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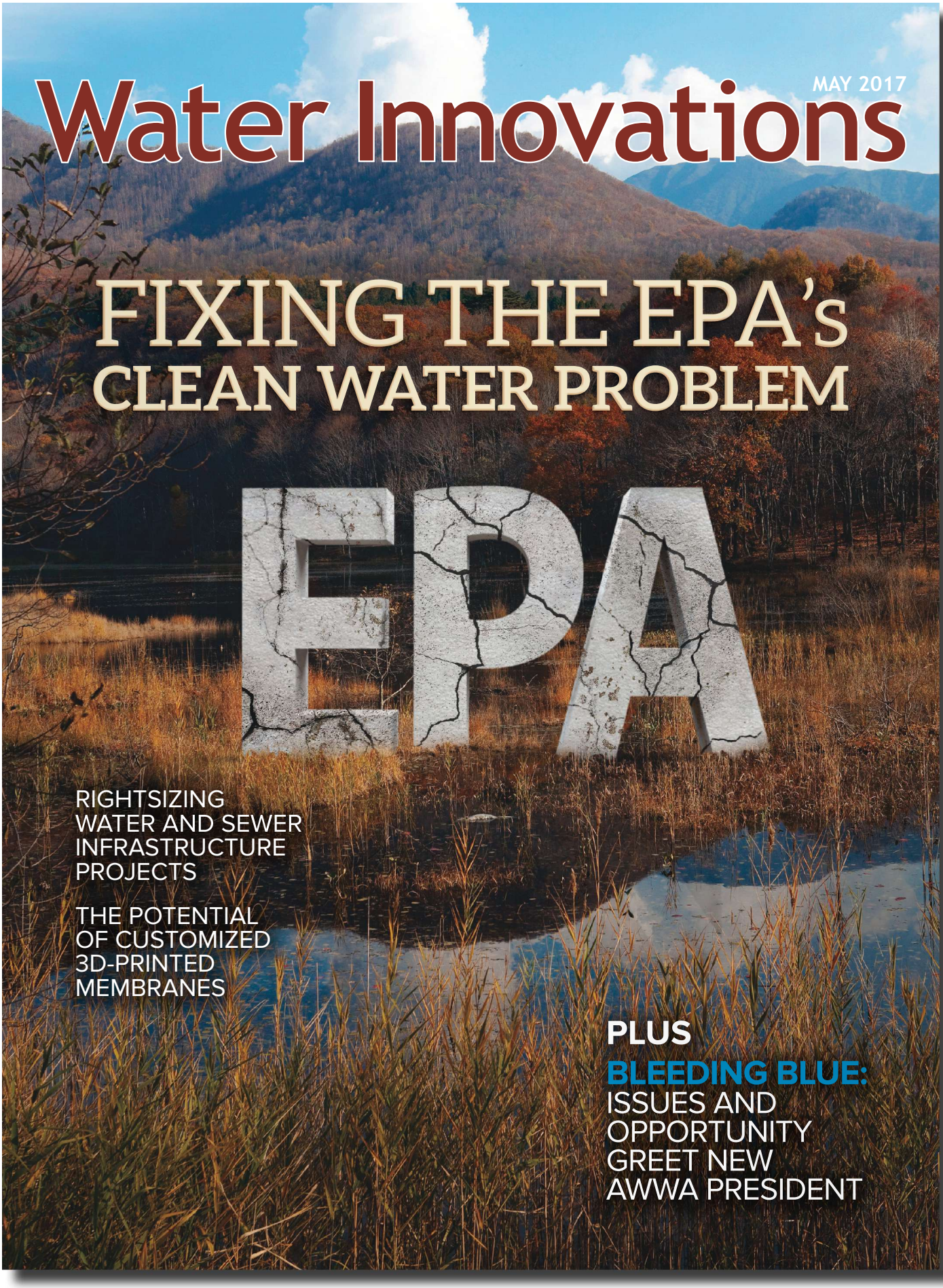

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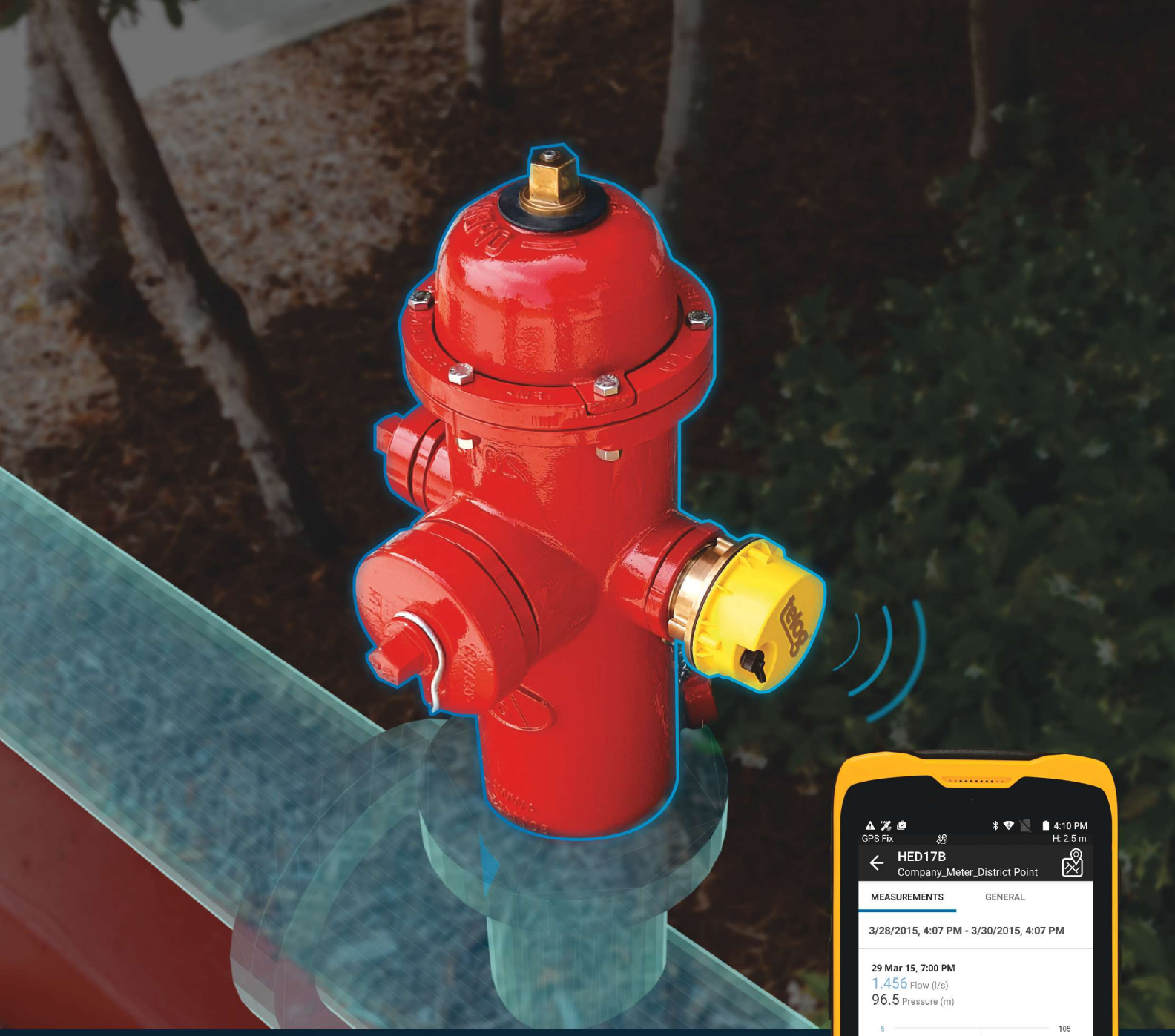

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EDITOR'S LETTER

By Kevin Westerling
Chief Editor, editor@wateronline.com

Bleeding Blue: Issues, Opportunity Greet New AWWA President

Airtime for water industry issues used to be a rarity in mainstream news, but that has changed of late — a development that is not particularly welcome, considering that bad news makes for good copy. ("If it bleeds, it leads.") The long shadow of Flint's lead crisis is still being cast over the industry, compounded by the American Society of Civil Engineers' 2017 Report Card that graded the U.S. a D+ overall (matching its last ASCE grade in 2013), including a D+ for drinking water and a D for wastewater. We had drought, then floods, emerging contaminants of concern — PFOS/PFOA, 1,4-dioxane, and hexavalent chromium all grabbed headlines — the upheaval of the U.S. EPA, and, in a bit of good news, some federal acknowledgement and action on infrastructure needs. To be sure, water is now a national storyline.

Which is all to say that this is an important time for the industry and, by extension, the American Water Works Association, its 50,000 members, and its new president (as of June), Brenda Lennox. After 26 years of service, Lennox recently retired as manager of customer and support services from the Tualatin Valley Water District in Beaverton, OR, and has since joined RH2 Engineering (Bothell, WA) as strategic relations manager. She is, therefore, no stranger to addressing questions or dealing with crises, suiting her perfectly for a Q&A on the state of the water industry in an era of rising consumer concerns and high-profile issues.

AWWA advocated strongly for the Water Infrastructure Finance and Innovation Act (WIFIA), which was finally signed into law. What impact do you project, and what is AWWA's next objective on the financing front?

It's still very early in the program, so it's difficult to project the impact it's going to have. But we've been working hard to facilitate contact between utilities and the EPA, so that they can discuss potential projects and submit letters of interest.

