October–December 2022 | vol.32 no.4

ADVANCES in WATER RESEARCH

A Publication of The Water Research Foundation

Forest Management

also in this issue

Climate Change

Utility Research

Potable Reuse

THE Water Research FOUNDATION®

VIEWPOINT

Natural Assets

Michael Markus

Peter Grevatt

At The Water Research Foundation (WRF), the interconnections between water and other natural resources are central to all that we do. These relationships are apparent as wildfires have significant impacts on water quality, stormwater carries pollutants from the land into the water, resources recovered from wastewater enrich the soil, water sector efforts to leverage nature-based solutions can yield climate benefits, and more.

Because of these interconnections, it is imperative that the water sector see natural resources as assets, and take not just a One Water approach, but a holistic approach accounting for the whole environment. The sector must increasingly consider the impacts that water resource management has on these natural assets and, conversely, how natural assets can be leveraged to protect and improve water resources. Recognizing this, many water utilities have established watershed management programs, developed programs to leverage and enhance natural assets, or have collaborated with community partners outside the sector to enhance natural assets. These programs facilitate partnerships between water utilities and local land managers, landowners, municipal planners, and other key watershed stakeholders. In this issue of *Advances in Water Research*, the article "Managing Forests to Protect Drinking Water Quality" presents a case study of a water utility that takes things a step further into owning and managing land itself. This utility, Central Arkansas Water, manages its natural assets based on the understanding that healthy forests lead to healthy water, and the utility has developed a unique forestry program run primarily by its own staff.

As WRF considers how we can contribute to the sustainability of natural assets, we have decided to go paperless with *Advances in Water Research*. For those subscribers who receive the printed copy of the magazine, this will be the last issue to arrive in your mailbox. The digital edition can be accessed any time at www.advancesinwaterresearch.org. To be notified when each new digital issue is published, sign up for our Announcements e-newsletter at www.waterrf.org/enews.

Effective management of the condition and performance of natural assets can greatly enhance a water utility's ability to deliver cost-effective and reliable water services to its community. Whether they have staff dedicated to natural asset management or rely primarily on partners to support their goals related to natural assets, WRF subscribers have access to a plethora of research to advance their natural asset management efforts. WRF natural asset research covers topics such as asset management planning, integrated planning, partnerships, green infrastructure, stream restoration, wildfires, and climate change. WRF will stay on the forefront of research on the interactions between water and other natural assets and continue to deliver effective tools for water utilities to support the growing needs of the communities they serve!

Michael R. Markus, PE
Chair, Board of Directors

Peter Grevatt, PhD
Chief Executive Officer

CONTENTS

VOL. 32 NO. 4

THE Water Research FOUNDATION®

The Water Research Foundation (WRF) is the leading research organization advancing the science of all water to meet the evolving needs of its subscribers and the water sector. WRF is a nonprofit, educational organization that funds, manages, and publishes research on the technology, operation, and management of drinking water, wastewater, reuse, and stormwater systems—all in pursuit of ensuring water quality and improving water services to the public.

ADVANCES in WATER RESEARCH

Editor: Alyse Greenberg
P 303.347.6116 • editor@waterrf.org
Copyeditors: Victoria Bloom, Julia Dinmore, and Angelina Dinsmore
Art director: Victoria Adams-Kotsch

Customer service
P 888.844.5082 or 303.347.6100
info@waterrf.org

Advances in Water Research (ISSN 1055-9140) is published quarterly for $100 a year in North America by The Water Research Foundation, 6666 W. Quincy Ave., Denver, CO 80235
Telephone: 303.347.6100
Periodicals postage paid at Denver, CO.

Postmaster: Send address changes to *Advances in Water Research*, The Water Research Foundation, 6666 W. Quincy Ave., Denver, CO 80235-3098

Advances in Water Research **Statement of Ownership, Management, and Circulation**
Owned by The Water Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235
Publisher: The Water Research Foundation; **Editor:** Alyse Greenberg; **Bondholders:** None; **Circulation:** Average number of copies distributed per month for 12-month period (October 2021-September 2022) - 8,232 as follows: paid and/or requested mail subscribers – 8,207; free distribution – 25. This statement has been filed on PS form 3526 with the USPS on 09/08/22 and is published herein in accord with USPS regulation 39 USC 3685.

BY THE NUMBERS

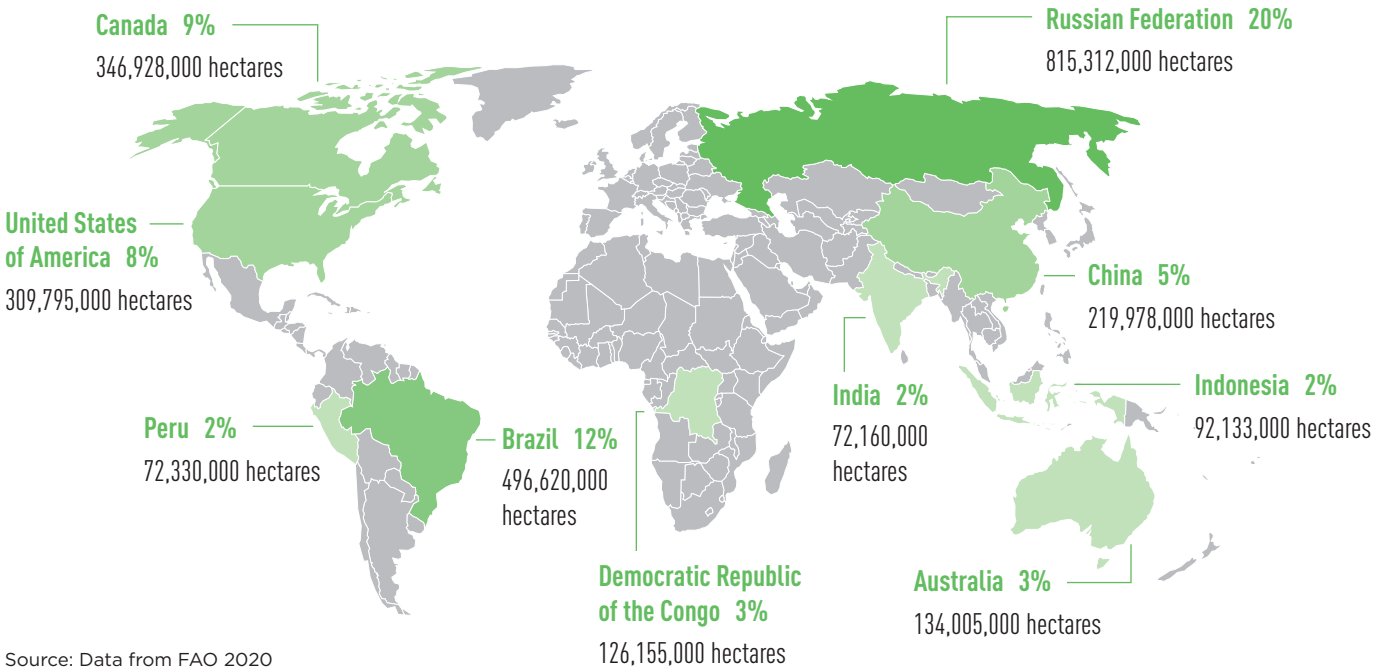
This edition of By the Numbers provides statistics on natural assets, including forests. For more information on forests, see the article Managing Forests to Protect Drinking Water Quality.

31
Percent of global land area covered by forest (FAO and UNEP 2020)

4.06 billion hectares
Total global forest area (FAO and UNEP 2020)

66
Percent of the world's forests located in just 10 countries (FAO and UNEP 2020)

Percentage of World Forest Area



Source: Data from FAO 2020

References

FAO (Food and Agriculture Organization of the United Nations). 2020. *Global Forest Resources Assessment 2020 – Main Report*. Rome: FAO. https://doi.org/10.4060/ca9825en.

FAO and UNEP (Food and Agriculture Organization of the United Nations and United Nations Environment Program). 2020. *The State of the World's Forests 2020: Forests, Biodiversity and People*. Rome: FAO and UNEP. https://doi.org/10.4060/ca8642en.

RAUCHER, R., K. Vause, M. Lorie, T. Helgeson, and J. Cassin. 2020. *Asset Management Framework for Forested and Natural Assets*. Project 4727. Denver, CO: The Water Research Foundation.

Forests and other natural assets, such as wetlands and streams, provide key services and benefits to water utilities and the communities they serve.

Potential Natural Asset Contributions to Utility Goals

Utility Goals and Beneficial Services	Forest	Wetland	Grassland	Rivers, Lakes	Glaciers, Snowpack
Climate Goals					
Carbon sequestration, climate mitigation	♦♦♦♦♦	♦♦♦	♦♦♦♦♦	♦♦	
Climate resilience, adaptation	♦♦♦♦	♦♦♦♦	♦♦♦	♦♦♦♦	♦♦♦♦
Environmental Goals					
Habitat protection, biodiversity	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦
Protection for species of special concern	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦♦	♦♦♦
Water quality (non-regulatory)	♦♦♦♦♦	♦♦♦♦♦	♦♦♦♦		
Community and Social Responsibility Goals					
Cultural and spiritual services (e.g., locations or animals with cultural significance)	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
Wild harvest foods (e.g., salmon, shellfish)	♦♦♦♦	♦♦♦	♦♦	♦♦♦♦	
Recreational services	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
Aesthetic services (iconic landscapes)	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
Improved health outcomes	♦♦♦♦	♦♦♦	♦♦♦	♦♦♦	

Source: Raucher et al. 2020

Number of diamonds reflects relative potential benefit

Utilities put significant effort into maintaining their built assets. Natural assets can provide many benefits that will help a utility meet its goals; therefore, it is important for a utility to maintain those assets as well.

Examples of Maintenance Activities for Natural Assets

Natural Asset Type	Asset Stressor or Hazard	Maintenance Activities	Purpose
Forested watershed	Wildfire	• Thinning mature trees and debris on forest floor • Prescribed burns	Minimizes the likelihood of large, intense fires that can result in sediment and debris flows into source waters and reservoirs
	Erosion on trails	• Install and maintain water bars, diversions, and breaks to slow runoff on trails	Minimizes sedimentation to reservoirs and reduce suspended solids in source waters
	Cattle grazing	• Implement best management practices with livestock owners who graze cattle in the forest	Minimizes nutrient loads into streams, which reduces the likelihood of algal blooms
Restored stream	Large storms	• Maintain healthy vegetation along streambanks and riparian zones	Stabilizes the streambank, which minimizes erosion
Aquifer recharge areas under conservation easements	Impervious surface	• Monitor and inspect conserved lands to track and enforce restrictions on the construction of impervious surfaces	Maintains adequate land area for target recharge rates

Source: Raucher et al. 2020

Q&A

Interview with Jack Kiefer

Understanding Water Demand

In June, The Water Research Foundation (WRF) presented Jack Kiefer, Senior Associate at Hazen and Sawyer, with the Dr. Pankaj Parekh Research Innovation Award. Named for Dr. Parekh, who dedicated his life to ensuring safe drinking water and protecting public health, this award honors researchers who have made significant contributions to advancing the science of water through WRF-sponsored research.

Dr. Kiefer has dedicated his career to exploring factors that impact water use and water demand, including climate change, economic recessions, and specific customer categories. He has served as a key researcher on ten WRF research projects and as a Project Advisory Committee member for four projects.

How did you get started in the water sector? I graduated from Southern Illinois University (SIU) with my Master's in Monetary Theory and Policy. I was looking for a job in that field and considering a PhD if I couldn't find a job. There was a consulting firm in southern Illinois, Planning & Management Consultants, that was looking for someone with a firm grasp of econometrics to model the demand for water, and I landed the job. Shortly after starting that position, I found myself applying what I learned in the academic environment to water resources—not only econometrics, but other concepts such as valuing public services; monetary and non-monetary benefits and costs of supply development; and measuring damages from drought.

