure, and often the first step is a transition to smart metering and AMI. AMI systems allow utilities to collect detailed data on water usage in nearly real time. This continuous monitoring helps identify irregularities, such as potential leaks, before they escalate into significant issues. AMI also provides insights into consumer usage patterns and system-wide pressure, enabling better demand management and pressure management. The implementation of smart metering and AMI in North Battleford, Saskatchewan transformed the city's approach to water management. With its Sensus FlexNet communication network, the city not only gained the ability to monitor water distribution remotely but also uncovered inefficiencies in the network. The utility reduced water loss, improved service reliability, and optimized overall resource use.

"We needed to modernize our technology for the 21st century. At one point, we tried to estimate our water losses, but our old metering system was so inaccurate that our calculations showed we were charging for more water than what we were producing at the plants," said Stewart Schafer, director of operations at the city of North Battleford. "Transitioning to AMI has allowed us to generate timely and accurate meter readings to serve our customers more efficiently."

Digital Solutions Pinpoint Water Loss

AMI may be the first step for many utilities. Building on the foundation of AMI, utilities can deploy software and tools that increase understanding of the system. One such tool is virtual district metering areas (DMAs), which divide a utility's water distribution system into smaller, manageable zones. These segments are monitored independently, allowing utilities to track water flow and pressure and to quickly isolate issues. Virtual DMAs enhance this approach further by using advanced analytics to provide a detailed view of the system's performance.

The city of Hot Springs, Arkansas has a 143-year-old system, which covers 923 miles of water mains in rocky terrain, making it difficult to detect leaks. The city had already updated its system to utilize AMI in 2011, which allowed the utility to monitor the system more efficiently. Hot Springs then extended its use of digital solutions by establishing virtual DMAs supported by an integrated software and analytics platform. Inline flow meters were deployed alongside AMI to create smaller, more manageable zones within the network.

"With virtual DMAs, there is a cost-effective return on investment," said Monty Ledbetter, director of utilities at the city of Hot Springs. "They pay for themselves by providing notifications that allow us to address leaks sooner and more efficiently."

This strategic approach enabled the utility to pinpoint high-water-loss areas with greater accuracy. The initiative began on a small scale with five virtual DMAs, targeting isolated systems with one-way feeds to demonstrate the system's capabilities. This enabled the city to respond swiftly to leaks and optimize water pressure across its network. The integration of DMAs with the AMI network has proven successful in improving the efficiency of aging infrastructure while minimizing costs. Hot Springs has reduced non-revenue water loss by nearly half with the goal of further improvements through additional DMAs.

Real Results: Cost Savings, Efficiency, And Improved Customer Service

The adoption of digital solutions by cities like North Battleford and Hot Springs has demonstrated clear benefits:

- Reduction in NRW — Both cities reduced their NRW levels, conserving water and lowering operational costs.
- Enhanced Operational Efficiency — Near-real-time data collection and analysis enabled proactive maintenance, reducing the need for manual inspections and emergency repairs.
- Improved Customer Service — Transparency through digital monitoring fosters trust between utilities and their customers, while alerts and usage data empower consumers to better manage their own water usage.

These outcomes highlight the transformative impact of digital technology in addressing aging infrastructure challenges.

Build For The Future: Resilient Water Systems Start Today

While the issue of aging water infrastructure may seem daunting, digital solutions offer scalable, practical ways to manage it. Improvements like AMI and DMAs help reduce water loss, enhance services, and upgrade operational resilience.

Utilities can take meaningful steps toward long-term sustainability and efficiency, setting a solid foundation for the future by investing in these technologies. As North Battleford and Hot Springs have shown, embracing innovation is key to overcoming the challenges of aging infrastructure while safeguarding essential water resources for generations to come. ■

About The Author

Trey Overman is the senior director of global water product management at Sensus, a Xylem brand. Overman has five years of experience in the water industry. He holds undergraduate degrees from Appalachian State University and an MBA from the University of North Carolina at Chapel Hill.

The Compounding Benefits Of Driving A Safety-Conscious Culture

On the collaborative path toward a safer workplace, employers and employees can discover a whole lot more.

By Tanya Moniz-Witten

Safety should be a priority for any responsible leader, but organizational mechanisms and procedures focused on ensuring workplace safety are often perceived as "necessary evils" — bothersome impediments to efficiency and progress.

What often gets overlooked are the complementary benefits that come with driving a safety-conscious culture. When a company prioritizes safety, it not only protects its employees physically but also fosters a strong sense of trust and wellbeing, leading to significantly higher employee engagement. People feel valued and empowered. That atmosphere presents enormous opportunity.

In my experience, prioritizing safety opens new channels for collaborative creativity — which is essential to efficiency and progress.