Certainly, the one thing we do know is that WIFIA's leveraging impact is enormous. Of the $17 million that's been made available to seed loans, WIFIA leverages federal dollars, so that for every dollar Congress appropriates, $50 to $60 is expected to be loaned out. That means up to $1.02 billion could be available for loans. That's a lot of capital projects that can begin moving forward. Our hope is that utilities will take advantage this year and demonstrate the need this program addresses, so that we can justifiably encourage Congress to increase funding even more.

Lead is another hot-button issue, drawing scrutiny since Flint. What is the current state of America's lead issue in terms of scope and potential for resolution?

A recent study that ran in the *Journal AWWA* showed that there are 6.1 million lead service lines (LSLs) still in use in the U.S. This number is a bit daunting, and it shows that overcoming this problem is not going to be easy.

Initially, resolving the problem is going to take strengthening the protections that we

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have in place today. AWWA's job is to help utilities implement proper corrosion control and to communicate properly with their customers on everything from filters to explaining the household action level.

Long term, we are advocating for a future where water doesn't come into contact with lead materials at all — meaning the removal of LSLs over time. Our goal is to help communities develop plans to do this in a collaborative manner that involves the utility, customers, public health officials, and other stakeholders.

As a longtime customer and support services manager, what lessons or advice do you have for utilities dealing with concerns such as contamination threats, the need for rate hikes, or other issues?

I can't say this enough — engage your stakeholders, media, and customers early and often. You need to form alliances and educate them on an ongoing basis. You need to have your customers' trust, so they know you're being good stewards of their money and that you take your job seriously in providing safe water. Create those relationships in advance of any problems.

I also recommend relying heavily on a team of experts from across the utility, including finance, engineering, communications, and customer service. Running a utility is not a one-team show — everyone plays a pivotal role.

> *"When we think of utility workers, I think we tend to focus primarily on the technical folks. But there's a ton of other work that goes into managing a successful utility, such as succession planning, customer analytics, communications, asset management, and finance."*
>
> **Brenda Lennox**, president-elect, American Water Works Association

What are the major utility management considerations of the day — those being addressed by AWWA's Management & Leadership Division, of which you have been a member?

I've always been a big fan of AWWA's Utility Management Conference, because it's the event that focuses on the nontechnical/operational side of the business. When we think of utility workers, I think we tend to focus primarily on the technical folks. But there's a ton of other work that goes into managing a successful utility, such as succession planning, customer analytics, communications, asset management, and finance. AWWA is in the process of trying to highlight the opportunities we have available for this group more effectively, and I'm so glad to see it. This is a whole part of the water profession that often gets overlooked, and we need to tell their story better, if for no other reason than because it will help us recruit new and different professionals into the water sector.

How about the role of AWWA's Diversity & Member Inclusion Committee, which you have also worked with?

When I first started working in the water sector almost 30 years ago, diversity wasn't something we focused on very much, and if we did, it was primarily to make sure women were better represented. Since then, it's been gratifying to see a lot of progress in expanding the idea of what diversity means.

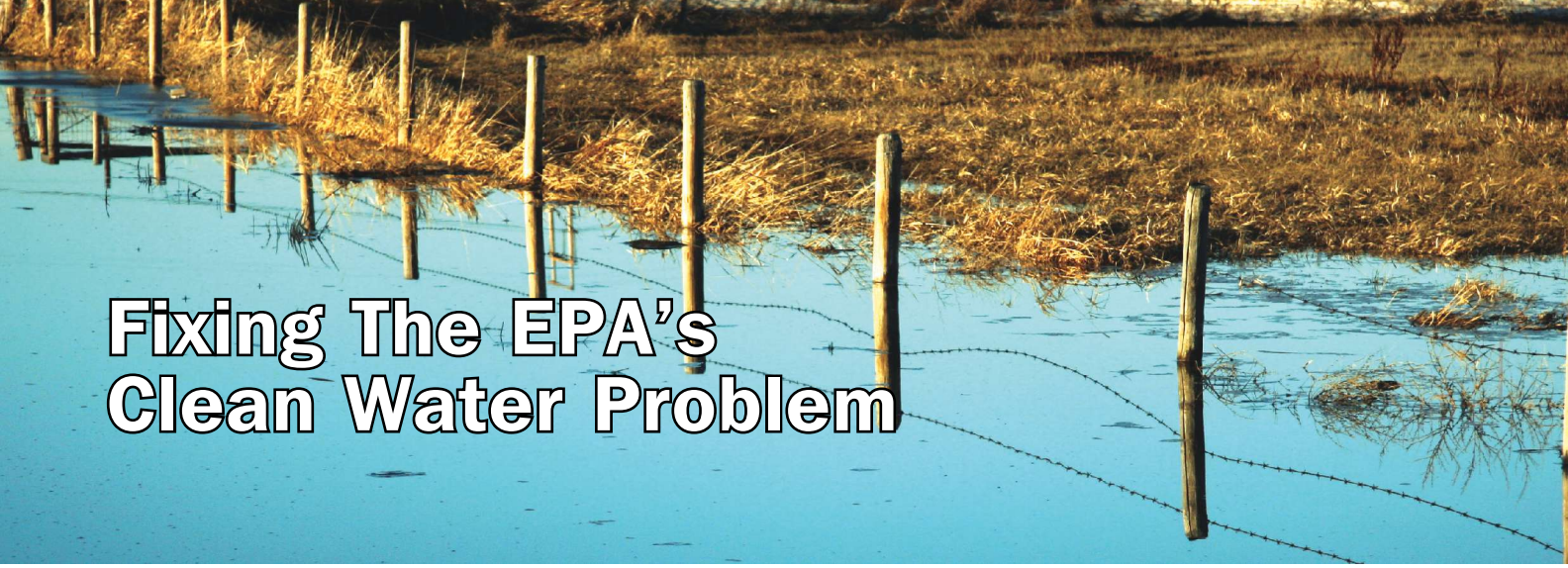
Over the past couple of years, my predecessor, Jeanne Bennett-Bailey, has focused on this extensively, and I've had members tell me how much they appreciate the work that she's done to elevate diversity and inclusiveness in our community. Fostering diversity and inclusion is even one of the core values in AWWA's current strategic plan, right up there with protecting public health and safeguarding the environment.

How would you characterize the current utility labor situation? Are you optimistic or worried about keeping utilities staffed with qualified personnel?

It's no secret that our workforce is aging, and the pool of qualified personnel is shrinking, but there are many options still available. There are many veterans available who already have the skills we need. There are young professionals (YPs), and for them many of the skills you need are second nature, even if they haven't done a specific job before. Plus, working in the water sector requires being committed to public health and a steward of the environment — YPs have demonstrated an interest in careers where they feel they are giving back. I'm optimistic, but I do have concerns as well. As we have turnover in senior staff and institutional memory walks out the door, there's going to be a blend of staff who have different values and work styles. It will lead to friction and changes, which can be uncomfortable. Some things may fall through the cracks, and it's definitely going to be different.

How is AWWA's Annual Conference & Exposition, ACE17 in particular, helping to shape the future course of the industry?

Given the current challenges we're facing, ACE17 offers a strong water quality focus. We're also working to expand the conference to appeal to a more diverse and international audience. And for me, I always look forward to the networking. As someone who's come from a nontraditional water background, having those relationships has been invaluable as I've navigated my career. The people you meet at ACE become both friends and your expert resources.



Fixing The EPA's Clean Water Problem

A chasm in the Clean Water Act, coupled with EPA's misguided direction, create an environmental suing spree that threatens to cost everyone that pays a sewer bill $100 billion and more – for pollution you didn't cause, using remedies that don't work. There's a way to turn this around and help the taxpayer and the environment, based on lessons learned in Iowa and Idaho.

By Mark Gibson

The year of the Apollo moon landing, *Time* magazine featured an arresting photo of the Cuyahoga River on fire, with flames leaping up from the water, engulfing a ship — a product of decades of pollution. The photo was actually taken in 1952, long before this transformational event that catapulted the environmental movement.

After 1969, the Clean Water Act became law, and we no longer see such carnage. Regulations on so-called "point sources" ratchet pollution so much that the industry now espouses "zero-emission" factories. But creating National Pollution Discharge Elimination System (NPDES) permits has done practically nothing to abate eutrophication and severe water impairment. The 'dead zone' in the Gulf of Mexico and rampant algae blooms in Lake Erie are caused by excessive nitrogen and phosphorus — biologic building blocks (nutrients) — arguably the most prolific threat to water.[1]

Nutrient pollution is staggering. Algae blooms in Lake Erie deprived 400,000 people in Toledo of water and forced $13 million in water treatment. Galveston Bay suffered $15 million in shellfish bed closures. For every 10 miles that red tides affect Florida coasts, their communities lose $5 million a week in tourism. The National Oceanic and Atmospheric Administration estimates that dead zones cost over $82 million per year in lost fisheries and tourism.[2,3] This is a worldwide problem, from the Baltic Sea to the Adriatic to the North Sea.

Mandates Miss The Point

The overwhelming source of this pollution is from so-called "nonpoint sources." In EPA parlance, a nonpoint source is anything that isn't a point source, i.e., anything without a discharge permit. The main cause of such nonpoint source pollution — the big elephant in the room that few wish to discuss — is agriculture. Agriculture is immune from the Clean Water Act, and few regulatory teeth exist to bite on other nonpoint sources, like golf courses, septic tanks, or dog poop.