Since I concentrated on monetary theory in graduate school, I envisioned that I would work for the Federal Reserve System. I had a series of interviews with the Federal Reserve System, and they were surprised and impressed by the economics I was applying in the real world. They offered me a couple of jobs, but one of the interviewers suggested I may be better off by staying in my current role. The rest is history. I stuck with my job, and ended up going back to SIU and getting my PhD in geography, concentrating on water resources. I kept learning, gained clients, and ultimately focused on a career in the water sector.

How long have you been with Hazen? About 15 years. I was with Planning & Management Consultants for about 13 years when the firm was acquired. It was an employee-owned firm, and so we bought ourselves from the owners and sold ourselves to CDM Smith. After a few more years, I had the opportunity to join Hazen.

What does working in the water sector mean to you? It's fulfilling to know that there is a segment of the world out there that takes the provision and management of water seriously. The vast majority of people do not have to be concerned with obtaining reliable, high-quality water supplies that have adequate pressure. The benefits generated by the water sector are enormous relative to the costs, despite the array of pressures that exist from natural and man-made sources. I'm glad to help in any way I can.

What does winning the Dr. Pankaj Parekh Research Innovation Award mean to you? It's an honor and a product of hard work and collaboration with many people. There are points in life when you expect something and you don't get it, and then other points when you're surprised with something great that you did not expect. The Research Innovation Award is one of those delightful surprises.

When did you first hear about The Water Research Foundation? In the late 1990s, my colleagues and I at Planning & Management Consultants were doing a lot of work on water demand forecasting and water conservation program evaluation. With our friends from Aquacraft, we

developed a one-of-a-kind research proposal that we took to WRF focusing on residential and commercial end uses of water. That was my entry point to WRF. After that, I was periodically engaged in submitting proposals to WRF. There were certainly some losses along the way, but the focus area on water demand forecasting was a great fit for my skills and experience. It also led to some momentum and synergies for me professionally.

How have you benefited from your involvement with WRF? Working with WRF has benefited me greatly, especially in terms of the depth and breadth of knowledge that I have gained working with utilities across the country. Utilities often face unique circumstances related to data, staff experience, or how to address different planning objectives and risks. This often requires innovation. My involvement in WRF projects has led to a great appreciation of the work of utility practitioners and managers and the risks they confront in delivering clean and reliable water. It has also helped me establish some long-term relationships and provided opportunities to present our work at WRF symposia and other conferences.

What are the most impactful WRF projects that you've worked on? All of the projects I worked on have been impactful in some way. The end uses of water studies received the most interest. The project on climate change impacts on the demand for water, *Changes in Water Use Under Regional Climate Change Scenarios* (4263), was well overdue. *Water Demand Forecasting in Uncertain Times: Isolating the Effects of the Great Recession* (4458) also highlighted how an acute event can change existing plans—that project served as a refresher on the many economic aspects that can influence the demand for water. *Uncertainty in Long-Term Water Demand Forecasting* (4558) has contributed to more dialogue about addressing, portraying, and communicating risks in decision making. The most recent research, *Long Term Water Demand Forecasting Practices for Water Resources and Infrastructure Planning* (4667), represents somewhat of a capstone project. The research products provide lessons learned and recommendations by experts and practitioners in this topic area.

How would you describe the current state of water research? The water sector is coming to terms with the amount of information that can be gathered, processed, and analyzed to generate solutions. Turning data into actionable information or knowledge is critical. Artificial intelligence and machine learning are becoming invaluable for sifting through the data and discovering patterns. It takes time to catch up with data processing power and to understand and build knowledge around the relationships we are modeling. Understanding and promulgating how human and physical systems are interconnected is paramount to decision making.

What do you want to see next for WRF's research agenda? I would like to see WRF further promote and maintain a reasonable degree of social science research in its portfolio. There is always more to learn about behaviors and values surrounding the use of water, particularly what we collectively expect from water providers. More research is needed on how to deal with risks, and how managing risks affects outlays and what consumers pay. In the provision of public services, water providers often find themselves at the forefront of equity, affordability, and social justice issues. We may need to rethink and research new ways to build these concerns into planning objectives instead of treating them as constraints.

We do sometimes hear that WRF should do more social science research, but we also have some utilities say that's not the role they see for WRF. I think the water sector is largely driven by engineers. So, most of the interest is in engineering, operating, and building systems that deliver high-quality water. That's why I am interested in demand. The demand side is the human side, the customer side, and that's where the benefits of all this hard work are generated. I've always been interested in human interactions with physical environments. It mixes economics, geography, and even political science. Sometimes the focus of WRF research is technically oriented towards engineers because they are a large portion of your audience. However, there are also utility directors, managers, and executives who would benefit from better understanding who their customers are and what their customers think they're paying for. That is really the human dimension, and we need to continue to think in terms of the mission or objective of the water utility.

Managing Forests to Protect Drinking Water Quality

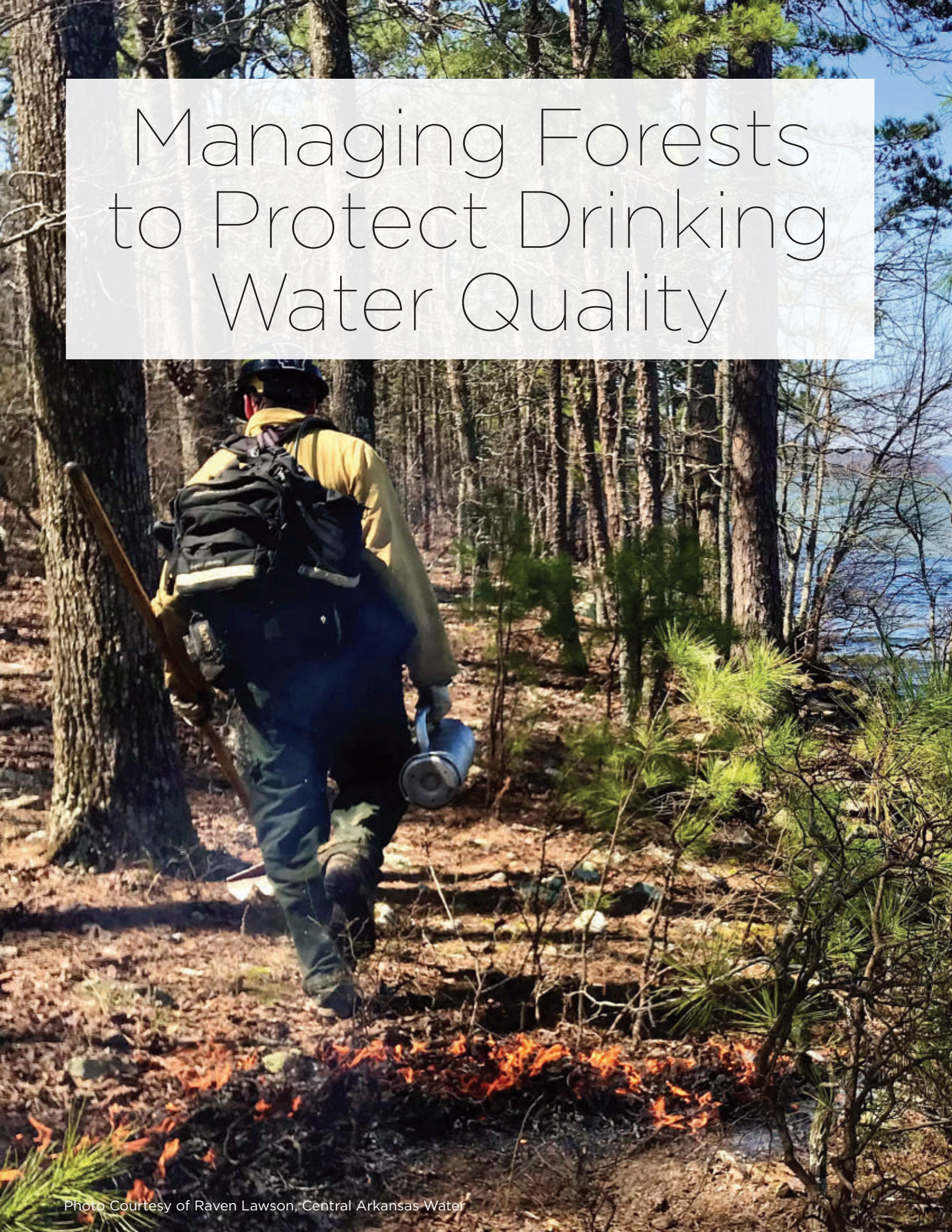


Photo Courtesy of Raven Lawson, Central Arkansas Water

Prescribed burns and other forest management strategies can play key roles in source water protection.

By Raven L. Lawson, Central Arkansas Water

A crew gathers under a heavy forest canopy mid-morning. Dressed in bright yellow flame-resistant shirts and hardhats, they wield a suite of gear ranging from heavily outfitted utility terrain vehicles hauling tanks of water to an assortment of rakes, hand tools, and metal cannisters that drip fire onto the ground. These workers are meeting up for their prescribed fire safety briefing before the day's events get underway. A recognizable scene for some—especially for folks in the southeastern part of the United States—you might be surprised to learn that this crew is employed by a local drinking water utility: Central Arkansas Water (CAW). For CAW's Watershed Protection Team, this is just another day at the office, and a growing part of their daily job duties (Figure 1).

Central Arkansas Water is Arkansas' largest water utility, serving safe, reliable, high-quality drinking water to more than 500,000 Arkansans each day. An elaborate network of more than 2,600 miles of pipes and two treatment plants distributes water to community members day-in and day-out. This water's journey starts at the utility's source water reservoirs, Lakes Maumelle and Winona, both nestled in the Ouachita Mountains west of Little Rock.

CAW created its Watershed Protection Program (Program) following recommendations from the 2007 *Lake Maumelle Watershed Management Plan* (Plan; Tetra Tech 2007). The Plan provides guidance on how to implement measures throughout the watershed's 88,000 acres to protect the 8,900-acre Lake Maumelle, which supplies two-thirds of

Source: Courtesy of Ben Thesing, Central Arkansas Water

Figure 1. Crew meeting before a cooperative burn with The Nature Conservancy of Arkansas

the utility's daily water demand. The Plan proposes a series of strategies, such as managing the impacts of new development, promoting household best management practices, and maintaining good land management practices, including using prescribed fire and ecological timber thinning as management tools for improving forest health.

For the areas around Lakes Maumelle and Winona, CAW set forest management goals to improve the health of the watersheds and maintain the quality of drinking water in central Arkansas. When forests are healthy, watersheds are healthy, and each of these watersheds boasts more than 90% forest cover—a figure that drives much of the Program's activities. While Lake Winona's watershed is primarily within the Ouachita National Forest, Lake Maumelle's lies just a few miles from Arkansas' largest metropolitan area and remains largely unprotected from forest conversion.

Land Acquisitions

CAW'S LAND ACQUISITION program stands at the forefront of our watershed protection strategy. Urban sprawl and rural development pose some of the largest threats to southeastern forests, which are becoming valuable assets to those longing to move away from the threats of wildfires and the diminishing water availability of the western United States. Without large, intact, and well-managed forests, however, the southeast could face similar issues. Our land acquisition goals are to keep as much of these lands as possible in forest cover, paying particular attention to riparian areas and tributary corridors across contiguous landscapes in our watersheds.