Safety Matters

Earlier this year, I took the helm of San Jose Water (SJW), one of the largest and most technologically sophisticated water systems in the country. While I have decades of utility experience in sizable, regulated, and complex organizations, I was new to SJW. I knew I needed to quickly immerse myself in the culture, get to know the people and processes, and clearly understand how the organization functioned day to day.

Within that context, prioritizing workplace safety was my first leadership initiative — and I considered it a no-brainer. My dad was an electric crew foreman who made safety a way of life. He taught me at a young age the importance of safety and following the rules, and he always said shortcuts had no place in the work environment. No employee should return home injured. Families should expect their loved ones to be in a safe environment. It's an issue that also directly affects the health of our business — ultimately, safety impacts the hundreds of thousands of customers who rely on SJW for quality drinking water.

> **If leaders aren't talking about safety on a daily basis, they can't expect staff to believe it's a real priority.**

Water companies provide an essential and highly regulated service. And SJW has been in business for nearly 160 years. So when it came to safety protocols, there was no need to start from scratch — we could just elevate the systems already in place. SJW already had successful and well-established safety guidelines and procedures, and my colleagues are smart and extremely capable — they know how to do their jobs.

But having good safety guidelines is not the same as being safety conscious. If leaders aren't talking about safety on a daily basis, they can't expect staff to believe it's a real priority. And without intentional direction, it is far too easy for expedient quick fixes to morph into unnecessarily risky standard practices.

Consider what happened to worklife all over the country during the pandemic. People had to figure out how to perform their jobs under extremely different and difficult circumstances, pretty much overnight. Most utilities admirably adapted and improvised to keep systems up and running. In the process, we were all required to tap some serious creativity, and we probably discovered some innovative ways of doing things that have since been integrated into daily operations. But in the aftermath, we may have also let some potentially detrimental workarounds become institutionalized, or just lost "muscle memory" for important safety habits. No good business should be perpetually operating in "emergency" mode.

According to Liberty Mutual's 2024 Safety Index, workplace injuries cost U.S. businesses over $1 billion a week, "with total injuries costing more than $58 billion every year." Considering those astounding numbers, it doesn't take exceptional insight to see that accidents and injuries happen in the workplace. Or that they incur huge costs and sap productivity. Or that actively trying to prevent them is sound policy that directly benefits everyone.

Safety As A Spark

It turns out that my initial call for renewed focus on, and adherence to, safety procedures and best practices was a great kickstart for frank and productive dialog. I've been in numerous department meetings, on ride-alongs, in the field, manning a call center, and more as I spend time with our employees. In nearly every interaction, I've found that safety is a topic that immediately generates real candor — helping me understand potential pain points and what our teams need to succeed.

This candor has pinpointed issues that are remedied fairly easily for improved efficiency and protocol adherence, such as more comfortable safety vests, work gloves, or safety goggles. It also provides insight into areas where I need to listen and learn, addresses what causes employees to feel overstretched, and identifies how we can better align goals and processes together. And it reveals inspiring safety-conscious ingenuity. For example, one of our teams devised a safer way to collect test samples from a remote creek feeding our mountain surface water supply. Using available materials, they simply secure a jug to the end of a pole: An essential task that once involved rushing water and a steep, slippery trek down a rugged slope is now routinely performed from the relative safety of a nearby platform. Another team at our newest water treatment plant manages 28 valves on each of the seven membrane trains used to filter water. They recently developed a safer way to clear faults from stuck air valves by using an air hose console instead of having to deploy ladders to reach the valves and air lines. Furthermore, since the console is located on the interior of the membrane train frame and not easily accessible for some operators, the team is also in the process of relocating it outside the frame for even easier — and safer — use.

> **I may not have been exposed to the depth of character in our crews or the nature of work in various departments without the subject of safety as a spark.**

These conversations have given me a great deal of confidence in my colleagues. I may not have been exposed to the depth of character in our crews or the nature of work in various departments without the subject of safety as a spark. When we set our minds to matters of mutual concern and impact, people are open to offering both genuine criticism and authentic praise — and invested in developing solutions and sharing best practices. That's the kind of stakeholder participation you get in a safety-conscious organization — enabling collaborative service, training, leadership, and career development opportunities.

In This Together

Our people are the reason we're able to serve high-quality water, reliably, to customers and local communities every day. Any decent leader understands that keeping your workforce safe creates the kind of organization people are proud and excited to be a part of. I may be new to the company, but I've been in utilities long enough to know that the compounding benefits of driving a safety-conscious culture — building trust, instilling confidence, and maintaining a spirit of collaboration — are critical to an effective operation. ■

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About The Author

Tanya Moniz-Witten is the president of San Jose Water. She is dedicated to delivering reliable, clean, high-quality water to over 1 million customers in the greater San Jose area. In her role, she is responsible for driving strategy and operational excellence and ensuring regulatory compliance for one of the most technologically advanced urban water systems in the country. With over 20 years of utility experience in large, complex organizations, she has a strong commitment to employee safety and engagement. Moniz-Witten attended the University of California, Santa Barbara, where she received a Bachelor of Environmental Studies. She also has a Master of Business Administration from the Wharton School, University of Pennsylvania.