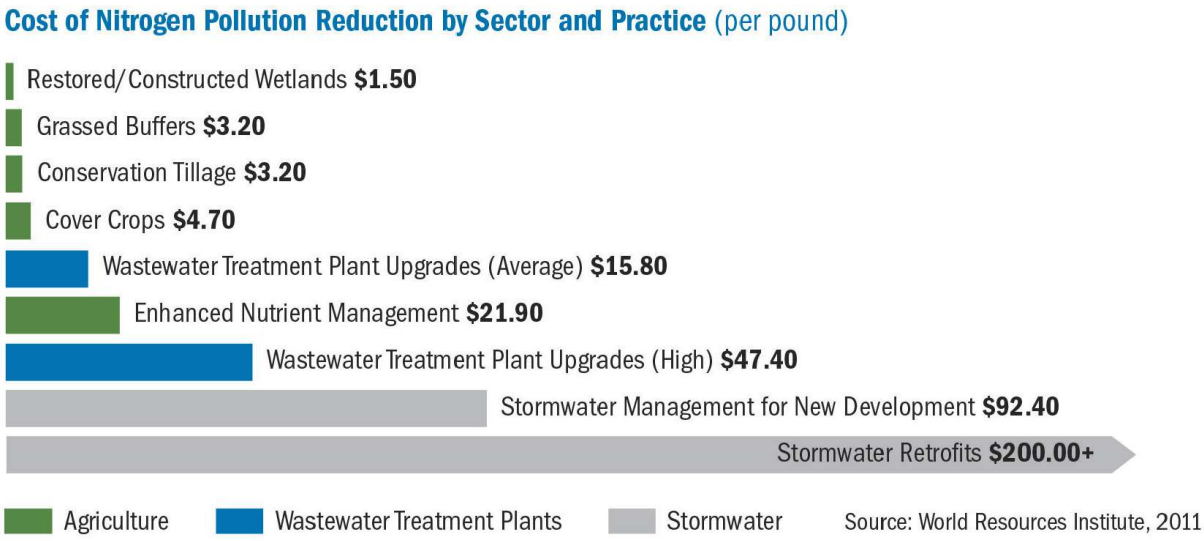
None of this is lost on environmentalists. Since the turn of this century, the water litigation tool of choice has been the 303(d) impairment suit. Enviros' 303(d) claims have amassed $80 billion in consent decrees against municipalities (that is, you and I), forcing construction of advanced sewage treatment and stormwater controls. The movement has leveraged total maximum daily load (TMDL) regulations, properly coined "Too Many Damned Lawyers." It tries to force remedies for the Gulf of Mexico or any place where fish or fauna are harmed. As we saw during the Reagan Administration, during the Trump Administration we can expect environmental organizations to enjoy record fundraising, fueling a tidal wave of lawsuits. While litigation and public costs mount, it's not doing much good.

Take the Chesapeake. Since 2003, about 500 sewage plants along the bay were forced to purchase $7 billion in upgrades, decreasing their phosphorus and nitrogen loads by 29 and 39 percent, respectively.[4] Yet today, only 37 percent of the bay meets water quality standards, and 74 percent of the tidal segments have partial or full impairments, while 40 percent of the nutrient loadings are from agriculture and 19 percent from sewage plants (which load less nutrients than out-of-basin air pollution).[5,6]

A vexing aspect of EPA regulation is how liability for nonpoint pollution shifts to point sources. Under EPA guidance, "There must be reasonable assurances that nonpoint source reduction will in fact be achieved. Where there are not reasonable assurances … the entire load reduction must be assigned to point sources."[7] As a Park Foundation grant beneficiary from the University of Alabama School of Law relates, "Eventually, you end up with a horrible situation where you're not complying with water quality standards, and the only choice is to make the point sources comply even more, or clean up their act even more at incredible cost, or to do more enforcement against the point sources."[8]

Yes, that's right: Via wastewater bills, you and I get to pay for agriculture's pollution.

A few years ago, Denver's wastewater authority was accused of impairing the South Platte River. Spurred by environmental litigation, the city was forced to buy advanced nutrient removal technologies for an extra $211 million.[9] Denver wastewater officials testified, "In nutrient-impacted watersheds where point



sources are a *de minimis* contributor ... it will be exceedingly difficult for ... utilities to garner community support and funding for expensive treatment technologies that result in little to no improvement in overall water quality. ... This is especially evident in the Gulf of Mexico and Chesapeake Bay."[10]

The Iowa Example

In Iowa, a few dozen miles upstream of Des Moines, lay the most productive corn and soybean farming in the world. Called the Des Moines Lobe, it also produces the largest nutrient loads to the Gulf of Mexico.[11] Not surprisingly, the Des Moines River's average nitrate level veers to 13 mg/L, compared to EPA's maximum limit 10 mg/L.[12] The City of Des Moines uses this river for drinking water; its utility spends up to $7,000 daily for nitrogen treatment to produce legal drinking water. Another $180 million may be needed to treat the farm-impacted water.[12] Ironically, a few miles downstream of Des Moines' river intakes, their wastewater authority spent $1 billion for upgrades to reduce emissions.

So costly is Des Moines' plight that its Water Works' CEO (an attorney), Bill Stowe, is spearheading a groundbreaking lawsuit against upstream counties governing agricultural drainage districts in order to stop the districts' nutrient releases. A true leader among water authority administrators, Stowe has stoked a virtual war in corn country: Big City vs. Rural Agriculture.

Yet, six months before Des Moines filed suit, a few miles from Stowe's office, another brilliant leader, Dean Lemke, worked to address the problem at the Iowa Department of Agriculture and Land Stewardship. Lemke directed a precedential assessment of edge-of-field and on-farm nutrient reduction techniques when he published the Iowa Nutrient Reduction Strategy. Apparently ignored by regulators was the report's finding that constructed wetlands can reduce nitrogen loads for $2,800 per ton, bioreactors can do so for $1,800 per ton, and controlled drainage management and buffers work at $2,500 to $3,800 per ton.[13] The report acknowledged that 130 of Iowa's wastewater plants will be permitted to reduce nitrogen for about $6,800 per ton — in order to decrease statewide loads 4 percent.

Why are Iowa's ratepayers subsidizing expensive sewage technologies for a mere 4 percent reduction? Such a scheme is like an elephant giving birth to a gnat: implausible and painful to watch.

Based on the state's figures, if Iowans were to subsidize farm-centric mitigation rather than end-of-pipe wastewater technology, nitrogen loading could decrease threefold. As the EPA's Iowa "regulate the wastewater plants" strategy inevitably fails, Iowans should expect their costs to go even higher as regulations spiral; engineering and construction firms win, farmers take flak, Iowa and the environment loses — just like the Chesapeake.

Cost-Effective Accountability

The economic elegance of mitigating nutrient sources near to the farm is bootstrapped by additional science.

Engineers from powerhouse Black & Veatch calculated what it would take to cut nutrients in the Illinois River Basin with simple near-stream treatment plants. Reducing nitrate loads to the Gulf of Mexico by up to 20 percent was estimated to require merely $760 million, at less than $2,000/ton of nitrogen removed.[14] By comparison, Rockford, IL, spent an extra $30 million to remove about 3 mg/L of nitrogen, a marginal cost of around $5,000/ton.[15] In the Chesapeake, enhanced nitrogen removal at sewage plants has cost $6,000/ton.[16]

The Wetlands Initiative in Illinois analyzed seven Chicago wastewater plant upgrades. They determined 200,000 acres of passive wetlands would save $1.6 billion, compared to Chicago's retrofits.[17] From the National Association of Clean Water Agencies, "The cost to remove a pound of nitrogen or phosphorus from farm runoff and drainage is typically 4-5, sometimes 10-20, times less than the cost to remove the same amount from municipal wastewater or stormwater."[18]

Confounding environmentalists is the reality that as EPA

regulators force ratepayers' wastewater upgrades, greenhouse gas emissions increase. Regulating nitrogen releases below 3 mg/L decreases nutrient loads by 1 percent, while increasing greenhouse gas emissions 70 percent.[19] In the interest of the environment, when it comes to sewage regulation, we have come to the point of diminishing returns.

The Idaho Example

The saneness of nonpoint source cures is proven — under EPA permit — in Idaho. A growing city surrounded by phosphorus-rich farmland, Boise faced regulatory pressures on its sewage plant expansion. Avoiding costly conventional upgrades, the city devised a plan to treat agricultural runoff with simple alum-based dosing. Their Dixie Drain facility opened this year at a cost of $17 million, in lieu of spending $55 million for high-tech wastewater treatment. It only took Boise a decade with continuous congressional prodding to force EPA to agree to the innovation.[20]

This suggests a better way of doing business: Call it nutrient farming or nonpoint source mitigation; it's really nutrient pollution offsets. As Boise shows, point sources should be encouraged to meet permit obligations with nonpoint source *offsets* — similar to Clean Air Act offsets.

Let's get real. Regulating agriculture is off the table; it's not going to happen in our lifetime — outside of a few communal conclaves in California. Barring a game-changing legal precedent out of Des Moines, the reality is that farmers will do what we pay them to do. It is economically and environmentally inefficient to expect otherwise.

A Path Forward

Conventional-thinking engineers argue that wetlands and bioreactors won't offset pathogenic and other releases. Granted, but hybrid solutions controlling nutrients and pathogens collectively (basinwide) will maximize environmental quality at least cost — better than being held hostage to capital-intensive, high-tech contraptions tied to massive billable hours for consulting firms. New thinking and modern monitoring will remedy the challenges of aggregating and policing nonpoint source methods, as demonstrated by Dean Lemke's amazing achievements at the Iowa Department of Agriculture and Land Stewardship — where the country's most comprehensive plot-specific inventory of near- or in-field agriculture mitigation opportunities has been amassed.