Since the adoption of the Plan, CAW has purchased more than 5,000 acres of land, and owns and manages a total of 24,000 acres of land and water sources. How does a public water utility buy land? In 2008, rate payers asked CAW to implement a watershed protection fee to carry out the Plan's land purchasing goals (1,500 acres at the time of adoption). This fee was added as a transparent line item to customers' bills in May of 2009 as a monthly charge of $0.45 per meter, which went unchanged for more than a decade. Today the fund nets just over $2.2 million per year through a $0.90 per meter per month charge on consumer bills dedicated to land acquisitions and watershed land conservation. Having this fund has allowed CAW to be innovative in extending land holdings and placing privately owned lands under permanent protection through conservation easements. CAW has been able to successfully leverage these funds against grants and buy and flip properties with conservation easements (a strategy we term "buy-protect-sell").

In 2020, CAW issued the world's first-ever Green Certified Bond to purchase forestlands as part of water infrastructure (CAW 2021). CAW views forests as a critical part of our utility's infrastructure and a key factor in the Program's success. As with any traditional infrastructure, these assets need regular maintenance and monitoring. Central Arkansas Water believes that a managed forest is a healthy forest, and healthy forests foster healthy water—a true forests to faucets approach to providing water to our communities.

Prescribed Fire as a Management Tool

PRESCRIBED FIRE ENHANCES, maintains, and restores natural forest communities, while simultaneously improving public safety and increasing recreational opportunities. In the last decade, Arkansas has increased the amount of land managed with prescribed fire (Figure 2) to average about 300,000 acres annually across the state—a number that grows every year. This positive trend can be attributed to the partnerships among state and local agencies, nonprofits,

Source: Courtesy of Bryan Rupar, Central Arkansas Water

Figure 2. Prescribed burn at Lake Maumelle

and NGOs who make up the Arkansas Prescribed Fire Council (Council), of which CAW is an active member.

In 2016, the utility developed its Fire Support and Safety Team. The team's original intent was to assist contractors on burns, ensure proper protocol usage, perform maintenance fires, and assist agencies in emergency response, all while keeping the utility's goals for utilizing fire at the forefront of every burn. As of 2021, the utility has eight employees on the team, each of whom has attended the Arkansas Prescribed Fire School: a week-long, intensive, hands-on state training program put on by members of the Council for practitioners of prescribed fire. In 2020, CAW hired a registered forester and trained burn boss to join the Program as the land conservation coordinator; this position now leads the utility's prescribed fire efforts. Enhancing capacity in this way has dramatically increased the number of utility-owned acres that are treated annually. Utility employees can now tackle a larger portion of the burn work that was previously 100% dependent on hired contractors. Since the start of our burning program in 2011, CAW has burned nearly 5,600 acres, with 42% of those acres burned in 2021 and the first half of 2022. Nearly 30% of the acres burned in 2022 were burned by the utility's own employees.

For CAW, forest management is multi-faceted. Our top priority in utilizing prescribed fire is to reduce the amount of total organic carbon (TOC) that enters the reservoir from the landscape. Prescribed fire breaks down and removes downed timber and accumulated leaf litter from forests, ensuring that less TOC enters our lakes than would if the timber was left to decay naturally. TOC in raw water supplies can lead to the formation of disinfection byproducts (DBPs), many of which are federally regulated drinking water contaminants that utilities are required to control. While several methods of DBP removal exist, limiting the input of TOC to raw water sources is the best control for DBP formation. If we reduce the amount of TOC in forests, we reduce the amount entering surrounding reservoirs, leaving the treatment plant with less to manage. Any time a contaminant can be reduced before it reaches the treatment plant, there are fewer energy, time, and chemical needs to treat the water to meet federally required levels for safe consumption—a cost-savings we gladly pass along to our customers.

> In 2020, CAW issued the world's first-ever Green Certified Bond to purchase forestlands as part of water infrastructure.

Secondarily, the combination of prescribed fire and ecological timber thinning enhances water filtration on the forest floor. In dense and crowded forests, more organisms compete for limited nutrients and water, making the vegetation more susceptible to drought, disease, and pests. Prescribed burns control undesirable vegetation and allow more sunlight to reach the forest floor, reducing competition. Prescribed fires also return valuable nutrients to the soil through the resulting ash, thereby improving conditions for new plant growth. These changes promote an abundant and diverse grassy understory with more resilient vegetation. The robust root complexes and new vegetation growth help slow and absorb runoff, turning the forest into a first line of defense against pollutants that could enter the lake from rain events.

Forest management also reduces wildfire risks. Much of CAW's forestland had not been managed in over 50 years, resulting in dense and overcrowded forests with an abundance of leaf litter, downed woody debris, and potentially diseased or damaged vegetation that burns easily and at high intensity. Heavy fuel loads can be responsible for intense fires that move into adjacent forests and cause serious damage to standing timber or buildings. With the proactive implementation of prescribed burns, we can remove heavy fuel loads and provide opportunities for firebreak installations, which aid in wildfire containment and response should a wildfire occur. Wildfire is not only detrimental to landscapes, habitats, and communities in the traditional sense; for a water utility, the onslaught of material and TOC flushed into water supplies after catastrophic fires (often followed by heavy rain events) is very hard to treat and increases the potential for DBP formation. Many utilities in the western United States experienced this as wildfires have increased in size and intensity over the past 25 years. Reacting to wildfires often involves changes in water treatment processes and rebuilding of landscapes, which can cost tens of

millions of dollars, making proactive management a desirable and cost-effective alternative.

CAW also utilizes prescribed fire to enhance wildlife habitat, increase plant and animal diversity, and create recreational opportunities. Burning activities stimulate the growth of seeds that are often buried beneath leaves and debris. Without burning, these seeds can lay dormant for many years until conditions become favorable for growth. In the short duration of the CAW prescribed burning program, the diversity of native wildflower species in demonstration areas and other treated lands has increased. One reason for this is that approximately 46% of the state's rare terrestrial plants and animals depend on fire at some point during their lifecycle. Some of the plants now growing in CAW prescribed burn areas had not been found in abundance there in years, if at all. One of the recently recorded plant species is an obligate host plant to a rare moth. Others are endemic to the immediate region, and state botanists track them as species of interest. These native grasses and wildflowers provide food and habitat for wildlife, including pollinators and migrating bird species. This valuable ecological process provides optimal habitat for a diverse mix of plants and animals, including game species like quail, turkey, and deer.

Source: Courtesy of Raven Lawson, Central Arkansas Water

Figure 3. Prescribed fire demonstration using different fuel types

The simple reality of a utility owning land is that those lands must be maintained and managed.

The Program's forest management efforts don't stop at prescribed fire and ecological thinning. In 2021, CAW became the first water utility to certify its lands (in the Lake Maumelle watershed, in this case) under the Sustainable Forestry Initiative standards for forest management, demonstrating a commitment to responsible stewardship. The Program has also planted more than 130,000 trees since 2016, most recently working to restore areas of native short leaf pine that were heavily harvested and replaced by non-native, timber-producing species.

Forest Management Education and Outreach

THE SIMPLE REALITY OF A utility owning land is that those lands must be maintained and managed. However, building a forest management program within the organization wasn't easy. It took a decade to obtain the necessary resources and begin observing the success we see today. We had to obligate funds within our small operations and maintenance budget, increase the number of trained staff, add critical personnel, and purchase equipment. Even with all those pieces in place, educating others on the importance of active forest management, both internally (within the utility's leadership and employees) and externally (our customer base and local landowners) was one of our toughest challenges.

Internal support was easier to obtain. Presenting sound science and the connections of forest management to our end water product was effective, but creating the internal capacity to execute a portion of this management in-house took some time. Today, we carry out most of our internal education through tours of our forest management demonstration area, where interns and employees visit the watershed and enjoy a

A critical part of this multi-barrier approach is prevention: preventing contaminants from entering source waters.

2.3-mile interpretive hike lead by Program staff.

External support has slowly built over time. It's rare for a water utility to assume an active role in natural resource management. Most consumers pay their bills and turn on a tap without giving much thought to the process of delivering that water safely and reliably. Some may connect the lines back to the treatment process, but, in reality, a large number of consumers do not know where their water originates. So, when a water utility begins the very visible act of dabbling in forest and recreation management, fears arise. Customers fear that this will create higher water bills, nearby landowners see fires along roadways and worry about wildfire inundating their lands, and general questions about the "what" and "why" emerge quickly.

To ease the minds of both consumers and landowners, CAW has taken to educating the community in a few different ways. At a higher level (and at the biggest benefit to rate-paying customers), we have given presentations at many local civic and city organizations' regular meetings and have provided burn demonstrations for student and teacher workshops (Figure 3). We also host a larger utility effort called the Citizen's Water Academy twice a year. This academy is for local leaders in city, civic, and business organizations. They spend an entire day touring utility operations "from forest to faucet" and learn about the inner workings of the services we provide to the community. For the nearby watershed landowners, we have utilized a mailing campaign over the years. This campaign begins each burning season (autumn), using maps to forecast projected burn areas and acreage and sending a letter to explain the "why" of our prescribed fire efforts. In 2015, after a few years of burning a small number of acres each year, we spearheaded a monthly postcard campaign that provided updates about our burning efforts for that season and answered frequently asked questions. Today we perform an annual mailout, and run a listserv for those wishing to receive day-of-burn announcements. Each year, we've seen progress from these efforts as more community members and leaders understand the importance of forest management and share our story.

Protection of water quality at modern utilities is done in accordance with the Safe Drinking Water Act's "multi-barrier approach." These barriers are actions taken throughout the storage, treatment, and distribution of drinking water to ensure its safety. Multiple barriers must be breached for the customer to receive water that does not meet safe consumption standards. A critical part of this multi-barrier approach is prevention: preventing contaminants from entering source waters. This can be accomplished through sound watershed forest management.

CAW is taking a proactive approach to ensure healthy forests through the use of prescribed burns and ecological forest thinning. These approaches have many benefits, including improved source water TOC management, enhanced water filtration through the forest floor, reduced wildfire risk, healthier habitats, and an increasingly supportive customer base. The community is so supportive that some customers have become forest management ambassadors. The benefits of active forest management far outweigh the costs of reactionary measures. At CAW, we believe that forest management is an important part of water quality protection.

References

CAW (Central Arkansas Water). 2021. "Certified Green Bond." Accessed August 31, 2022. https://lakemaumelle.com/pages/caw-is-first-in-world-with-certified-green-bond-to-protect-drinking-watershed-for-water-quality/.

TETRA Tech. 2007. *Lake Maumelle Watershed Management Plan*. Little Rock, AR: Central Arkansas Water. https://carkw.com/site/assets/files/1476/lake_maumelle_watershed_management_plan_-_revised_-_february_2007.pdf.

Innovative Water Research

The water sector is continuously exploring new and innovative ideas, processes, and technologies. To aid the sector on this journey, The Water Research Foundation (WRF) has supported a variety of innovation-focused research projects over the past decade, with more on the horizon.

One of WRF's most significant innovation projects, *Fostering Innovation Within Water Utilities* (4642), was funded in 2015 and completed in 2017. Approximately 50 utilities from across the globe participated in this project with the goal of assisting water utilities in fostering new ideas and implementing new approaches that transform their organizations and enhance their ability to meet future challenges. The specific objectives of the project were to (1) characterize existing innovation activities from the participants, (2) define the value of those activities, (3) develop a transferable framework (Figure 1) for fostering innovation, and (4) assemble a guidance document for utilities.

This research resulted in two follow up projects. *Funding Innovation: Turning an Idea into a Line Item* (4739) held a workshop that used the 4642 framework as a baseline and took a deep dive into strategies for funding innovative thinking, projects, and programs despite having limited budgets and ongoing strains on existing employee capacity. *Leading Water Utility Innovation* (4907) built on 4642 by assessing strategies that equip utility leaders to effectively foster collaboration within their workforces, build powerful external partnerships, and maintain momentum through meaningful innovation strategies.