Goodbye Forever After:

From Simulations Come Real Promise For PFAS Solutions

Chemical simulations powered by artificial intelligence — and a trifecta of companies — may be the beginning of the end for "forever chemicals."

By Arman Zaribafiyan

Once lauded as a miracle of modern science, per- and polyfluoroalkyl substances, commonly known as PFAS, are currently at the epicenter of an increasing number of serious global health concerns and pose an existential threat to Earth's food and water supplies, as well as many fragile ecosystems. In an ironic twist, the very attributes that make these virtually indestructible chemicals — boasting anti-degradation qualities that make consumer and industrial products more effective and durable — have instead created one of the most pressing, multigenerational environmental challenges that has ever existed.

In a bleak summation, these so-called "forever chemicals" have done, and are doing, their job too well — with severe ramifications.

PFAS were made to repel oil, grease, water, and heat, becoming prevalent in a variety of materials with broad applications from household paint to waterproof clothing, shampoo, and non-stick cookware. Without the capacity to decompose naturally, these roughly 15,000[1] substances accumulate in our bodies and the environment, contaminating both land and waterways while entering the food chain through crops and wild/farmed animals and fish. The concentrations of harmful, long-lasting formulations are also having a profound impact on human health, with increases in cancer, reproductive challenges, liver damage, and other conditions linked to exposure. A 2023 study by Emory University[2] revealed the presence of measurable levels of PFAS chemicals in the blood samples of newborns shortly after birth.

Today, more than 97%[3] of Americans have PFAS in their systems.

Chemical Reaction

With a seemingly perpetual cycle of detrimental effects, there is now a global consensus and sustained movement across the public and private sectors to dramatically reduce and ultimately eliminate PFAS on a scale that is commensurate with accelerating contamination rates worldwide. The dire consequences of these forever chemicals will continue to reverberate until bold measures are taken not only to stem the tide but also curb their usage from the outset through the production of less harmful and more eco-friendly chemicals.

While concerns[4] for the apparent risks associated with PFAS have been voiced for decades, in the U.S. alone, the harmful effects[5] gained attention in the 2000s with major manufacturers voluntarily phasing out certain compounds. U.S. EPA provisional health advisories began in 2009, with increasing state and federal regulations enacted in subsequent years. As of 2024, the EPA finalized a range of mandates, such as designating certain PFAS as hazardous substances and establishing national primary drinking water regulations targeting two older toxic chemical compounds — perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). As a future safeguard, the agency also established new limits on the combination of certain chemicals developed as PFAS alternatives.

The EU is also taking significant measures to quell the PFAS surge. In 2023[6], delegations from Denmark, Germany, the Netherlands, Norway, and Sweden proposed far-reaching restrictions on PFAS emissions, products, and manufacturing, which are continuing rollout. New mandates have also been placed upon member states of the European Environment Agency to ensure compliance with an updated Drinking Water Directive[7]. Chemicals are also regulated through the EU's REACH[8] framework, managed by the European Chemicals Agency (ECHA)[9].

Economic implications for PFAS are mind-boggling but vary widely, with overall cost projections[10] for mitigating these toxic chemicals reaching $17.5 trillion annually. The enormity of the PFAS issue is stretching the limits of our current technical and scientific capabilities. These are complex, multifaceted problems that require creative solutions to combat existing contamination, innovation to reverse and reduce the damage done, and the development of responsible alternative solutions to address market demand. Fully addressing the forever chemical challenge on a comprehensive level and macro scale has been previously thought both financially and technologically implausible.

From a public sector and socioeconomic standpoint, one would be hard pressed to find an area of greater need for human ingenuity, determination, and focus. With these stakes, the call to action has been resoundingly loud and clear, and there has been an uptick in global leadership and cross-industry collaboration that are demonstrating the transcendent value of joining forces to achieve common, ambitious goals against tremendous odds.

Boldly Going…

While scientists possessed the knowledge and creativity to conceptualize these chemicals in the late 1940s, they were unaware of their creations' extraordinary lifespan and the resounding ripple effect they would have. Yet, even if they understood these unintended consequences, the insights, technologies, and dynamic processes needed to break down PFAS were another eight decades away. Advancements within only the last two years in AI, computational chemistry, and scalable compute power — graphic processing units (GPUs) in the cloud — have upended the paradigm for the ultimate eradication of PFAS.