It's long past time for a new model. EPA must aggressively encourage NPDES permit holders with nutrient liabilities to employ offsets with simple, verifiable technologies. This must not be confused with "nutrient banking" or "water quality trading," where environmentalists have hijacked these convoluted schemes and diluted them with "trading ratios" to foster perpetual condemnation of agricultural land.

We all eat food, and we're all part of the nutrient cycle. If sewage fees are a proxy for our collective nutrient pollution, then (ratepayers') wastewater authorities must be encouraged to seek least-cost paths to reduce basinwide pollution. EPA and its guidance should help leaders like Lemke and Stowe work together. As such an approach improves our water, support for environmental fundraising and 303(d) litigation evaporates. ■

New thinking and modern monitoring will remedy the challenges of aggregating and policing nonpoint source methods.

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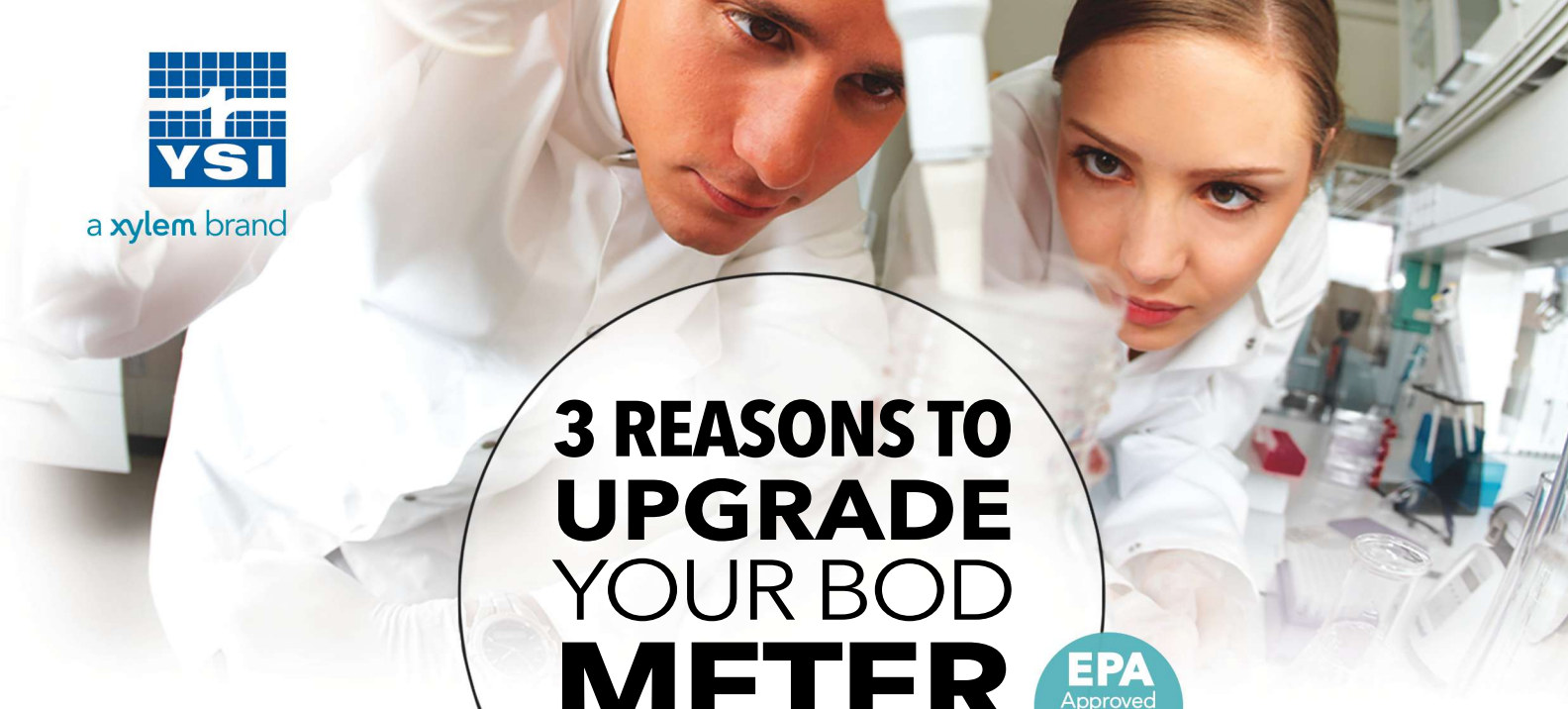

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Two case studies prove that the key to cost-effective condition assessment is choosing the right approach for your system.

By Daniel Buonadonna and Tammy Cleys

Aging infrastructure and infrastructure spending are two hot topics in the news today. Given that much of the United States' infrastructure is aging and reaching the end of its useful life, many municipalities and water/wastewater utilities recognize the cash infusion needed to update, repair, or replace their water infrastructure. In the U.S. alone, an estimated 240,000 water main breaks occur every year; addressing this issue is estimated to cost in the hundreds of billions. Wastewater and stormwater systems need attention, too, with an estimated cost of nearly $200 billion over the next 20 years.

For centuries, centralized large-diameter wastewater interceptors and large-diameter drinking water transmission lines have frequently been the backbone of a municipal system. Today, we are seeing many large-diameter pipelines that have been in service well past their design life fail, which is why sinkholes, pipe collapses, and overflows are making the local headlines frequently. The consequences of pipe failures to the communities, including fines cities must pay, are significant.

By quantifying the likelihood of failure (in time) and reducing all the consequences of failure, as well as the potential alternatives down to triple bottom-line costs (in dollars), much of the subjectivity of other alternative analysis methods is avoided.

Portland Trailblazing

To prevent these types of problems from occurring in wastewater collection systems, many cities and utilities are taking proactive steps. By implementing asset management programs to assess the condition of their large-diameter pipelines, they are addressing problem areas before they become worse. The City of Portland, OR, is one utility that has established an asset management team and invested in a strategy to identify the pipes with the highest risk exposure and prioritize between urgent projects by determining which rehabilitation approach provides the greatest value.

The city put its strategy to the test on one of its aging brick sewers, the Taggart Outfall 30. Constructed in 1906, the 7,600-linear-foot (LF), 66 to 120" brick sewer was used to replace cesspools, helping reduce the death rate from typhoid fever and other infectious diseases in Portland's densely settled neighborhoods. At the time, with an initial budget of $250,000, it was the largest diameter and most expensive sewer Portland had constructed. Over the past century, the city's Bureau of Environmental Services has continued to utilize this asset with multiple retrofits that allow the tunnel to function today as a critical piece of the combined sewer infrastructure, rerouting wet weather flows through different diversion structures and relief sewers.

In 2014, the city engaged CH2M to perform a condition assessment to evaluate rehabilitation alternatives that could provide a long-term solution to the historic pipeline. The unique characteristics and large dimensions of the outfall allowed a broad range of trenchless technologies to be considered, including tunnel rehabilitation technologies. To address the city's challenges and find the "right-size rehabilitation" plan, a net benefit cost ratio (NBCR) approach, which took into consideration the consequence of failure, likelihood of failure, and cost of alternatives, was used to evaluate the life cycle costs and risk mitigation for each rehabilitation strategy.

The outcomes of the NBCR calculation and evaluation method were sufficient for the City of Portland to make an informed

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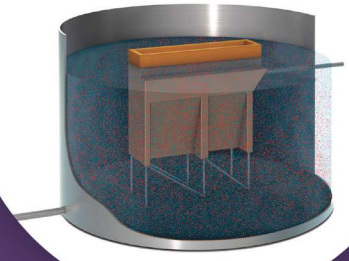

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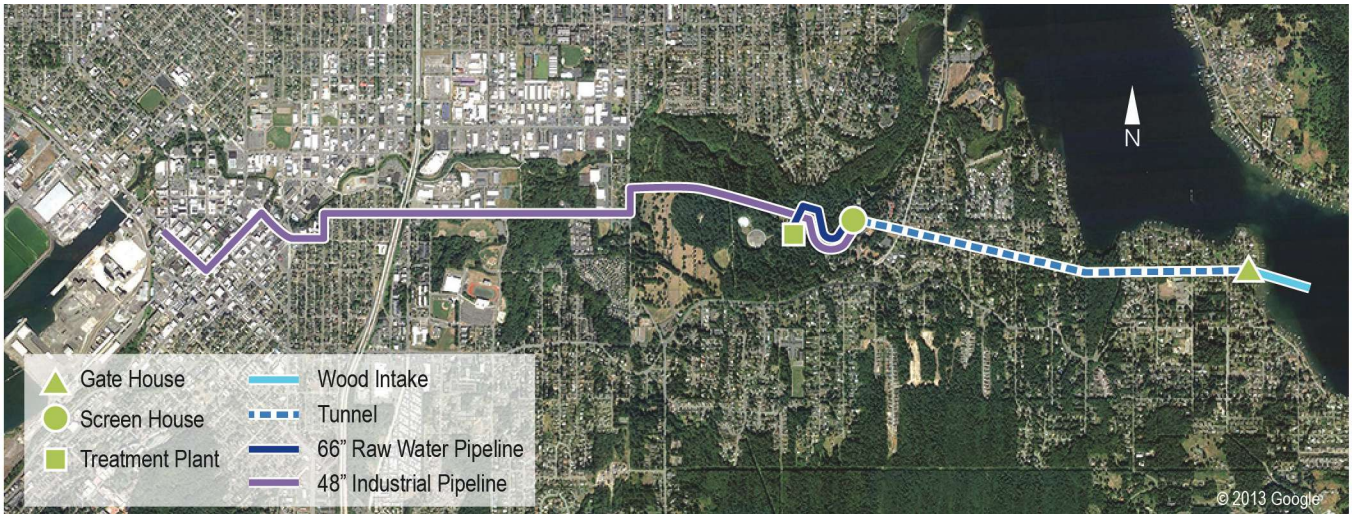

City of Bellingham water supply facilities

and valid alternative selection. By quantifying the likelihood of failure (in time) and reducing all the consequences of failure, as well as the potential alternatives down to triple bottom-line costs (in dollars), much of the subjectivity of other alternative analysis methods is avoided. While the Taggart Outfall 30 project team moves forward into design, the Portland Bureau of Environmental Services is continuing to refine and improve their powerful NBCR asset management tool.