In addition to these past projects, WRF is looking to the future of innovation in water. We recently released Requests for Proposals for 20 projects, some of which include innovative approaches or technologies. *Feasibility and Applicability of Emerging Utility-Led Innovations in Addressing Affordability* (5179) will look at emerging affordability program options and evaluate the benefits and costs of implementing these programs. *Preparing the Water Sector to Embrace Technology: Skillsets and Enterprise Management Approaches for the Digital Age* (5178) will assess the skillsets and training needed as utilities transition to the digital age, proposing a new paradigm for water sector workforce roles and responsibilities. On the technology side, *Evaluating Innovative and Sustainable Treatment Options for Biosolids* (5169) will identify and evaluate technologies and approaches for solids management, including destruction of per- and polyfluoroalkyl substances; and *Innovative Technologies to Improve Monitoring of Assets* (5191) will conduct case studies demonstrating applications of new and emerging technologies to increase utility resilience.

Innovative ideas, processes, and technologies are exciting pathways to a more resilient and efficient sector. As a trusted source of science that advances water, WRF will continue to explore innovative research and help propel the sector forward.

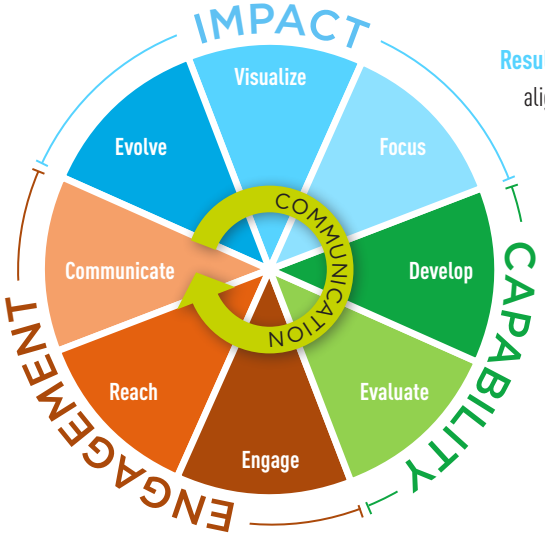
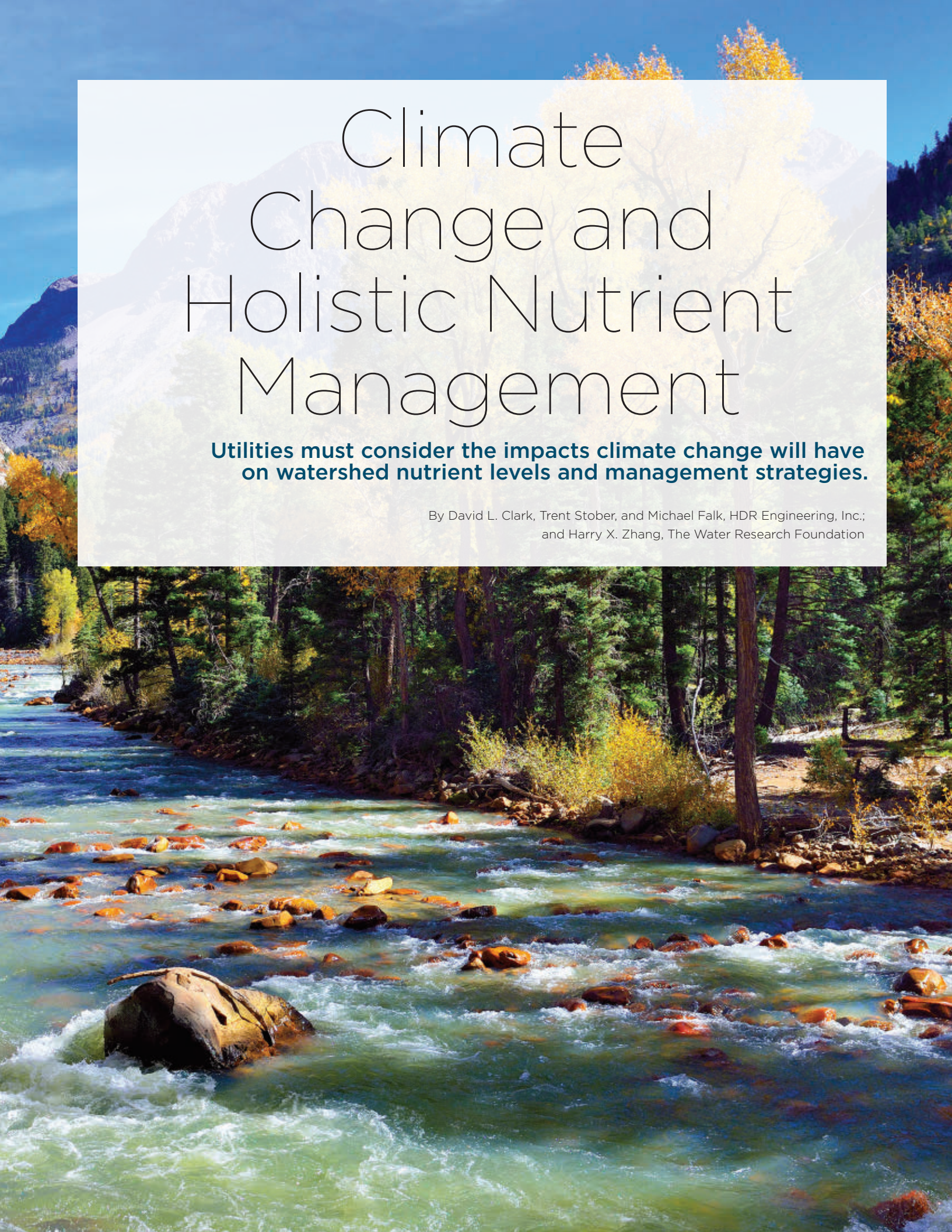


Figure 1. Utility innovation framework



Climate Change and Holistic Nutrient Management

Utilities must consider the impacts climate change will have on watershed nutrient levels and management strategies.

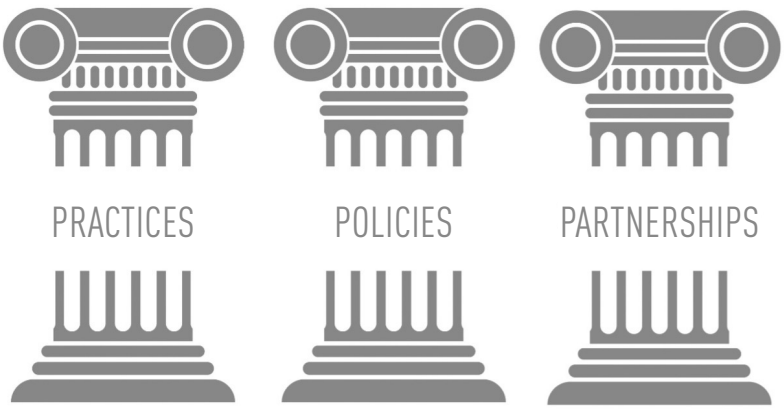
By David L. Clark, Trent Stober, and Michael Falk, HDR Engineering, Inc.; and Harry X. Zhang, The Water Research Foundation

The overall goal of *Holistic Approach to Improved Nutrient Management: Phase 1* (Clark et al., forthcoming) is to improve nutrient management on a national scale by using a holistic watershed approach to address both urban and agricultural issues. This effort has engaged utilities, both point and nonpoint source representatives, regulatory agencies, and other watershed stakeholders across geographic regions to develop a research roadmap and actions to advance nutrient management in new and improved ways.

The state-of-the-practice, lessons learned, and future research opportunities have been identified in each of three key factors: practices, policies, and partnerships (Figure 1). The potential for improved watershed nutrient management rests in further development of these individual factors, as well as understanding their interrelationships.

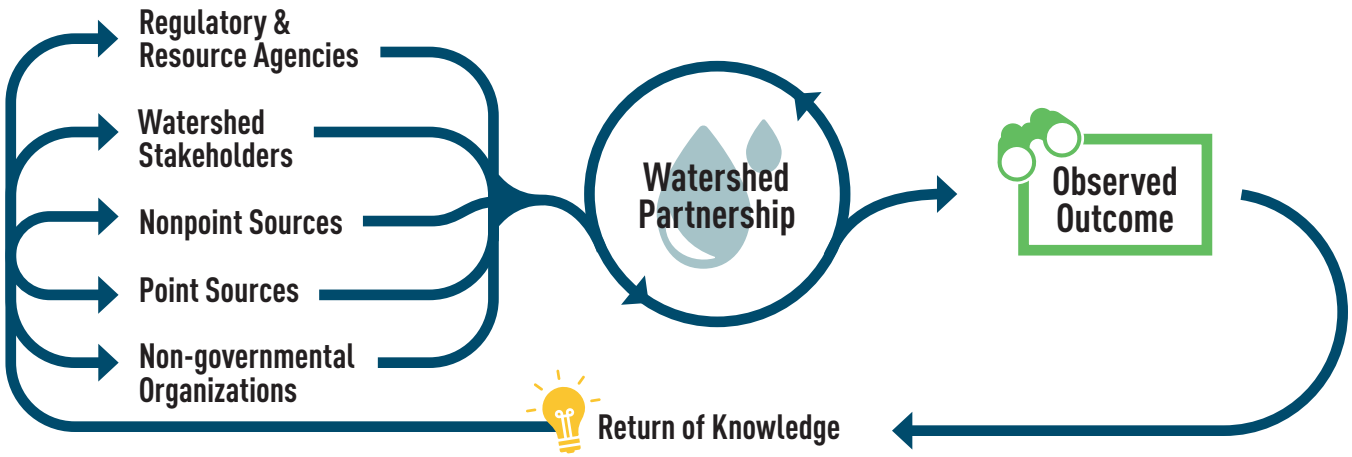
These three key factors influence and guide holistic nutrient management. "Practices" refers to the technical considerations related to nutrient removal from wastewater, best management practices for nonpoint sources such as stormwater and agricultural land uses, nutrient processing, impacts on receiving waters, and impacts on the atmosphere from greenhouse gas emissions. "Policies" refers to the regulatory, institutional, and administrative aspects that govern nutrient management. This includes nutrient discharge permitting and compliance with receiving water quality standards, as well as watershed management requirements. "Partnerships" refers to the potential for collaboration, building relationships and trust, and leadership in watershed nutrient management. This includes consideration of diverse stakeholders with varied interests that may, or may not, be aligned. Figure 2 shows some of the key stakeholders involved in nutrient management and the optimal partnership process, where stakeholders maintain a shared vision and actively participate in an iterative watershed partnership.

Practices, policies, and partnerships can be used to analyze barriers to watershed nutrient management. Identification of limiting factors may lead to improved strategies that affect change in a constructive manner and alleviate an over-emphasis on management actions that are not likely to result in water quality improvements or net environmental benefits. Integrating practices, policies, and partnerships in a balanced fashion that avoids skewing management considerations and illuminates the potential convergence of these factors may result in opportunities for improved nutrient management. For example, in watersheds where stakeholders have invested in practices to remove nutrients from wastewater and accomplished substantial point source nutrient reduction, exploring opportunities in policies and partnerships may advance watershed restoration even further. Developing a common understanding of nutrient reduction requirements and the context in which stakeholders will encounter these additional challenges is important to developing the trust needed for effective collaborations. Managers from individual disciplines may find it essential to operate outside of



Source: Clark et al., forthcoming

Figure 1. Practices, policies, and partnerships for holistic nutrient management



Source: Clark et al., forthcoming

Figure 2. Interrelationships between nutrient management stakeholders in an optimal partnership process

traditional boundaries to identify and develop areas of convergent interests with other stakeholders.