A showcase example is the remarkable work underway through a forward-thinking partnership between SandboxAQ, Amazon Web Services (AWS), and Accenture that is leveraging AI and advanced computing at scale to identify effective PFAS remediation pathways. This cloud-supported computational chemistry process facilitates macro-level, complex simulations of chemical reactions more quickly, economically, and effectively than that of traditional wet lab experiments.

This approach is showing encouraging signs with the ability to model chemical reactions with dramatically improved accuracy by breaking a complex simulation into smaller components and massively parallelizing calculations in the cloud. The power of parallelism allows far more exploration of scenarios than possible in the physical realm. SandboxAQ's cloud platform combined with the expansive cloud infrastructure of AWS, supported by Accenture's experience with PFAS chemistry simulation, serves as a powerful engine to conduct this granular analysis.

As evidence, these joint efforts have yielded a record-breaking computational chemistry simulation, powered by more than a million cores, allowing previously unseen levels of accuracy in analyzing the bond-breaking energy requirements for three of the most common PFAS molecules, which was previously considered impossible. The simulation's incomparable power and scale generate vast amounts of high-quality data that SandboxAQ's Large Quantitative Models (LQMs) can use to analyze PFAS and other chemicals with unprecedented detail — down to their most fundamental building blocks — revealing how these toxic chemicals can be broken down into harmless elements. The same technologies can also accelerate the development and testing of PFAS replacements, bringing timely, costly, cumbersome materials-science experimentation from the lab world into the digital world.

Advancements within only the last two years in AI, computational chemistry, and scalable compute power — graphic processing units (GPUs) in the cloud — have upended the paradigm for the ultimate eradication of PFAS.

In addition to helping reverse the damage done to the environment and our health, the fight against PFAS has created incredible possibilities for revolutionizing R&D, sustainable product development, and business growth across industries. Progress thus far suggests a potential new viable path for exciting possibilities, including faster drug discovery, food innovation, new battery materials, solar power, and beyond. ■

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About The Author

Arman Zaribafiyan leads product for AI simulation platforms at SandboxAQ. He joined the company following the acquisition of Good Chemistry, which he founded and served as CEO. Throughout his career, he has directed strategic partnerships and cutting-edge R&D collaborations with Fortune 100 companies in various roles as a technology and product leader. He earned his Ph.D. in electrical and computer engineering from UBC, where he received the prestigious Mitacs fellowship for his research on hybrid quantum computing.

8 Trends In Decentralized Wastewater Treatment: Shaping A Sustainable Future

Centralized wastewater treatment is sometimes not an option — and sometimes simply not the best choice, considering the expanding capabilities of decentralized systems.

By Ashley Donnelly and Dennis F. Hallahan

For onsite wastewater professionals looking ahead, there are several new up-and-coming trends in the industry, including a focus on environmentally sensitive areas, advancements in treatment technologies, and concerns over water scarcity. Decentralized wastewater treatment systems have always been vital to our infrastructure and the communities they serve, providing system designers with the flexibility to tailor a wastewater system to meet the needs of the community. Much of the public still views a decentralized wastewater treatment system as a single-family septic system. However, these systems are more complex. They can offer solutions for commercial and community systems, and at times, work in conjunction with centralized systems. At the intersection of technology, sustainability, and resilience, decentralized wastewater treatment systems — and their ability to meet the unique needs of the communities, challenging sites, and facilities they serve — are indispensable solutions for modern wastewater infrastructure. The following are some examples of the emerging trends and innovative design approaches that are shaping the future of decentralized wastewater treatment systems.

Addressing Nutrients

Nitrogen management, eutrophication, and nutrient removal are critical challenges due to increasingly stringent discharge limits. Elevated nitrogen levels contribute to eutrophication in waterbodies, posing serious threats to ecosystems. Decentralized wastewater treatment systems offer flexible solutions, capable of integrating advanced technologies to enhance nitrogen reduction and nutrient removal. These systems can be designed to meet stringent regulatory requirements.

PFAS – The Forever Chemicals

The emergence of per- and polyfluoroalkyl substances (PFAS), often referred to as "forever chemicals," presents a daunting challenge. Decentralized systems will have to be modified to incorporate treatment technologies such as granular activated carbon (GAC), ion exchange resins, and advanced oxidation processes to reduce PFAS contamination. This will allow localized treatment, reducing the need for costly, large-scale interventions. As regulations develop for PFAS management, decentralized systems will meet the challenge.

Advanced Treatment

Advanced treatment systems are revolutionizing decentralized wastewater treatment systems for challenging sites such as small lots, areas with tight soils, high water tables, and fast-moving soils. Specifying advanced treatment systems offers an innovative solution by using compact, efficient designs. Systems such as suspended growth aerobic treatment units and fixed film textile filters provide higher levels of treatment in limited spaces, improving effluent quality while minimizing the footprint. These systems can also allow sites that have high water tables and fast-moving soils to be buildable by ensuring reliable performance even in difficult conditions. For engineers, these technologies provide the tools to design systems that meet stringent environmental standards, while addressing the unique challenges of complex site conditions.