Tiers In Bellingham

For drinking water assets, the City of Bellingham, WA, is another example of a city taking proactive steps to address its aging water system. Constructed in 1939, the city's five-mile buried water supply system, which consists of a 66" wood stave intake pipe, a 78" hand-dug tunnel, and 48"/68" concrete cylinder supply pipelines, was constructed to take raw water from Lake Whatcom and convey it to the city's 24-MGD Whatcom Falls Water Treatment Plant. For the eight decades it has been in use, the system has reliably served the city.

In an effort to extend the system's useful life, the City of Bellingham engaged CH2M to perform a condition assessment of the intake system between Lake Whatcom and the treatment plant.

Undertaking this thorough condition assessment was an important component of the city's approach to characterize its assets, identify the key repairs needed, and prioritize the repairs with the available budget and resources. A tiered approach with three levels of assessment was utilized for the condition assessment.

- Tier 1 assessment represents the first-level, least-invasive, and least-costly methods of inspection, such as non-destructive and visual testing.
- Tier 2 efforts would be warranted if issues or concerns are discovered during the Tier 1 assessment. Tier 2 activities primarily include methods such as excavation of test pits and collection of pipe materials or samples. Entry into the interior of the pipe could be considered a Tier 2 activity if access is readily available or reasonably feasible without major modification.
- Tier 3 activities, if warranted, could be considered upon completion of Tier 2 activities and evaluation of those results. Tier 3 activities involve deploying instruments within the pipe and/or removing the asset from service and conducting a manned entry examination of the interior of the asset. Tier 3 activities are typically the most costly to implement of the three tiers of assessment activities.

Applying the same approach to each of the city's buried water assets, the tiered approach provided a cost-effective way to assess the condition of the whole intake system within the budget constraints of the city and provided meaningful data on what steps the city must take to keep its water infrastructure functioning properly. While Bellingham's existing intake system remains useful and in relatively good condition, preserving the long-term usable condition of this system and others like it will require regular monitoring, inspection, analysis, improvements, and target replacement of key elements.

To stay ahead of the problems associated with deteriorating aging infrastructure, condition assessment and rehabilitation is a critical component of a pipeline asset management program. As these case studies demonstrate, it is equally as important to select a "right-size" condition assessment strategy to identify the most cost-effective method. Thoughtful implementation of such a program is necessary to avoid overspending on inspection and overanalyzing the system beyond what is necessary to provide our cities with a high level of service, while managing acceptable risks and minimizing costs to ratepayers. ■

About The Authors

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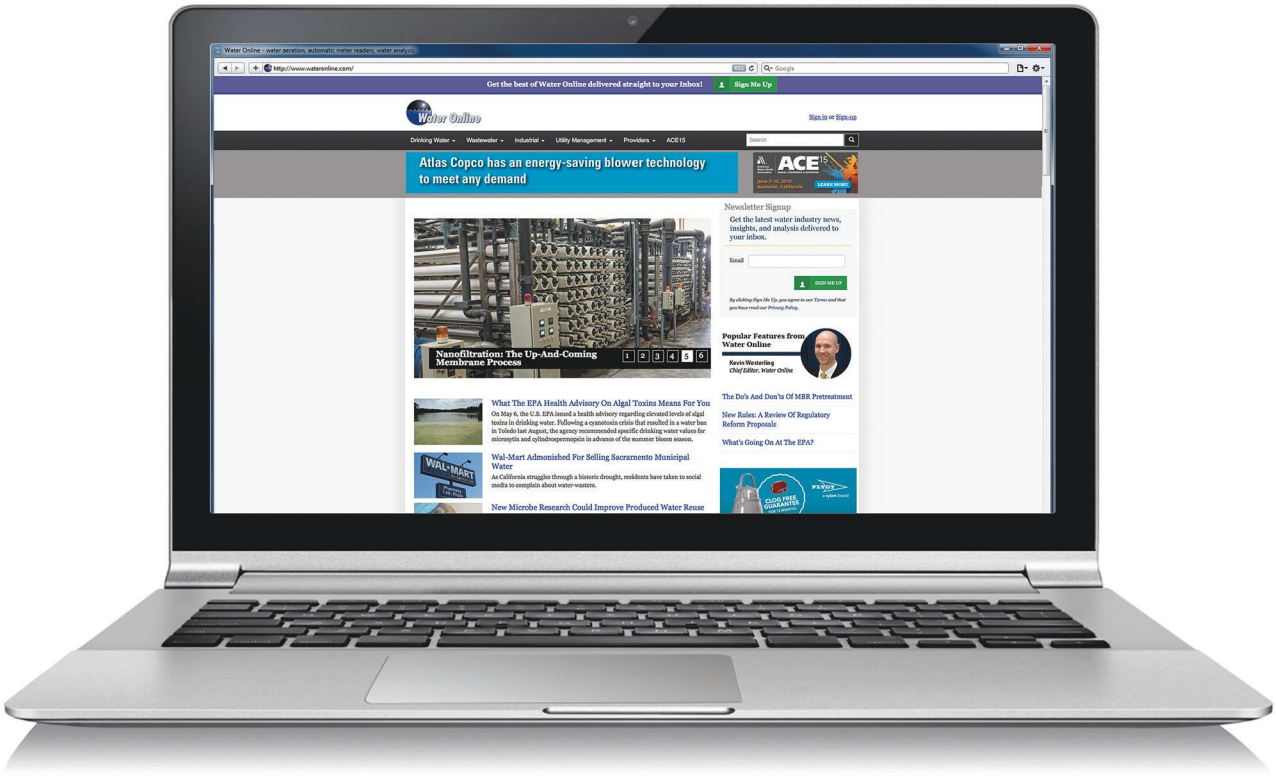

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The Science Of Public Outreach – And Successful AMI Deployment

As consumer buy-in is critical to the success of advanced metering infrastructure, so is behavioral science, in guiding utilities' engagement efforts around the technology.

By Sapna Mulki, Mike Clark-Madison, Shelly Gupta, and Ryan Orendorf

Advanced metering infrastructure (AMI), commonly referred to as "smart meter" technology, is currently far more prevalent in the electric sector than in water; however, a number of water utilities are increasingly considering the ways in which the technology can improve their operational efficiency. AMI allows utilities to track resource usage on a near real-time basis, which allows for better leak detection, demand-response management, billing accuracy, and effective revenue collection. Some utilities are also beginning to realize the benefits of improving customer satisfaction using AMI; however, this role for AMI is often overlooked or viewed as secondary.

The water utility industry also realizes the need to prioritize "[p]ublic understanding of the value of water resources" and "[p]ublic understanding of the value of water systems and services" (AWWA, 2016). In a 2013 report, Bloomberg New Energy Finance predicted that U.S. water utilities will spend $2 billion on AMI through 2020 (Doom, 2013). This article focuses on the value that communications campaigns add to AMI investments by improving adoption of the technology and encouraging behavioral changes.

Creating desired behavioral changes, as opposed to simply publicizing the availability of AMI, requires going beyond traditional public information strategies for utilities.

The Benefits Of AMI Technology

Diffusion of new technologies has enabled consumers to gain access to, and utilize, a wider range of information than ever before, allowing them to better understand trends, habits, and choices and thus make more informed decisions that can improve their well-being. Technologies such as activity trackers (Fitbit), home automation hubs (Amazon Echo), and smart thermostats (Nest) have been adopted, after being marketed as devices that empower the consumers, by giving them data-driven insights into their own habits and behaviors.

Water and electric utilities can now make similar technology available, but they are grappling with how to encourage a similar level of customer adoption and engagement. AMI helps utilities to connect with customers to share data about, and improve understanding of, water and energy usage at the residential and commercial levels. From the customer perspective, AMI represents an evolution of existing Internet of Things (IoT) technologies that already inform their water and energy usage, such as bill and data usage alerts to online accounts and mobile devices or remote management of building temperatures or security control systems.