Climate Change and Environmental Justice

CLIMATE CHANGE AND environmental justice are overarching factors in watershed nutrient management considerations. Climate change is a major influence on both water quantity and quality management. In addition, poor water quality can have a disproportionate impact on disadvantaged communities. In that regard, nutrients may further exacerbate those impacts, and management efforts may raise additional environmental justice concerns. Table 1 summarizes the relationship nutrient management has with climate change and environmental justice.

Climate Change

CLIMATE CHANGE COMPLICATES water resource management in multiple ways. Increased precipitation results in new extremes in peak wastewater flows, which may cause sewage spills and conditions that make nutrient removal more difficult. Climate-driven regional drought is resulting in water supply shortages. This may increase the demand for water reuse, which can be advantageous in diverting nutrient loadings away from surface waters. At the same time, water scarcity may have a negative impact on watersheds by reducing the instream flows necessary to support beneficial uses, such as aquatic life, especially in the late summer. This would pose challenges for utilities and municipalities to meet receiving water quality standards and Total Maximum Daily Load requirements (the maximum amount of a pollutant that can enter a waterbody without the waterbody violating water quality standards for that pollutant).

For these reasons, climate change is an overarching influence over practices, policies, and partnerships. From a policy standpoint, priorities may be focused on reducing adverse impacts of climate change. From a nutrient management standpoint, recognizing

Table 1. Climate and environmental justice influences on watershed nutrient management

Factor	Climate Change	Environmental Justice
Practices	Increasing water temperatures, algal blooms, and hypoxia. Increasing peak wet weather flows. Drought.	Degraded surface water quality. Treatment facility expansion into neighborhoods. Treatment optimization and densification.
Policies	Balancing nutrient regulation vs. increased greenhouse gas (GHG) emissions from advanced treatment.	Disproportionate impact of utility rate increases on disadvantaged communities.
Partnerships	Increased need for cross-discipline coordination and collaboration.	Lack of collaborations needed to aggregate funding.

Source: Clark et al., forthcoming

For watershed nutrient management, climate change necessitates looking beyond the science and technology considerations of nutrient treatment and water quality impacts.

sustainable management practices is increasingly important. Biological nutrient removal treatment can be accomplished sustainably; however, that may not be adequate to meet the most challenging receiving water quality standards. Regulatory processes driving the application of limits of technology treatment may result in disproportionate greenhouse gas (GHG) emissions that impact climate and may result in little, if any, additional water quality benefit. On the other hand, nonpoint source nutrient management may be necessary to accomplish improvements in water quality and to provide benefits beyond nutrient reduction alone. Nonpoint source best management practices that reduce nutrient loadings may also reduce erosion and sedimentation, provide habitat improvements, and sequester carbon. Regulatory policies that consider these factors and promote a balance of both water quality benefits and minimization of adverse climate impacts, rather than strict adherence to existing regulatory structures alone, will be better suited to holistic nutrient management for a sustainable future.

There are additional aspects of climate change that influence the need for holistic approaches to nutrient management. First, there is increasing awareness of the impacts of nutrient enrichment of surface waters, such as eutrophication and increases in GHG emissions. Nutrient-driven cyanobacterial/algal blooms that then senesce and decompose create anoxic conditions in watersheds and emit GHGs to the atmosphere. Second, the combination of nutrient enrichment and climate-change-driven water temperature increases may result in more frequent occurrences of cyanobacterial harmful algal blooms. Cyanobacterial harmful algal blooms impact multiple beneficial watershed uses because they impair water supplies, endanger animals, and may even threaten human health. Increased drought can lead to the concentration of nutrients in certain catchments, thus exacerbating eutrophication issues. A recent report from the U.S. Environmental Protection Agency predicts that "harmful algal bloom occurrences in recreational waters and drinking water sources will increase as excess nutrients continue to flow into waterbodies, temperatures warm, and extreme weather events occur due to climate change" (EPA 2021).

For water resource recovery facilities (WRRFs), GHG emissions have typically been associated with nutrient removal technologies. The chemicals used in nutrient removal processes and the energy associated with aeration and pumping lead to GHG emissions. These emissions have been shown to increase significantly when increasing the level of treatment for nutrient removal (Falk et al. 2011). However, nutrients discharged into waterbodies can also lead to atmospheric GHG emissions. Aerobic or anaerobic degradation of organic matter in freshwater systems, such as lakes and reservoirs, results in the formation of carbon dioxide and methane, adding to GHG emissions. Apart from water quality impacts on watersheds, nutrients from WRRFs released to surface waters have the potential to impact climate change. GHG emissions from watersheds have not been widely studied, and therefore warrant further research and attention. Although scientific studies have shown the importance of lakes and reservoirs in the global carbon cycle and GHG emissions, the development of policies in this area is still at an early stage. This is partly due to difficulty in understanding and estimating the effects of these GHG emissions. This is coupled with a lack of standard measurement techniques and tools for quantifying net GHG exchanges from reservoirs, time consuming efforts, and the lack of datasets for long-term predictions (Goldenfum 2012). Developing regulations to address GHG emissions from freshwater systems can be challenging due to the variety of stakeholders involved in the flow and storage of water. Moreover, these GHG emissions, in addition to other impacts of climate change (e.g., rising sea levels, coastal

flooding, and increasing temperatures), can impact vulnerable communities. The negative impacts of climate change are seen to be disproportionate among people from lower income households and racial minorities. Policies related to climate risk analysis, impact predictions, and course of recovery can vary greatly for these groups. Due to longer adaptation and recovery from climate change impacts, these groups need special attention when it comes to mitigating climate change.

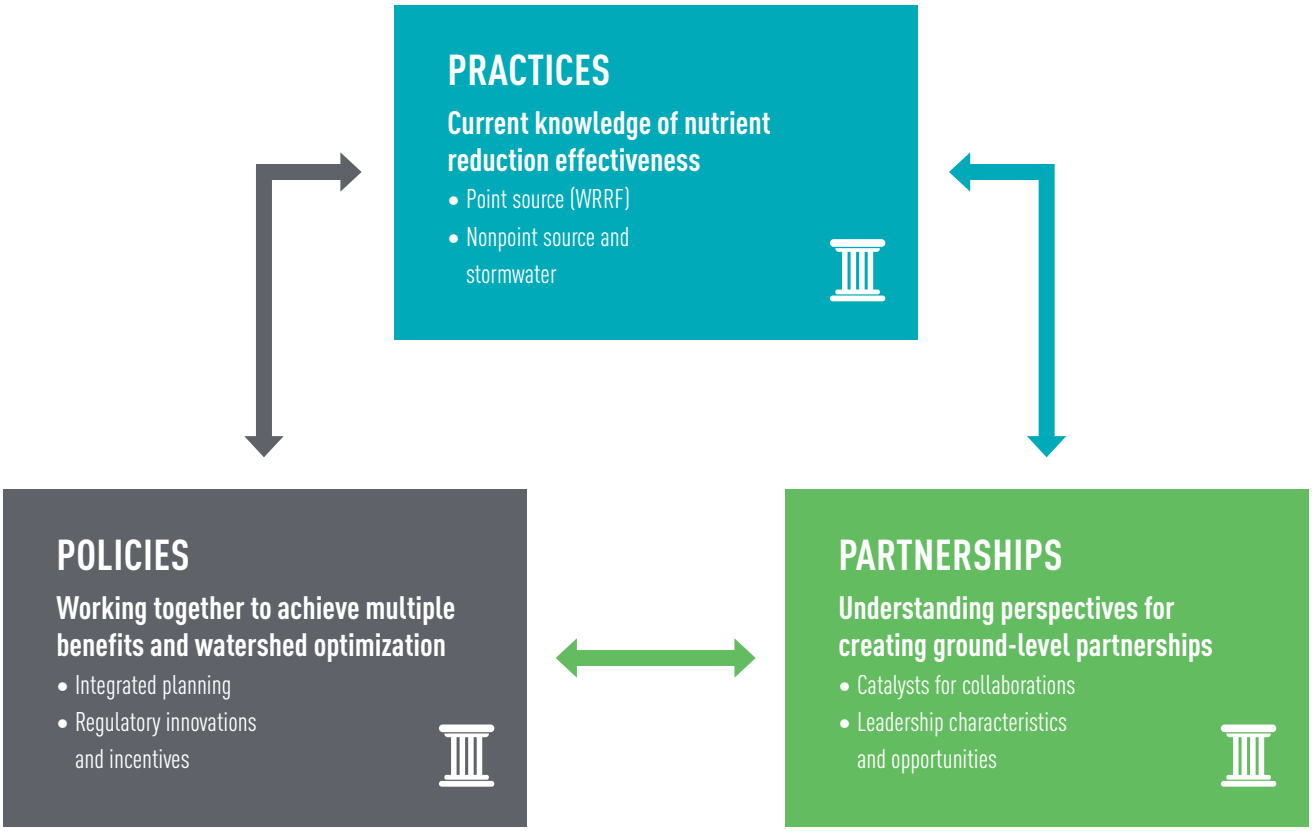
The challenges of mitigating climate change drive the need for more effective collaborations involving partnerships across diverse sectors of society. For watershed nutrient management, climate change necessitates looking beyond the science and technology considerations of nutrient treatment and water quality impacts. This increases the need for effective partnerships to address watershed-scale problems because they cannot be solved by a single sector acting alone. Leaders who recognize the need to work across sectors and form collaborations around common interests are likely to be more successful in improving holistic nutrient management. Climate change may be the primary issue that brings individual sectors together to move beyond their traditional positions and interests.

Environmental Justice

ENVIRONMENTAL JUSTICE IS another transcendent issue spanning the three nutrient management dimensions of practices, policies, and partnerships. Poor water quality may disproportionately impact certain disadvantaged communities where impaired conditions cannot be avoided, or where the community cannot afford to address the causes of the impairment. From a practice standpoint, wastewater treatment technology with advanced nutrient removal is well known, but relatively expensive. Nutrient management investments result in increases in utility rates. Those increased charges disproportionately impact lower income households. For that reason, nutrient management becomes an environmental and social justice issue that may impact both urban and rural communities.

One Water Challenges

WATERSHED NUTRIENT management has long presented challenges



Source: Clark et al., forthcoming

Figure 3. Interrelationships among practices, policies, and partnerships for One Water challenges

for wastewater, stormwater, drinking water, and water reuse utilities. Whether it is the need to control effluent nutrient loadings to surface water to prevent eutrophication, or to protect water quality in surface reservoirs to avoid tastes, odors, and toxics in drinking water supplies, the combination of challenges illustrates the integrated nature of the water environment. In recent years, utilities that have pursued nutrient removal have also embraced the recovery of nutrients from wastewater. This paradigm shift from seeing products previously thought of as wastes to recognizing them as resources includes water reuse, biosolids recycling, and energy recovery from solids stabilization. At the same time, climate-driven regional drought has created new demands for recycled water, and increasingly intense weather events have compounded challenges involved in managing peak wet-weather-driven wastewater flows to prevent sewer overflows. The combination of these issues illustrates the importance of managing all water in a comprehensive, integrated, sustainable, and equitable manner.

As the water sector moves closer to a One Water paradigm, it is increasingly important to view nutrient management in a broader context (Figure 3). Central to this vision is understanding that all water has value and managers need to collaborate to solve water challenges, whether these challenges encompass wastewater, stormwater, drinking water, or recycled water. The practices, policies, and partnerships associated with the management of water may differ, be interrelated, and at times, be in conflict. Nevertheless, all water has value, regardless of the source. Addressing water challenges, including nutrient management, is the responsibility of a diverse array of managers, technologists, policymakers, community members, and watershed stakeholders.