Scalability And Customization For Community Systems

Decentralized systems are no longer one-size-fits-all solutions. Modular designs and scalable technologies allow systems to grow with community needs. Pre-engineered, plug-and-play units allow ease of installation and future expansion. Communities can customize treatment configurations to address specific challenges, such as nutrient removal, water reuse, and seasonal or intermittent flows, making these systems adaptable and future-ready — all while recharging local aquifers.

A modular treatment plant shipped to site and specified to meet permit limits. Plumbing is attached and electrical service provided to begin treating effluent.

Creative Solutions For Challenging Sites

From rocky terrain to steep slopes, difficult sites require innovative engineering and products. Combined treatment and dispersal (CTD) systems allow treatment and dispersal within the same footprint. These systems can meet NSF40 levels of treatment with no power inputs, providing a sustainable solution.

Septic Tank Effluent Pumping (STEP), Septic Tank Effluent Gravity (STEG), And Liquid-Only Sewer Systems

These systems use septic tanks to provide primary treatment which removes solids. Then the treated effluent (liquid only) is pumped to a decentralized community system or centralized facility. These systems offer flexibility, cost efficiency, and improved water quality management, making them ideal choices for communities seeking decentralized alternatives or hybrid systems.

Aquifer Recharge

Water scarcity is driving the adoption of decentralized systems to address water reuse and aquifer recharge. These systems treat wastewater to high standards, enabling their use for irrigation, industrial processes, or potable applications. Managed aquifer recharge (MAR) is another promising approach, whereby treated water is stored in underground aquifers for future use. Advanced filtration and disinfection technologies, such as UV and reverse osmosis, are integral to these applications, ensuring safety and reliability.

Large subsurface dispersal systems are practical solutions for communities. These systems provide additional benefits of polishing and aquifer recharge..

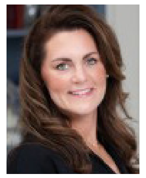
Operation And Maintenance

The success of decentralized systems hinges on effective operation and maintenance (O&M). Advances in contractor equipment and automation are making O&M more accessible and less labor-intensive. Mobile apps and remote monitoring provide operators with real-time insights, enabling proactive management. Additionally, the development of compact, user-friendly equipment reduces the need for specialized training, empowering local contractors to manage systems effectively.