Since fully realizing the potential of AMI relies on customer engagement — not just adopting, but interacting with, the technology — AMI is being promoted as a tool to improve customer satisfaction. However, AMI also offers more direct operational advantages to utilities, such as:

1. Detecting leaks and occurrences of water theft
2. Promoting education on conservation at the residential and commercial levels
3. Building a sense of ownership and accountability among customers
4. Reducing operational costs from outdated methods of data collection and billing
5. Revenue realization through accurate billing
6. Targeted water efficiency messaging
7. Overcoming billing shock or surprise

Challenges To Implementing AMI Technology

While there are tangible benefits from AMI adoption, it requires a financial investment from utilities to pilot-test the technology (if they decide to go this route) and conduct cost-benefit analyses. Furthermore, changing over to new interfaces and learning new systems can be a significant barrier to overcome, especially for smaller water utilities. Electric utilities have made these investments more quickly; the U.S. Energy Information

Administration reported that by 2014, "U.S. electric utilities had about 58.5 million [AMI] installations. About 88 percent were residential customer installations" (EIA, 2016). On the other hand, in the water sector, AMI "remains a rarity in the U.S., accounting for less than 20 percent of the roughly 100 million water meters nationwide" (Wang, 2015).

One challenge to adoption of AMI is public opposition driven by both health and privacy concerns. The former is linked to perceived health risks associated with the radio frequency electromagnetic fields generated by AMI smart meters, although the Federal Communications Commission has concluded that there is no evidence confirming that these risks exist. As for privacy, opponents often spread the fear that AMI hardware will transmit personal data that allows "Big Brother"-like government authorities to monitor the activities of citizens.

Given that this kind of opposition to AMI has been well-documented, utilities must embark early upon awareness campaigns that explain the true capabilities of the technology and help minimize sensationalist attacks that overemphasize phantom risks. This will alleviate customers' concerns and help them to realize that AMI can add value to their lives and not just to utilities' bottom lines.

Behavioral Science Models For AMI Adoption

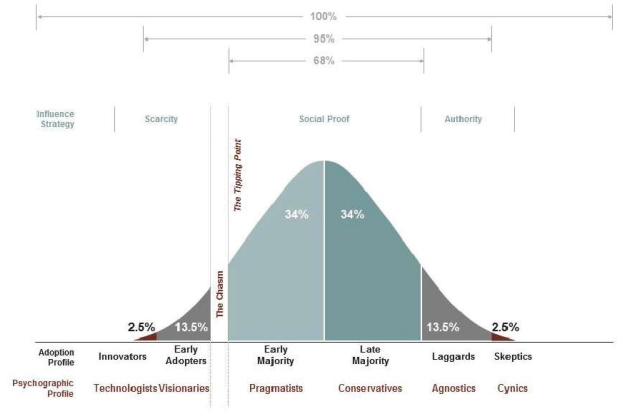
Creating desired behavioral changes, as opposed to simply publicizing the availability of AMI, requires going beyond traditional public information strategies for utilities. Research shows that campaigns that are focused merely on informing and educating customers, or even appealing to their economic self-interests, are less effective than those designed to appeal to the cultures, values, and principles of target audiences (McKenzie-Mohr, 2000). Behavioral science models can provide a holistic and strategic framework for developing and delivering programs encouraging public engagement and empowerment.

Diffusion Of Innovation

Developed by communication scholar and sociologist Everett Rogers in 1962, the Diffusion of Innovation Model seeks to explain how, why, and at what pace new ideas and technologies, such as AMI, are adopted by a given population.

Different segments of that population, as defined by Rogers, fall along the model's curve based on their disposition to adopt innovations:

1. Innovators (2.5 percent) — the technologists who are eager to learn and curious to experiment with new ideas, even if doing so involves the risk of failure or disappointment
2. Early Adopters (13.5 percent) — visionaries who seek ways to improve their lives and learn from innovators about ideas and technologies that are worth adopting
3. Early Majority (34 percent) — the pragmatists who want to see and assess ideas and technologies based on feedback from innovators and early adopters, before they choose to commit (Reaching the early majority — "crossing the chasm" — is often viewed as the most difficult phase in the diffusion process.)
4. Late Majority (34 percent) — more conservative individuals who wait to adopt new ideas or technologies until they become pervasive enough that *not* adopting them creates its own risks and costs
5. Laggards (13.5 percent) — individuals more likely to be agnostic or apathetic about innovations and see no benefit in adopting them until the new ideas or technologies are nearly outdated
6. Skeptics (2.5 percent) — cynics who are actively suspicious of new ideas or technologies, and who may take action to resist their adoption by others



Diffusion of Innovation Model (Sources: Rogers [1962], Cialdini [1984], Gladwell [2000], and Maloney [2010])

As messages regarding an innovation are disseminated, they are processed by target audiences in five stages:

1. Knowledge: gaining awareness about the technology
2. Persuasion: forming an opinion on the technology
3. Decision: making a choice on whether to adopt or reject the technology
4. Implementation: putting the technology to use
5. Confirmation: seeking assurance for the decision to adopt the technology

Core Motives Model

In his seminal work, *Influence: The Psychology of Persuasion,* Dr. Robert Cialdini identifies and fully describes six principles (or "weapons of influence") of ethical persuasion, driven by three core motives — building relationships, reducing uncertainty, and motivating action.

The Core Motives Model offers great guidance to communicators in sectors like utilities, to shape behavioral change campaigns, and in fact, has been used directly for that purpose. Since the 1980s, Cialdini has helped to develop pro-environment messaging for campaigns that focus on finding the "sweet spot" where utilities can create the greatest level of

behavioral change for the least amount of effort and money.

Scarcity is a uniquely relevant principle for messaging to support energy efficiency and water conservation programs. Cialdini notes, "The idea of potential loss plays a large role in human decision-making. In fact, people seem to be more motivated by the thought of losing something than by the thought of gaining something of equal value" (2007). During times of drought, usage drops because people appreciate water more because it is scarce and recognize a threat to themselves if they do not conserve water for the future.

Community-Based Social Marketing

Developed by Dr. Doug McKenzie-Mohr, community-based social marketing (CBSM) is a behavioral change model based on goal-setting (Sheehy, 2004), creating a sense of community, and inspiring concerns for the environment (Anda et al, 2013) among end users.

The first step in CBSM is to identify behaviors that are "non-divisible" and "end-of-state." For example, "adopting water efficient measures to reduce lawn irrigation" can be further divided into specific nondivisible behaviors, such as installing automatic sprinkler systems or replacing lawns with drought-resistant plants. These can also be end-of-state behaviors, which are those that lead to defined and final outcomes.

Once nondivisible and end-of-state behaviors are identified, the second step in CBSM is to identify both the benefits of and the barriers to these actions. The third step, developing strategies to maximize benefits and overcome barriers, incorporates consideration of the following elements:

1. Commitment: gaining support from potential advocates
2. Prompts: friendly reminders to take actions that are positive, noticeable, self-explanatory, and in close proximity to where and when the actions must be taken
3. Norms: drawing on the likelihood of people to follow suit when witnessing others engaging in desired behaviors by actively publicizing those behaviors to help reinforce norms (McKenzie-Mohr [2011] observes the most effective strategy for reinforcing norms is one-on-one contact.)
4. Social diffusion: facilitating the adoption of new behaviors, using the strategies based on Rogers' work, by showing that peers and influencers (early adopters) have already done so, through public advocacy and publicity
5. Communication: persuasive messaging (often framed by the scarcity principle) tailored to the target audience, deployed by respected figures and ideally by personal contact, with opportunities for audience feedback
6. Incentives and disincentives: shown to be more sustainable when not monetary — for example, recognition or other means of gaining social approval
7. Convenience: identifying and overcoming external barriers that deter people from making behavioral choices that they would otherwise consider

The fourth step in CBSM is to pilot the campaign to test both its feasibility and effectiveness. The findings from this experimental deployment guide the final step of bringing a campaign to scale to achieve its desired outcomes.

Social Norms Marketing

Social norms marketing (SNM) offers an alternative way of deploying theoretical insights regarding persuasion in the kinds of behavioral change campaigns that meet the needs of utilities. In 2013, East Bay Municipal Utility District (EBMUD)

Influence: Core Motives

Motive	Persuasion Principle	Activation	Amplification
Building Relationships "Why should I trust you?"	**Reciprocity** (beginning)	Gifts and concessions	When gifts are significant, personalized, and unexpected; concessions work best when retreating
	Liking (strengthens)	Similarity, praise, and cooperation	Liking the one you're with
Reducing Uncertainty "Why should I consider your offer?"	**Consensus** (style and preference)	By evidence of how others are thinking, feeling, and acting	Offering evidence from many others, similar others, and by using uncertainty.
	Authority (evidence)	Trappings — the cues of authority	Establishing credibility, demonstrating expertise and trustworthiness
Motivating Action "Why should I act now?"	**Consistency** (internal)	By commitments, prior choices, or stands	By commitments that are active, public, and voluntary
	Scarcity (external)	Info suggesting something is rare or dwindling in availability	Loss framing, competition, exclusive information

in California initiated a year-long pilot SNM campaign to promote household water efficiency. The developers of that campaign describe SNM as follows:

> *The central idea behind social norms marketing is that much of people's behavior is influenced by their perceptions of what is "normal" or "typical." According to social norms theory, if people are shown that their behavior is outside of the norm or that their perception of the norm is incorrect, they will be motivated to change the way they behave so they conform more closely to the norm. (Mitchell et al., 2013)*

In order to test the effectiveness of the SNM model, EBMUD sent Water Reports (HWRs) to 10,000 homes by mail and email. These reports shared data tailored to household water consumption, provided comparisons with similar households to encourage social competition, and rated each household's performance as "great," "good," or "take action," with corresponding images illustrating happiness, neutrality, and sadness.

Behavioral science offers tangible solutions, not only to raising awareness, but changing behavior, and it does not take much financial investment if done right.