References

CLARK, D., T. Stober, M. Falk, H. Holmberg, and P. Vanrolleghem. Forthcoming. *Holistic Approach to Improved Nutrient Management: Phase 1*. Project 4974. Denver, CO: The Water Research Foundation.

EPA (U.S. Environmental Protection Agency). 2021. *EPA Needs an Agencywide Strategic Action Plan to Address Harmful Algal Blooms*. Report No. 21-E-0264. EPA.

FALK, M., J. B. Neethling, and D. J. Reardon. 2011. *Striking the Balance between Nutrient Removal in Wastewater Treatment and Sustainability*. Project 1515/NUTR1R06n. Alexandria, VA: Water Environment Research Foundation.

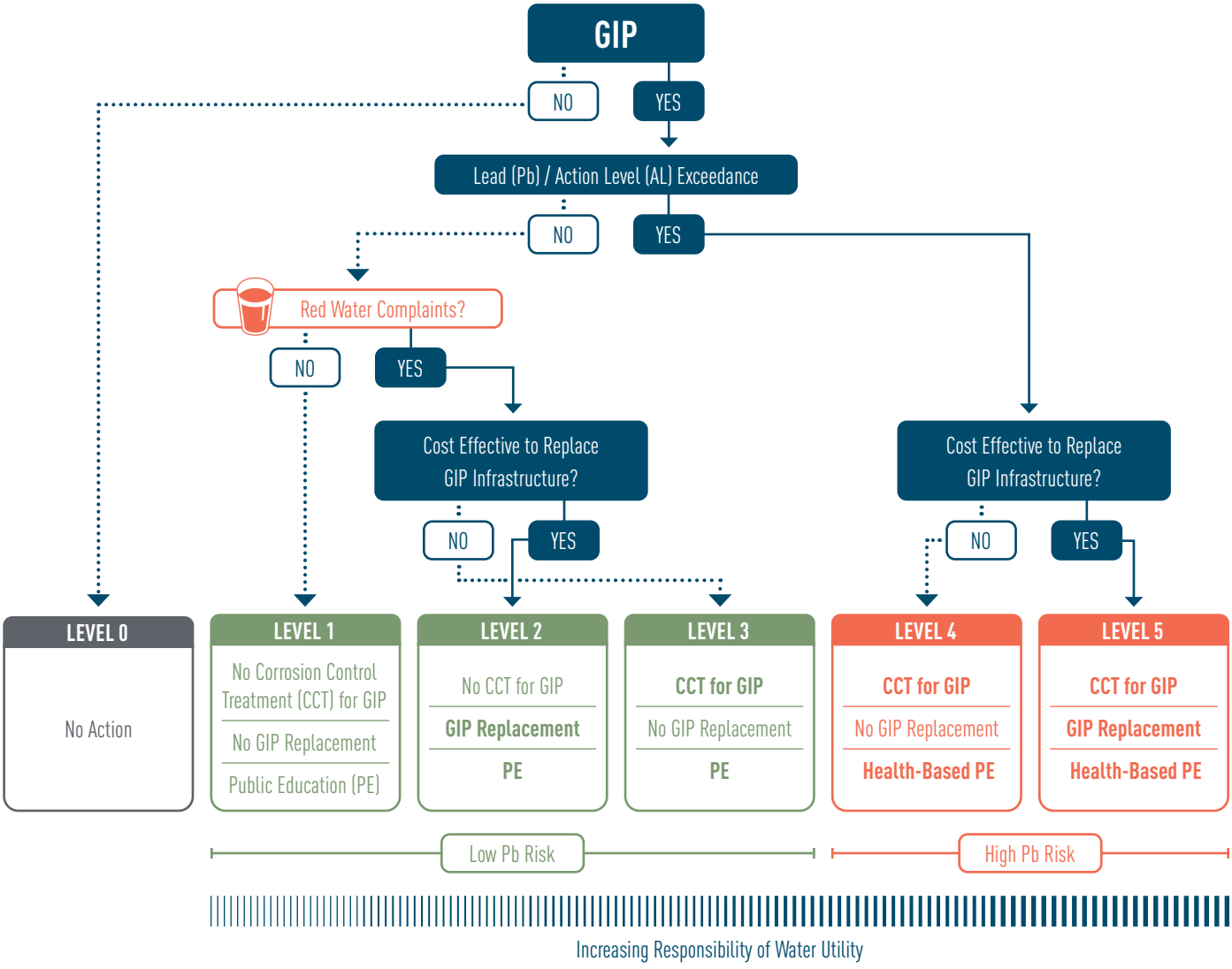
GOLDENFUM, J. A. 2012. "Challenges and Solutions for Assessing the Impact of Freshwater Reservoirs on Natural GHG Emissions." *Ecohydrology and Hydrobiology*, 12 (2): 115–122.

Nitrosamine Precursors (5005)

There is growing interest in nitrosamines, including their precursors and their presence in recycled water. *Nitrosamine Precursors in Direct and Indirect Potable Reuse Water* assessed the importance of nine nitrosamines in potable reuse facilities and sought to determine which precursors contribute the greatest to the formation of nitrosamines in finished water. The occurrence of the nine nitrosamines was measured at a representative potable reuse facility where high-resolution mass spectrometry and diagnostic fingerprinting methods were used to identify precursors of N-nitrosodimethylamine (NDMA). NDMA was found to be the most commonly occurring nitrosamine present in reverse osmosis and advanced-oxidation-process-treated water from potable reuse facilities. Bench- and pilot-scale experiments were also conducted to assess changes in the reactivity of nitrosamine precursors during advanced oxidation to determine whether advanced oxidation treatment at potable reuse facilities can increase the potential for NDMA formation.

Release of Lead from Galvanized Pipes (4910)

Galvanized iron pipe (GIP) is frequently found in home plumbing and was often used to connect consumers' homes to water mains. GIP is formed by coating a steel tube with a layer of zinc in order to slow iron corrosion, and can contain 0.5–1.4% lead in the galvanized coating. New GIP can release lead from the coating, and, over time, the coating can be removed and expose the underlying iron pipe. The exposed iron pipe can adsorb lead that is released from upstream sources, and the adsorbed lead on the GIP can then be released back into the water. *Evaluating Key Factors that Affect the Accumulation and Release of Lead from Galvanized Pipes* provides utilities with a management plan framework to guide GIP replacement, corrosion control, and public education based on system characteristics and prior utility experience. Methods are provided for identification and classification of unique utility scenarios. In addition, a bench-scale testing protocol is detailed as a model for utilities to assesses potential corrosion control strategies for reduction of iron and/or lead leaching from GIP.



Overview of the GIP management plan framework

Developing Successful Utility Research Programs

Today's water utilities face many challenges, ranging from deteriorating infrastructure and constituents of emerging concern to climate change and workforce changes.

By Nancy E. McTigue, Cornwell Engineering Group; Alice Fulmer, The Water Research Foundation; and Adam Hendricks, Philadelphia Water Department

Research can help utilities identify solutions to many challenges by pilot testing new technologies, optimizing treatment, supporting regulatory negotiations, or finding ways to operate more efficiently. However, resources dedicated to research need to be allocated and managed in a timely manner so that solutions are available when needed and information can be used to support long-term strategic planning. Funding research is expensive, sometimes risky, and not always prioritized at the broader utility level.

Utility research can take many forms: partnering with research organizations, hiring consultants to perform large projects, or working with local universities. In addition, an increasing number of utilities recognize the benefits of conducting research themselves to directly manage and coordinate their research needs. For example, Philadelphia Water Department has an applied research group as part of its Planning and Research Unit. This group recently began expanding and is working on redefining its mission, vision, and workload. In order to best shape its future strategic plan, Philadelphia Water Department funded *Framework for the Development of a Utility Research Program* (McTigue, forthcoming) through The Water Research Foundation's (WRF's) Facilitated Research Program. This program allows WRF subscribers to utilize WRF's project management and expert review process for research funded by the utility.

The goal of this project was to learn from water utilities that have internal research groups, missions, and/or dedicated staff. The project results may enable utilities to create their own programs building on the successes of, and managing the roadblocks encountered by, other

> "The goal of funding this project was to not only understand how we continue to grow and prioritize our own research efforts, but to collaborate with other research leaders on a useful tool to advance research across the industry."
>
> —ADAM HENDRICKS, PHILADELPHIA WATER DEPARTMENT

Each individual utility must decide where the research group should be housed based on the utility's structure, organization, and culture.

utilities. The research team collected information from diverse utilities and programs, identified attributes of successful research programs, documented diverse case studies, and developed a framework for utilities to use when creating their own research programs.

A survey of 25 utilities was conducted to determine how and why the utilities developed research groups and how these groups operated (Table 1). These utilities were specifically chosen because of their ongoing commitment to research; thus, it was not a random survey of water utilities. Of the surveyed utilities, 21 were also interviewed. In general, the utility personnel were asked how their research groups were developed, how research needs are prioritized, and how the programs are managed with regard to the following:

- Research topic identification and prioritization
- Budgeting and funding mechanisms
- Collaboration with academic institutions, consultants, research organizations, and others
- Procurement
- Staffing/organization
- Contracting/structuring
- Communications

In May 2022, utility personnel from around North America attended a workshop to further explore these topics. There, 10 utility personnel presented on their organizations' research foci. The insights gathered were then used to develop a framework for those who wish to initiate a similar program at their utility. Seven key components of a research program were also identified (Figure 1), some of which are discussed below.

Drivers/Mission

THE COMMON FIRST STEP IN creating a research group was identifying an initial driver or a specific reason for conducting research at that utility. Next, the research group must define its ongoing mission. The mission is usually connected to the original driver in some way. Drivers identified through this project are wide ranging, but primarily focused on process optimization, regulatory compliance, or planning for future needs. There was also a significant number of utilities that created their research groups due to their interest in being on the forefront of technology and innovation. A strong mission helps keep the program on task and ensures the program does not expand into non-research endeavors.

Structure

EACH INDIVIDUAL UTILITY MUST decide where the research group should be housed based on the utility's structure, organization, and culture. Many research groups at utilities started as part of a laboratory, ranging from those conducting certified regulatory compliance analyses to those conducting operational support. The project report describes a wide variety of possibilities for the research group, from being part of the

Table 1. Description of utilities surveyed

Number	25 (from the United States and Canada)
Size (flow or production)	Range 50 MGD – 1.8 BGD Median 180 MGD
Size (population served)	Range 55,000 – 15 million Median serves 2 million
Type of utility	60% produce drinking water, 40% treat wastewater 50% treat drinking water and wastewater or recycled water
Have formal research group?	Yes, 81% Research focus in other departments, 19%
How long has it been in place?	3 to 50 years 75% longer than 15 years
Which group was instrumental in pushing the group formation?	100% had an advocate in management (Board or CEO)

Source: Adapted from McTigue, forthcoming

Source: McTigue, Forthcoming.

Figure 1. The critical components of a utility research group

management team to being a group embedded in the operations team. The type of research to be conducted and how it can best be accomplished must be considered. Notably, when a research group is part of the management team, it allows the research focus to be more closely aligned with the mission of the entire utility. However, if the group is not within management, it is important to find a champion in management or on the utility's board.

Setting a Research Agenda

IT IS IMPORTANT TO ESTABLISH AN agenda-setting process at the outset of the program. Many examples are included in the report and can serve as templates or starting points for new programs. For example, one utility holds a "Shark Tank" audition, in which anyone with a research idea has the opportunity to present their idea to a panel. At other utilities, staff can submit research request forms that are evaluated based on set criteria. Criteria should be used for prioritizing ideas, such as perceived benefit, cost of project, alignment with capital improvement plans, alignment with permits, or regulatory compliance. The process can change over time, but without a set process, the mission of the research group risks being diluted or fractured.