The Road Ahead

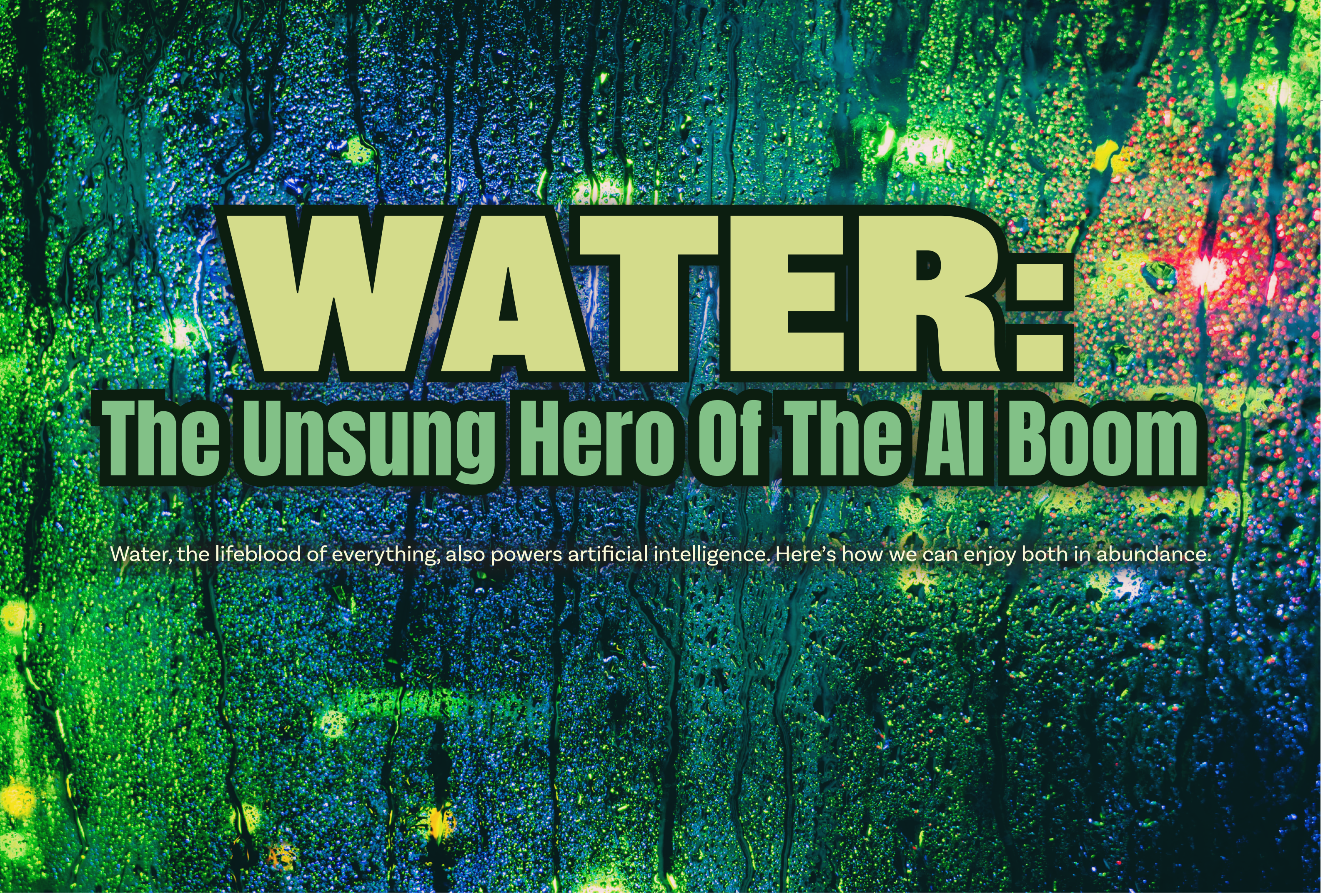
Decentralized wastewater treatment systems are at the forefront of innovation, providing adaptable, sustainable, and scalable solutions for diverse communities and industries. From advanced nutrient removal to PFAS management and water reuse, these systems are redefining wastewater management. To fully unlock their potential, continued investment in research, regulation development, and public education are essential. By embracing these trends, decentralized systems can play pivotal roles in achieving a sustainable water future, addressing environmental challenges while supporting community resilience and growth. ■

About The Authors



As Technical Training and Sales Development Manager at Infiltrator Water Technologies (IWT), Ashley Donnelly manages the inside sales team and is responsible for maintaining and building customer relationships, including assisting engineers, contractors, and regulators with technical and design information, training, installation, and O&M. She serves on several industry committees, including TOWA, NOWRA Emerging Professionals, and NEWEA Small Communities Committee.

Dennis F. Hallahan, PE, is the technical director of Infiltrator Water Technologies. Hallahan has over 30 years of experience with the design and construction of decentralized wastewater treatment systems. He has written numerous articles for onsite industry magazines and regularly gives presentations nationally on the science and fundamentals of onsite wastewater treatment systems. Hallahan also serves on various national industry association wastewater committees.



WATER: The Unsung Hero Of The AI Boom

Water, the lifeblood of everything, also powers artificial intelligence. Here's how we can enjoy both in abundance.

By Lihy Teuerstein

Artificial intelligence (AI) is rapidly transforming our lives, with its capabilities expanding at an unprecedented pace. From virtual assistants to machine learning algorithms, which power everything from medical diagnostics to financial forecasting, AI is becoming an essential part of our lives. However, this technological boom comes with a significant environmental cost, particularly related to water consumption. Data centers that power AI operations consume millions of liters of water to cool servers, with each operation on AI platforms having a tangible, yet often overlooked, impact on our water resources.

To put it into perspective, asking between 20 to 50 questions on AI systems like ChatGPT can use half a liter of water. According to research from the University of California Riverside, published in *Nature*, if each of the 100 million weekly users of virtual assistants submitted just one prompt, it could result in water consumption of up to 0.189 million gallons per day (MGD). In 2022 alone, tech giants like Google, Microsoft, and Meta consumed over 2 billion cubic meters of water for server cooling and electricity use, more than double Denmark's annual consumption. Virginia, a major data center hub, saw its water usage grow by nearly two-thirds between 2019 and 2023, rising from 1.13 billion gallons to 1.85 billion gallons. These numbers underscore the growing demand for water in AI infrastructure, and with AI innovation showing no signs of slowing, the question becomes: "How can we ensure lasting access to water in a world that is increasingly dependent on data?"