Results from the EBMUD pilot program were significant, with an average reduction in water usage of five percent across all 10,000 households. When customers were compared with similar households, they not only became competitive (an effective element of Cialdini's scarcity principle), but also developed the perceptions that all of the other customers were making efforts to improve their water scores (reflecting Cialdini's consistency and consensus principles).

Conclusion

Introducing a new technology requires a communication campaign designed with an understanding of the target customers' values, perceptions, and behaviors. In the case of AMI, utilities often struggle to encourage customer uptake of the technology. Behavioral science offers tangible solutions, not only to raising awareness, but changing behavior, and it does not take much financial investment if done right.

The AMI technology offers a promising path toward helping the utility realize greater efficiency, and also help it engage with the customer more, by offering data that can inform outreach and awareness based on insights from the behavioral sciences.

The insights into human behavior, perceptions, and attitudes offered by behavioral science can help shape smart communications and outreach campaigns that resonate with target customers — increasing social and environmental awareness, and appreciation of public services offered by water and electric utilities.

*View the full report and case studies at www.hahnpublic.com. ■

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As the leader of Hahn Public's water practice area, Sapna Mulki (Director, Water Utilities) consults with clients on water issues ranging from conservation outreach to rate structure communication. Sapna has over 10 years of expertise in water finance and policy and environmental education and policy. She holds a Bachelor of Arts in environmental studies and international relations from Eckerd College and a Master of Arts in sustainable international development from Brandeis University.

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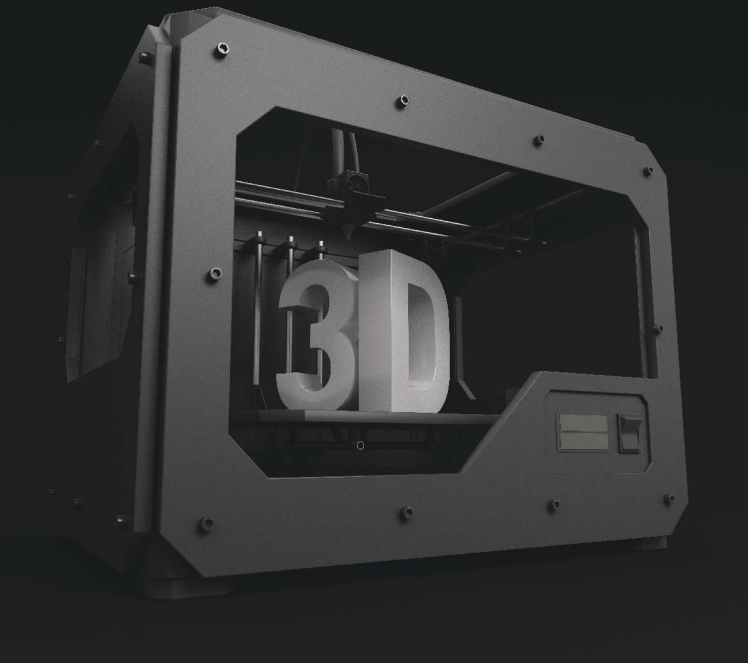


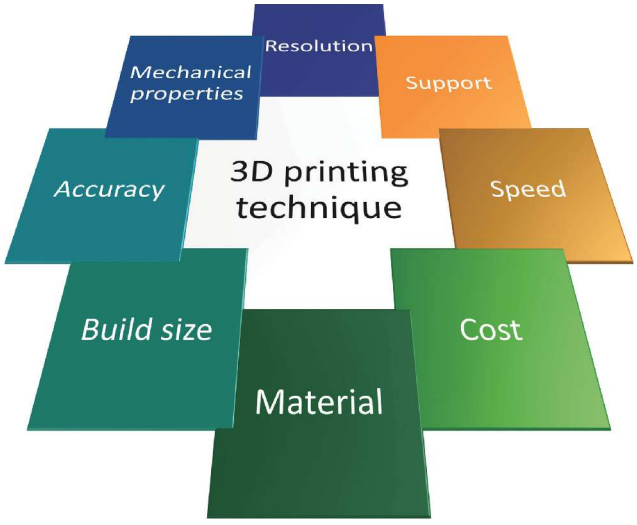
The Potential Of Customized 3D-Printed Membranes

Researchers have begun to explore the idea of 3D printing as a way to manufacture membranes. What could the cutting-edge technology mean for water and wastewater treatment?

By Peter Chawaga

3D printing appears to be the next horizon in production. It is a process in which a computer directs successive layers of material to accrue and form an inputted design. Traditional manufacturing, which relies on molds and fixed processes, tends to create the same object over and over. In 3D printing, because nearly any design can be put into the computer and then executed, resulting objects can be of almost any shape and highly specified for a given purpose. This gives manufacturers much more control over the designs of their products and the power to meet a given need nearly on the spot.

3D printing has been utilized by General Motors for the creation of automotive parts, by architects to create unique building models, and even by medical researchers to create prosthetics and artificial organs. Recently, a research project was conducted to find out what 3D printing could lend to the creation of treatment membranes.



Key properties of 3D printing techniques (Creative Commons license CC BY 4.0)

The process offers a chance to customize membranes to specific influents, to target certain contaminants of concern, and to react to emergency situations. 3D printing is a way to create a more specific membrane to solve treatment plant needs.

"The need was to find a way of controlling the architecture of membrane microstructures in a predictable way so that the performance of the membranes can be predicted and controlled from the outset of designing the membranes," said Dr. Darrell Patterson, the director for the Centre for Advanced Separations Engineering at the University of Bath, and an author of the study. "Currently, the main [production] methods of polymer membrane formation do not allow for this."

By getting more specific with a membrane's shape, treatment plants could do more within the same footprint. "A shaped membrane that can have a maximum surface area to increase the practical membrane surface-area-to-volume ratio, to increase membrane area in the same membrane holder, for example, could improve on the current flat sheet and hollow fiber membrane shapes," Patterson said. "3D printing would allow complete control over the design and fabrication of such shapes, which currently is not possible."

The authors of the study explored how 3D printing technology could be applied to membrane engineering. Over the past 10 years, they say, 3D printing has reached a point where it offers the control, resolution, and precision that allows for membrane fabrication. It also allows for the micro- and macro-structure of the membrane to be designed and built at once, offering the potential for integrated design between the materials used and their purposes. Tailormade membranes could be designed to keep particles from fouling the surface

and, one day, could be made on-site to respond to specific contamination problems.

"We think that shaped membranes could help reduce fouling and increase the area of the membrane that can be used in a typical membrane plant," said Patterson. "Additionally, the on-site production of membranes that are tailored to the separations needed would also be possible, allowing a quicker response and unprecedented changes in water and wastewater composition."

There are, however, still limitations on the use of this technology to build treatment membranes. Primarily, 3D printers aren't yet equipped to produce them.

"3D-printed membranes are currently limited by the resolution and build size of the current 3D printers," said Patterson. "We really are waiting for the 3D printing technology to catch up with our ambitions to allow 3D printing to become a realistic and cost-effective membrane production technology."

That being said, the researchers are so enthusiastic about the potential for 3D printers to revolutionize water and wastewater treatment that they don't want their thinking to be stunted by what's currently possible. Patterson mentioned the possibility of one day printing the membrane and module all in one piece, but out of different materials, creating a membrane with a range of different pores and surface structures to optimize flux. The membrane then becomes capable of selectively removing and recovering the molecules and particles that cause fouling and utilizing materials that don't age, to increase the lifespan of a membrane.

"We don't want to be limited to what is currently available in the membrane market," said Patterson. "We want to be able to do things that are not currently possible. … If these can be realized, then 3D printing could potentially become the go-to technology for membrane fabrication in the future. Given the rate of development of 3D printers, we would estimate that at least some of this will be possible within the next five to 10 years." ■

About The Author

Peter Chawaga is the associate editor for Water Online. He creates and manages engaging and relevant content on a variety of water and wastewater industry topics. Chawaga has worked as a reporter and editor in newsrooms throughout the country and holds a bachelor's degree in English and a minor in journalism. He can be reached at pchawaga@wateronline.com.

Enhanced Nutrient Removal That Saves Resources And Real Estate

True to its name, the State-of-the-Art Nitrogen Upgrade Program leverages the latest technology and innovation to clean up the Chesapeake Bay and the environment around our nation's capital.

By Kristina Twigg and Rich Voigt

Alexandria Renew Enterprises (AlexRenew) is an advanced water resource recovery facility — previously known as a wastewater treatment plant — that serves the City of Alexandria and parts of Fairfax County, VA. Designed to transform 54 million gallons of wastewater per day on just over 33 acres, AlexRenew is one of the smallest gallon per acre facilities in the nation. Being a good neighbor on a space-constrained urban site within the ecologically sensitive Chesapeake Bay watershed takes ingenuity.

In 2016, AlexRenew completed construction on its $160-million State-of-the-Art Nitrogen Upgrade Program (SANUP). This project, nearly 10 years in the making, was designed to protect the Chesapeake Bay by meeting more stringent nutrient limits. SANUP meets these nutrient challenges in a way that conserves space, achieves resource efficiencies, and involves the community.

The plan combined three different innovative processes that work together to support AlexRenew's vision and meet its nitrogen reduction target.