Funding

WHILE THE SIZE AND SOURCE OF research budgets can vary tremendously, all of the research groups in this study had at least one or two internally funded personnel. The utilities interviewed cited the following sources of funding:

- Utility operational budgets
- Utility capital improvement budgets
- Government sources
- Research group sources
- Alliances

An important aspect in maintaining research funding within an organization is to show a positive return on investment (ROI). All utilities interviewed stated that the benefits gained outweigh the amount of funding the programs receive. However, ROI can be difficult to quantify, especially since the benefits of research are often realized over a long period of time and may not be traditional cost savings. Therefore, communication is key, including using creativity when defining your ROI and discussing your successes and failures.

Communications

THE INTERVIEW RESPONSES demonstrated a common theme: communication is the key to keeping the program running. Every group in this project identified some means by which it communicated the findings of the research performed or sponsored. It is essential that the board or management continually be made aware of the results of the work. Participating utilities communicated with their boards both formally (e.g., presentations) and informally (e.g., group emails). Similarly, strategies for internal staff communications ranged from informal talks in the hallway to

weekly emails, staff meetings, and research symposia. If the utility staff does not know about the results of the research, willingness to help with the projects will diminish. Lastly, good media coverage can often stem from participation in research projects, so some groups made efforts to relay research results to customers and stakeholders.

To accomplish their missions, utilities must continually improve their operations and processes. Research conducted by the utilities, alone or in partnership with other organizations, can help them succeed in these efforts.

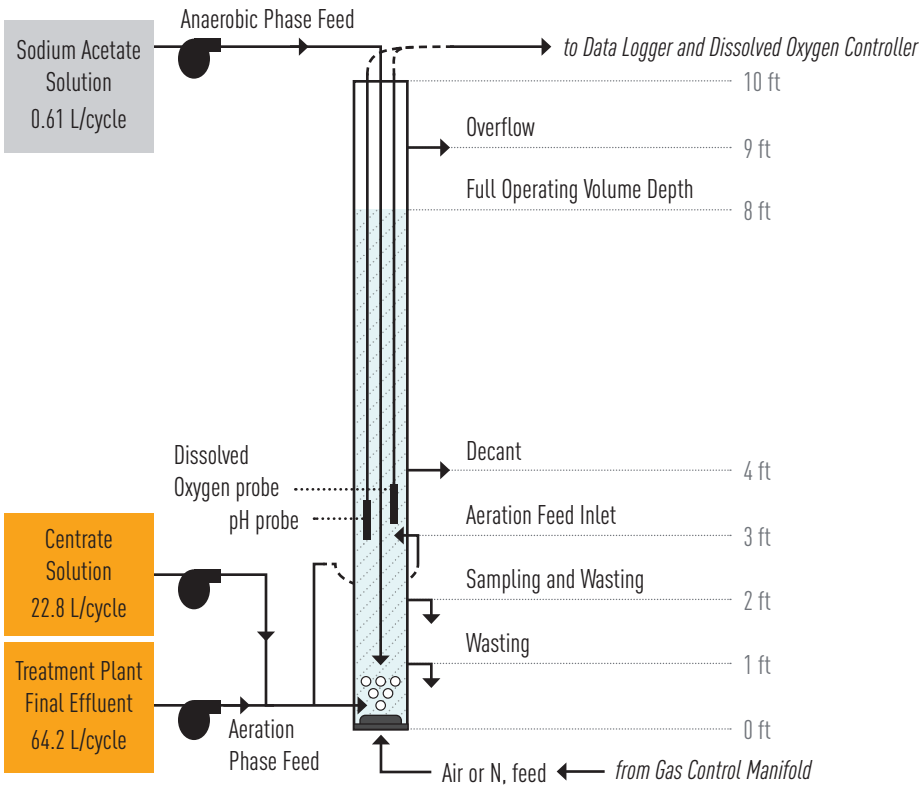
The interview responses demonstrated a common theme: communication is the key to keeping the program running.

References

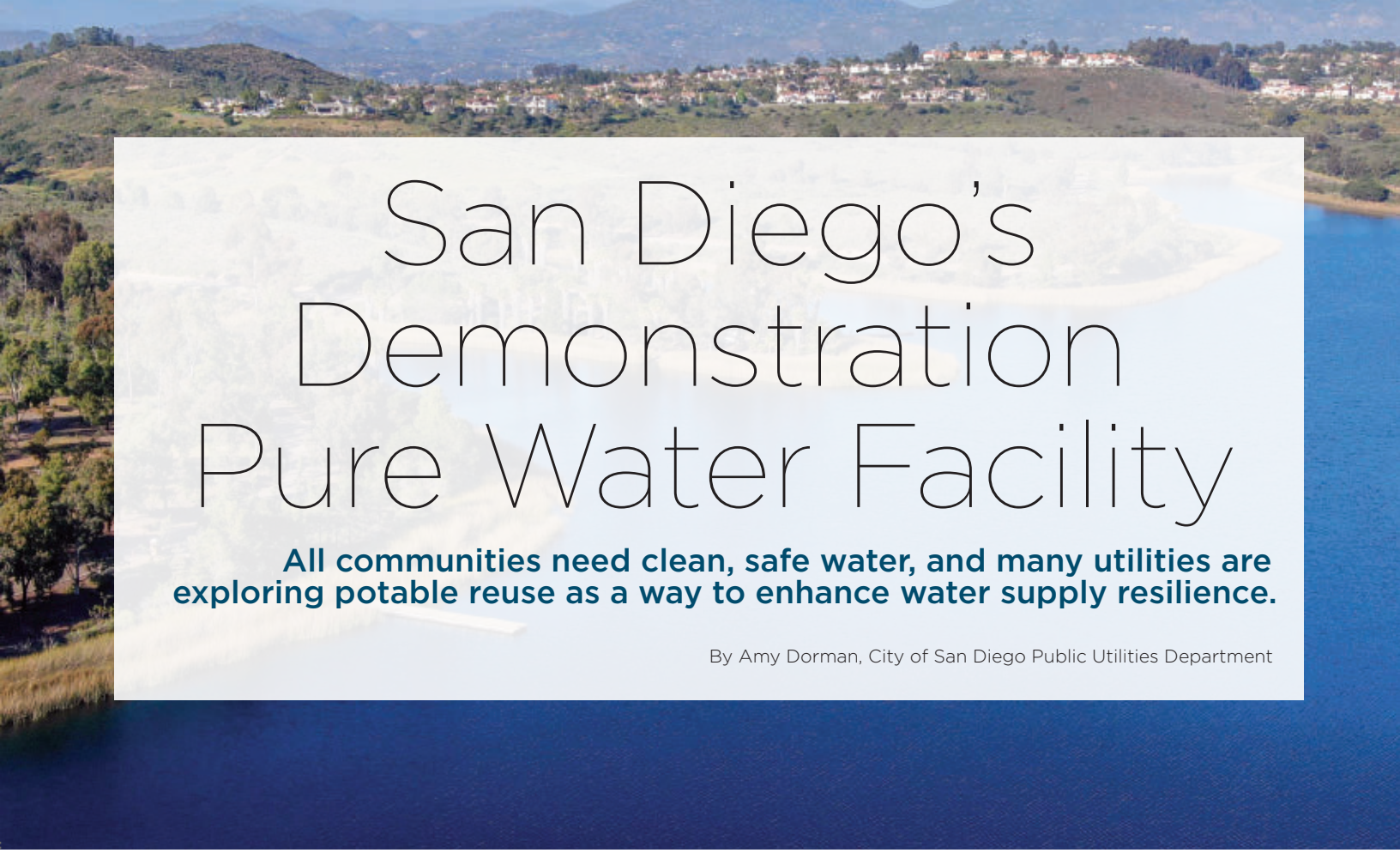
MCTIGUE, N. Forthcoming. *Framework for the Development of a Utility Research Program*. Project 5166. Denver, CO: The Water Research Foundation.

Biological Nutrient Removal (4864)

More stringent nutrient removal requirements may present significant challenges for many water resource recovery facilities due to increases in tank volume and footprint that are necessary when using conventional treatment approaches. Therefore, there is a need for process intensification options with fewer cost, space, energy, and chemical demands. *Bioaugmentation with Sidestream Granular Sludge for Biological Nutrient Removal* conducted a two-year pilot plant operation. The pilot evaluated a nitrifying granular sludge sidestream bioaugmentation process to enable nitrification and nutrient removal in mainstream treatment at a higher mixed liquor suspended solids concentration than is used for flocculent activated sludge.



Sidestream sequencing batch reactor



San Diego's Demonstration Pure Water Facility

All communities need clean, safe water, and many utilities are exploring potable reuse as a way to enhance water supply resilience.

By Amy Dorman, City of San Diego Public Utilities Department

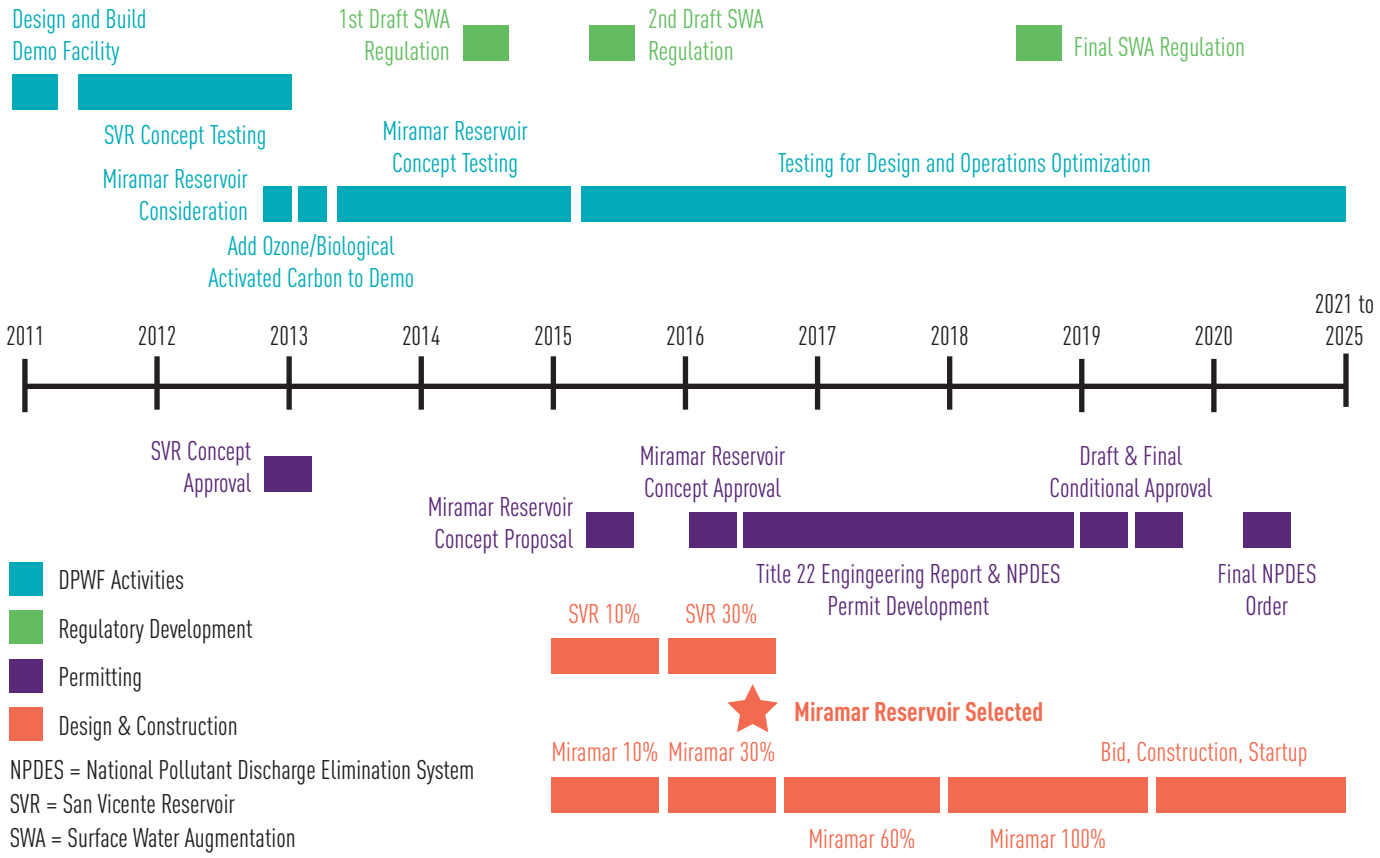
The City of San Diego, CA, began its potable reuse journey in the 1990s. The Pure Water Program, a multi-year initiative to provide nearly one-half of San Diego's water supply locally by 2035, jumpstarted the City's potable reuse success. In 2010, the City initiated design and construction of its 1 million gallon per day (MGD) Demonstration Pure Water Facility (DPWF) consisting of membrane filtration, reverse osmosis (RO), and ultraviolet light advanced oxidation process. Through initial testing and monitoring at the DPWF, the City secured approval from the California Department of Public Health in 2012 to augment San Vicente Reservoir with advanced treated recycled water prior to the establishment of surface water augmentation (SWA) regulations. The general program timeline is shown in Figure 1.