> **…with AI innovation showing no signs of slowing, the question becomes: "How can we ensure lasting access to water in a world that is increasingly dependent on data?"**

Strategies For Replenishing Water Supplies

To reduce water consumption tied to AI and data centers, companies can employ various water replenishment strategies:

- **Reuse wastewater:** Companies can treat their process effluent and reuse it in their systems, thus reducing the strain on local water resources. This can help reduce freshwater utilization and improve the overall sustainability of operations.
- **Use treated municipal water:** Companies can invest in treating local municipal water for reuse in their operations as feedwater. By using treated water from nearby municipalities, businesses can minimize their impact on freshwater resources while also contributing to local water management efforts.
- **New sources of water:** Another alternative is investing in the creation of new sources of water, such as seawater or brackish water desalination plants, ensuring a sustainable long-term supply of water without impacting freshwater resources. Desalination can provide a critical solution for data centers located near coastal areas where freshwater resources are limited or in areas where there is brackish groundwater.
- **Water offset/credits:** In the event that the aforementioned alternatives are not feasible or available, another option is to offset water usage by investing in regional or other water conservation, reuse, or desalination projects. By contributing to other projects and the creation of new water thus acquiring water benefits or credits, companies can compensate for their own consumption and help ensure balanced water supplies in their regions or states or even on a global level.

Additionally, regions looking to attract data centers or industrial operations for job creation and economic growth can invest in water infrastructure, such as centralized wastewater treatment and desalination plants. By creating new, sustainable water sources, these areas can position themselves as attractive locations for companies seeking reliable water supplies for their operations, encouraging them to set up facilities and contribute to their local economies.

Tech Giants Leading The Way

Several corporations are already embracing a water-positive approach in response to growing concerns over water usage. For example, PepsiCo's "Positive Water Impact" initiative aims to replenish more water than it consumes in high-risk areas by 2030. The company is working on watershed protection, improving water use efficiency in its operations, and providing safe water access in water-stressed regions. Also, Google has committed to replenishing 120% of the water it uses by 2030, primarily through investments in water stewardship, watershed restoration, and infrastructure improvements in water-scarce areas. The tech giant is actively working on projects that enhance community watershed health and support sustainable water practices. Similarly, Coca-Cola has already achieved its goal of replenishing 100% of the water used in its beverages by improving water efficiency, treating wastewater from its plants, and investing in community water projects.

These tech giants are setting a precedent for how AI-driven businesses and large corporations can minimize their environmental footprints. By taking proactive measures to mitigate their water usage, these companies are contributing to global sustainability efforts and setting an example for others to follow. But the question remains: Should we entrust corporations to lead the way, or should governments play a more active role in safeguarding our water resources?

> **By coupling regulations with financial incentives, governments can ensure that corporate efforts align with broader environmental sustainability goals, driving lasting change that benefits both businesses and communities.**

Why Government Intervention Is Key To Sustainable Water Management

While corporations are making strides toward reducing their water footprints, we need to see public policy get involved. Corporations have a duty to their shareholders to ensure profitability, which means that environmental initiatives and long-term sustainability goals, including becoming water-positive, would benefit from being enhanced by the public sector. Though efforts like water stewardship and water credits are important steps in the right direction, they often fall short of addressing the scale of the problem.

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Securing Our Water Future: A Collective Responsibility

AI, through its data centers, changes the traditional understanding of industry and industrial use. As AI continues to expand its reach, the water demands of the data centers powering this technology will only grow. While some companies are leading the charge in becoming water-positive, their efforts alone will not be enough to secure the future of our water resources. This should be a collaborative effort by the private and public sectors, through global initiatives and local regulations, to ensure that water remains available for future generations. ■

About The Author

Lihy Teuerstein, CEO of IDE Water Assets, has been with IDE since 2011 and has been leading the IDE Water Assets business as of 2018. Her previous roles included establishing and heading the Commercial Department of IDE and General Counsel for the IDE group. Teuerstein has a combined LL.B in Law and Far East Studies from the Hebrew University in Jerusalem and is a member of the Israel Bar Association. She also has an M.A. in Sociology and Anthropology from Tel Aviv University.

HOW CAPTURING RAIN CAN CONTRIBUTE TO ENVIRONMENTAL SAFETY

There are many ways to capture stormwater – whether as a homeowner, business, or municipality – and even more benefits.

By Ainsley Lawrence

Warmer air holds more water. That means that, across the globe, climate scientists are predicting increased, if irregular, precipitation rates[1]. Making the most of these sudden downpours is key, as climate change will also lead to more droughts and heat waves.

Eco-friendly plumbing technology can enhance efforts to combat climate change and minimize damage due to water runoff. Effective water management systems can mitigate the risk of floods in some areas by strengthening stormwater systems and absorbing sudden downpours.

Effective rainwater harvesting systems can also prevent runoff contamination and protect local ecosystems. This benefit is much needed, as high rainfall rates can lead to pollution in the local area. By harvesting water effectively, communities can increase their resilience and begin to harness the power of rainwater runoff.

Rainwater As A Resource

Treating rainwater as a precious resource is central to efforts to reduce water waste, increase resilience, and improve environmental safety in neighborhoods. Supporting this shift in mindset is critical, as community stakeholders will need to be convinced that rainwater harvesting is worth investing in *before* a flash flood or drought strikes. As such, rainwater harvesting advocates must highlight the benefits of harvesting[2], which include:

- Improved stormwater management;
- Reduced risk of contamination near industrial and agriculture sites;

Treating rainwater as a precious resource is central to efforts to reduce water waste, increase resilience, and improve environmental safety in neighborhoods.

- Reduced water bills; and
- Improved water management during droughts and dry spells.

Countries not receiving high precipitation have already invested in rainwater harvesting and are leading the charge in treating rainwater as a precious resource. In the UAE, researchers from Khalifa University have recently debuted an atmospheric water generator[3] capable of pulling 1,000 liters per day. This atmospheric water technology utilizes solar panels to harvest water from the air and improve the resilience of communities that regularly face droughts.

In the U.S., the use of semi-porous asphalt is rare but offers a window into the future of rainwater management. Soaking up the rain[4] reduces total runoff and filters some pollutants out of rainwater. This reduction can also minimize the need for salting during cold snaps and reduce costs for municipalities that would otherwise need to install drainage systems. Permeable pavements are relatively easy to install, too, and simply require the installation of pervious concrete, porous asphalt, or permeable interlocking pavers.

Home Modifications

Homeowners can aid efforts to improve environmental safety and reduce their water waste by investing in eco-friendly plumbing solutions[5] that harvest rainwater. For example, homeowners who have budgeted for major upgrades to their plumbing can install green drainage systems that work in tandem with their home's wastewater. These solutions can be effectively paired with smart systems, which can help homeowners track their water use and make data-driven decisions to enhance the overall efficiency of their rainwater harvesting efforts. This efficiency increase can help areas prone to drought.

Green drainage systems are designed to harvest and treat rainwater onsite for reuse in non-potable functions. This graywater is suitable for flushing toilets, irrigating and watering gardens, and cleaning laundry.

Implementing these solutions can reduce the strain on municipal water supplies and help conserve freshwater resources. This approach can also minimize the energy used to treat and purify water, as leveraging graywater safely can reduce the volume of water plants are responsible for treating.

Homeowners can further protect themselves and the environment by installing robust waterproofing. Properly waterproofing homes can minimize the risk of pollutants entering waterways and will enhance efforts to direct floodwaters to stormwater systems. They can also make houses more resistant to harsh weather.

Those who are concerned about the risk of flooding can aid efforts to build more resilient communities by learning how to waterproof their property. These efforts include common-sense solutions such as caulking, weatherstripping on doors, waterproof painting, and regular gutter maintenance. By investing in home fortifications, communities can protect the integrity of rainwater harvesting systems and improve the effectiveness of flood-resistance plans.

Fortifying Against Extreme Weather

An effective approach to rainwater harvesting can make communities more resilient. This is key, as global warming means that extreme weather events such as storms, droughts, and high rainfall are more likely to occur. Homeowners and municipalities can protect themselves against damage by proactively investing in rainwater harvesting techniques and mitigating the risk of flooding due to runoff.

Municipalities like Orange County, Florida, have already begun to pivot toward proactive stormwater management[6] and harvesting by installing automated pumps that direct stormwater flow away from valuable structures. This moved water from storm drains that are prone to flooding to canals ensures the community can survive the many strong storms common in the area.

Governmental organizations can also utilize parking lots as temporary wetlands during periods of heavy rainfall. These wetland lots are highly effective, as water tends to pool in open, concreted areas like parking lots already. By installing semi-permeable pavements and stormwater treatment solutions, municipalities can effectively filter the heavy rainfall and ensure that the rainfall entering waterways is clean.

Installing a few water butts will not prevent a flood or reduce the risk of storm-caused water damage. However, a community-oriented approach to rainwater management can enhance efforts to mitigate flood damage in the future. A community-first approach can improve buy-in and elevate the overall effectiveness of plans to naturally reduce runoff pollutants and create more resilient towns and cities.

A community-first approach has already been championed effectively in Boscastle, UK[7]. Following major flooding in 2004, community organizers partnered with governmental organizations to redesign the town with flood management and community preservation as a priority. This has led to modifications such as the widening of rivers, the installation of semi-permeable pavements, and improved use of greenspaces to soak up heavy rainfall.

Conclusion

Rainwater harvesting can reduce surface runoff and minimize the strain on water treatment plants. Harvesting graywater can save homeowners money, too, by reducing water bills. However, for rainwater harvesting systems to be effective, local governments must invest in innovative solutions like semi-permeable surfaces and should partner with local water conservation groups that are dedicated to the challenge of addressing pollutants in rainwater runoff. ■

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