Meanwhile, the City had another reservoir in mind for augmentation: Miramar Reservoir. Significantly smaller than San Vicente Reservoir (242,000 acre feet [AF] vs. 6,682 AF), Miramar Reservoir is much closer—only 9 miles away, while San Vicente Reservoir is 25 miles away. For regulators, Miramar Reservoir's substantially smaller size meant additional public health protections must be considered. With regulations for SWA in the early developmental stages, the Miramar Reservoir concept was pushing the limits of required retention time, raising the question of whether the project would be considered indirect or direct potable reuse.

The City enlisted its independent advisory panel (IAP) to help form a new concept for Miramar Reservoir. Ensuring levels of public health protection equivalent to those of San Vicente Reservoir, the new Miramar Reservoir concept included additional treatment to account for reduced environmental buffer size. In 2013, the City added ozone (O_3) and biological activated carbon (BAC) as pre-treatment to the DPWF's existing treatment train, providing additional pathogen and chemical control to counterbalance the smaller buffer. For the next two years, the City implemented testing and monitoring to demonstrate the benefits (particularly regarding public health) of the additional treatment.

Eager to implement potable reuse, the City developed designs for both reservoir options during ongoing testing at the DPWF. Testing results, along with support from the City's IAP, led to regulatory approval of the Miramar Reservoir concept in 2016; the City augmented it as an indirect potable reuse project. California finalized SWA regulations in 2018, and, in 2020, San Diego received the first National Pollutant Discharge Elimination System (NPDES) permit for its North City Pure Water Facility (currently under construction).

continued on page 26



Source: Courtesy of City of San Diego

Figure 1. Surface water augmentation program timeline

DPWF research played a critical role in the approval of the Miramar Reservoir concept and the development of the SWA and direct potable reuse (DPR) state regulations. The City has also utilized DPWF research to perform public outreach, train operators, optimize facility design, and pre-select process equipment (Figure 2). Some of the key DPWF projects (highlighted below) focused on producing data that would meet industry and regulators' needs.

Safely Pursuing DPR

TRUSSELL ET AL. (2018) WAS conducted to evaluate the benefits of treatment redundancy and continuous monitoring in achieving reliable public health protection in potable reuse. Year-long continuous monitoring assessed process performance for pathogenic and chemical control. To complement routine performance monitoring, chemical and viral surrogate challenge tests determined the enhanced treatment train's benefits. Quantitative microbial risk assessment demonstrated that a full-scale DPR treatment train can reliably meet performance goals and produce water with public health protection equivalent to, or greater than, conventional drinking water supplies. The project exhibited how a combination of redundancy, robustness, reliability, and resilience can ensure DPR safety, allowing the State of California to determine that DPR can be safely pursued.

Developing DPR Criteria

DEBROUX ET AL. (2021) INCLUDED data from the City's source control program and North City Water Reclamation Plant as a case study. This project also evaluated data from the Orange County Water District's Groundwater Replenishment System and Singapore's Public Utility Board. Researchers used this data to assess the removal of various chemicals by conventional wastewater treatment and advanced treatment to evaluate occurrence of chemical peaks and treatment options. Ultimately, this project provided four key strategies for utilities to "average" chemical peaks, and recommended a balanced approach that includes two or more of the following strategies: source control, monitoring, treatment, and blending. This project was one of five research projects used by the California State Water Resources Control Board to develop DPR criteria.

The City created a tiered membrane integrity monitoring framework and demonstrated O_3/BAC to be an effective pre-treatment method for controlling biological and organic fouling of membrane systems

Carbon-Based Advanced Treatment

DIRECTLY SUPPORTED BY THE DPWF, Robinson et al. (forthcoming) sought to:

1. Determine the effectiveness of ozone with biologically active filtration-based treatment trains regarding removal of constituents of emerging concern (CECs)
2. Demonstrate compliance with performance-based regulations
3. Identify and address knowledge gaps and additional optimization needs with respect to public health

As a study participant, the City contributed a wealth of water quality, design, and operational data from testing and monitoring CEC removal at the DPWF. This project may result in O_3/BAC being combined with other non-RO treatments to achieve viable, multi-barrier, carbon-based advanced treatment trains for potable reuse.

Addressing DPR Treatment Challenges

PECSON (FORTHCOMING) WILL address data management and real-time response for DPR treatment trains. If DPR process failures occur, there may only be minutes to hours to respond, instead of months to years of retention time. This calls for real-time and proactive control systems. Elements of this novel system include data filtering and screening, data evaluation for anomaly detection, automated classification of anomaly type, and selection of appropriate response actions.

U.S. Bureau of Reclamation Projects

THE UNITED STATES BUREAU OF Reclamation (USBR) funded other notable projects. Trussell et al. (2017) showed that naturally occurring surrogates could demonstrate up to 3.6-log pathogen removal through an RO membrane. Another project developed strategies to minimize the formation of undesirable disinfection byproducts and to extend RO membrane longevity. With these projects, the City created a tiered membrane integrity monitoring framework and demonstrated O_3/BAC to be an effective pre-treatment method for controlling biological and organic fouling

Source: Courtesy of City of San Diego

Figure 2. Example uses of DPWF research

of membrane systems, independent of chloramines. A follow-up USBR project is evaluating the impact of bromamines on RO membranes (bromamines can shorten RO membrane life and lead to accelerated loss of salt rejection). The results of this project should benefit utilities seeking to minimize formation of trihalomethanes and/or meet stringent standards such as the California Toxics Rule. This research is also evaluating the use of preformed chloramines, which is expected to double the useful life of RO membranes.

San Diego's DPWF has been an invaluable tool for the City's potable reuse success and industry-changing research. If the past ten years are any indication of what the DPWF can accomplish, the facility's role in addressing future potable reuse challenges will be essential and exciting for years to come.

References

DEBROUX, J., M. H. Plumlee, and S. Trussell. 2021. *Defining Potential Chemical Peaks and Management Options*. Project 4991. Denver, CO: The Water Research Foundation.

PECSON, B. Forthcoming. *Integration of High-Frequency Performance Data for Microbial and Chemical Compounds Control in Potable Reuse Treatment Systems*. Project 4954. Denver, CO: The Water Research Foundation.

ROBINSON, K., J. Drewes, J. Oppenheimer, and V. Sundaram. Forthcoming. *Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications*. Project 4832. Denver, CO: The Water Research Foundation.

TRUSSELL, R. S., B. M. Pecson, A. N. Pisarenko, E. Y. Idica, E. W. Howe, and R. R. Trussell. 2018. *Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse*. Project 4765. Denver, CO: The Water Research Foundation.

TRUSSELL, R. S., R. A. Tackaert, A. N. Pisarenko, E. Y. Idica, R. R. Trussell, and J. Minton. 2017. *Realizing Reverse Potential for Potable Reuse: Demonstrating Enhanced Pathogen Removal*. USBR R16AC00132. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation.

Legionella Occurrence and Detection (4983)

***Legionella* species are part of** the normal ecology of public water systems and are frequently detected in regulatory-compliant drinking water. Despite the consensus that preventing the proliferation of *Legionella* is the responsibility of building owners and operators, water utilities may be implicated in outbreaks of Legionnaires' disease. Therefore, it is important that water utility operators have an understanding of *Legionella* occurrence within their distribution systems. *Evaluating Legionella Detection Rates and Occurrence by Distribution System Characteristics in a Community Water System* demonstrated a *Legionella* monitoring protocol at a public water utility and determined the occurrence of *Legionella* throughout the system. The project results provide recommendations for other water utilities interested in monitoring for *Legionella*. A sample communication resource that can be useful for water utilities interested in promoting prevention of Legionnaires' disease is also included.

CALENDAR

January 15–19, 2023
IWA International Conference on Water Reclamation and Reuse
Chennai, India
iwa-network.org/events/13th-iwa-international-conference-on-water-reclamation-and-reuse

January 22–25, 2023
NEWEA Annual Conference
Boston, MA
annualconference.newea.org

February 7–11, 2023
AWWA/HWEA Pacific Water Conference
Honolulu, HI
pacificwaterconference.com

February 12–15, 2023
NARUC Winter Policy Summit
Washington, DC
naruc.org/meetings-and-events/naruc-winter-policy-summits/2023-winter-policy-summit

February 13–16, 2023
NACWA Winter Conference
Sonoma, CA
nacwa.org/conferences-events/events-at-a-glance/2023/02/13/nacwa-events/2023-winter-conference

February 20–23, 2023
WWETT Show
Indianapolis, IN
wwettshow.com/en/home.html

February 20–23, 2023
AMTA/AWWA Membrane Technology Conference
Knoxville, TN
awwa.org/Events-Education/Membrane-Technology

February 22–24, 2023
MSSC Summit
Las Vegas, NV
multi-statesalinitycoalition.com/mssc-summit

February 21–22, 2023
World Water-Tech Innovation Summit
London
worldwatertechinnovation.com

March 5–8, 2023
WateReuse Symposium
Atlanta, GA
watereuse.org/news-events/conferences/2023-watereuse-symposium

March 14–16, 2023
AWWA Contaminants of Concern Symposium
Virtual
awwa.org/Events-Education/Contaminants-of-Concern

March 20–22, 2023
WEF Forum — Intensification of Resource Recovery
Cary, NC
wef.org/events/conferences/upcoming-conferences/forum-2023

March 21–24, 2023
AWWA NJ Annual Conference
Atlantic City, NJ
njawwa.org/page/AC23PREPAGE

March 28–31, 2023
WEF/AWWA Utility Management Conference
Sacramento, CA
wef.org/events/conferences/upcoming-conferences/utilitymanagement2023/?gclid=CjwKCAjws--ZBhAXEiwAv-RNL1Os-soh2opdoHMAnKlLlS5a-Ctwep6ehu5jiG6GjlhQNF0OUAUe2hoCS40QAvD_BwE

ADVANCES in WATER RESEARCH

WE'RE GOING DIGITAL-ONLY!

The relevant research and insightful articles you've come to rely on

Conveniently Available on Your Computer, Tablet, or Phone

advancesinwaterresearch.org

Be the first to find out about new issues by signing up for WRF's Announcements e-newsletter at www.waterrf.org/enews

THE Water Research FOUNDATION®

advancing the science of water®