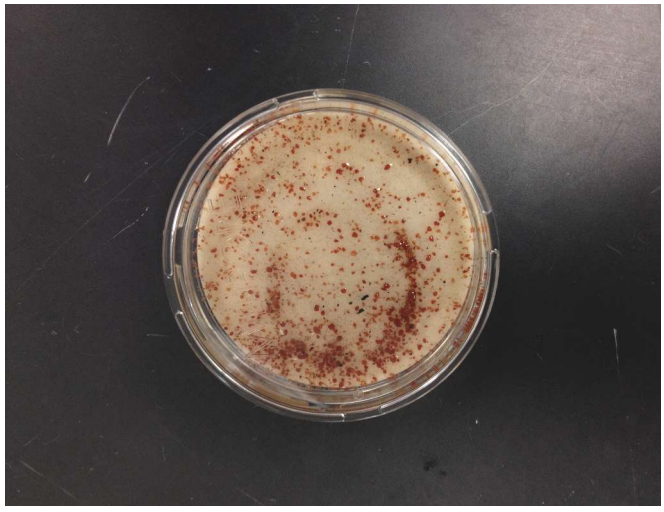
Challenges Prompt Infrastructure Innovation

The Chesapeake Bay is the largest estuary in the U.S. It borders Virginia and Maryland, but its watershed spans 64,000 square miles across six states and Washington, D.C. The bay is impaired by nitrogen, phosphorus, and sediment. According to the Chesapeake Bay Program's Bay Barometer released this February, the bay's condition is improving, in part because the region's water resource recovery facilities have met key nutrient reduction milestones 10 years ahead of schedule.

Driven by efforts to protect the bay in the late 1990s, AlexRenew initiated a $350-million nutrient upgrade to achieve an effluent limit of 8 mg/L total nitrogen based on permitted flow of 54 million GPD. In 2011, new assessments showed that additional nutrient reductions would be needed to improve the Chesapeake Bay's water quality, necessitating the SANUP program. Starting in 2017, AlexRenew is reducing its effluent total nitrogen concentration to just 3 mg/L, a nitrogen load cap of 493,000 lbs/year. With SANUP, AlexRenew's total nitrogen discharged to the Chesapeake Bay will be reduced by an additional 20 percent annually.

AlexRenew is located in Old Town Alexandria, VA — just outside of Washington, D.C. — a dense urban area along the Potomac River. The site is bounded by a large electrical substation, Interstate 495, a historic cemetery, and commercial and residential development. Just west of the facility's main campus is the South Carlyle site, previously an unregulated landfill and part of the area AlexRenew acquired to expand its facilities. This brownfield with contaminated soils required detailed sampling and analysis. AlexRenew was further challenged by resource protection areas that covered half of the South Carlyle site, as well as the need to create a consistent aesthetic with surrounding development.

AlexRenew, in partnership with the consulting firm CH2M (Herndon, VA), developed a technical plan that embraced these various challenges while delivering on the utility's vision to protect the environment, contribute to a vibrant local economy, maintain stable rates, and involve the community. The plan combined three different innovative processes that work together to support AlexRenew's vision and meet its nitrogen reduction target. These include mainstream and sidestream deammonification as well as a nutrient management facility that balances diurnal influent ammonia loading.



The microbial population must be carefully balanced so that Anammox bacteria can outcompete other microbes in the biomass. AlexRenew uses hydrocyclones to separate the heavier Anammox granules to keep them in the reactors while lighter biomass is removed.

Mainstream And Sidestream Anammox

Deammonification is an emerging technology that uses anaerobic ammonia-oxidizing bacteria, or Anammox, to remove nitrogen. By taking a shortcut in the conventional nitrification/denitrification process, Anammox bacteria use less process air — saving energy — and also less supplemental carbon — reducing the number of chemical delivery trucks visiting the facility and decreasing greenhouse gas emissions. Deammonification also offers a way to remove nitrogen in less space without additional aeration basins.

The microbial population must be carefully balanced so that Anammox bacteria can outcompete other microbes in the biomass. AlexRenew uses hydrocyclones to separate the heavier Anammox granules to keep them in the reactors while lighter biomass is removed.

In March 2015, AlexRenew started up its sidestream centrate pretreatment facility. The facility uses Anammox bacteria to treat the ammonia-rich sidestream from dewatered, anaerobically digested biosolids. The centrate holds as much as 25 percent of all nitrogen in the wastewater at AlexRenew. The centrate pretreatment facility — among the first of its kind in North America — can treat 276,000 gallons of centrate per day, removing 85 percent of the total nitrogen from this waste stream. The process was designed to use 60 percent less process air than conventional treatment, with no supplemental carbon required.

In spring 2017, AlexRenew will launch mainstream deammonification in its biological reactor basins. Mainstream Anammox is expected to reduce supplemental carbon use by more than 40 percent and aeration use by 26 percent while increasing biogas production by 10 percent — all with minimal capital investment, helping AlexRenew meet is fiscal sustainability goal.

AlexRenew's implementation of full-scale sidestream and mainstream deammonification is a milestone in the development of these technologies.

AlexRenew's implementation of full-scale sidestream and mainstream deammonification is a milestone in the development of these technologies. As such, AlexRenew is collaborating with universities, research organizations, and other utilities, including its international partner, VandCenter Syd (Odense, Denmark), to monitor, refine, and quantify any improvements.

Nutrient Management Facility

The largest SANUP component, AlexRenew's nutrient management facility (NMF), is an 18-million-gallon structure made of more than 1,700 precast concrete panels. The NMF stores primary effluent during daily ammonia peaks to balance ammonia-nitrogen loading to AlexRenew's biological reactor basins. Maintaining a constant nitrogen load to the biological reactor basins helps AlexRenew optimize microbial chemical use and air demand, all on a very limited footprint for treatment. The facility — located on AlexRenew's South Carlyle site — is topped by Limerick Street Field, a public, multipurpose athletic field that transforms a historic city garbage dump into a community amenity.

In December 2016, the Institute for Sustainable Infrastructure honored the NMF with an Envision Platinum Award — the first in Virginia and the D.C. metro area and also the first for a U.S. water resource recovery facility. Envision is a tool used for planning, designing, and rating all types of sustainable infrastructure projects, much like the LEED program is used to assess buildings.

Through a public-private partnership, AlexRenew, the City of Alexandria, and developer Carlyle Partners constructed Limerick Street Field and the Environmental Center, AlexRenew's administrative headquarters. The field and building share a consistent aesthetic with the South Carlyle development,

Four activated carbon treatment vessels (left), each with a capacity of 15,000 cubic feet per minute, treat odorous air in the NMF tank headspaces and exhaust clean air away from the field. The NMF operating gallery (right) houses process pumps, pipes, valves, and instrumentation to reduce the need for routine access into the tanks.

acting as a buffer between AlexRenew's treatment tanks to the south and the 1.2 million square feet of planned residential and commercial development to the north. Their integration also provides field access and a seamless connection to planned biking and pedestrian paths. Additionally, the NMF and Environmental Center both use AlexRenew's reclaimed water for nonpotable purposes.

During design and construction, AlexRenew worked with the public, stakeholders, and its public-private partners. The utility created a website for public comment that included community updates, blog posts, and a webcam to show current construction progress. As part of an ongoing commitment to be a good neighbor, AlexRenew's NMF operates with an advanced odor control system.

Due to various site constraints, less than half of the 10-acre South Carlyle site was available for development. Because of its history as an unregulated dump, the site was enrolled in Virginia's Voluntary Remediation Program, which encourages environmental cleanups that may not otherwise take place. Resource protection areas, which covered about half of the site, were not only maintained but repaired and improved as part of SANUP.

During construction, sustainability was a key focus of the NMF. For instance, AlexRenew:

- Removed 85,000 cubic yards of contaminated soil and restored a brownfield site;
- Planted more than 1,000 native trees and shrubs and expanded an adjacent streamside buffer by 69,000 square feet;
- Installed sustainable stormwater practices;
- Recycled 85 percent of demolition and construction waste;
- Used 21 percent recycled material and at least 90 percent regional material;
- Installed energy and water monitoring systems; and
- Built connections to future trails and green space.

To optimize space, provide public field access, and address contaminated soils, the team built vertically when possible and used pile foundations to support all structures. More than 2,200 precast concrete piles were driven on the project. The NMF is partially below grade, and all process piping, pumps, and chemical analysis equipment as well as allocations for future wet weather solutions, electrical systems, and instrumentation had to be internal to the structure or buried.

AlexRenew has a long history of innovation, driven by regulation, the need to process wastewater efficiently on its urban campus, and a customer-focused vision. The utility evaluates and leverages its unique circumstances so it can meet today's challenges while ensuring a healthy future for its community. SANUP is just one example of how utilities can go beyond meeting regulations to implementing projects that transform communities. ■

About The Authors

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Real-Time Monitoring: An Opportunity To Engage In Potable Reuse And Detect Failures Quickly

With public safety of primary concern, real-time sensors may be the catalyst for assurance and expansion of potable reuse treatment schemes.

By Justin Mattingly

Potable reuse of advanced treated reclaimed water is achieved through multibarrier treatment trains, using a combination of technologies such as microfiltration, reverse osmosis, advanced oxidation, ozonation, and/or granular activated carbon. To ensure efficacy of treatment, water quality may be evaluated in real time to verify that these barriers are operating as designed and to reassure communities that there are no adverse public health effects from using reclaimed water for potable purposes.

A research team led by Dr. Ian Pepper and Dr. Shane Snyder from the University of Arizona recently completed a study funded by the Water Environment & Reuse Foundation (WE&RF), U.S. Bureau of Reclamation, The Pentair Foundation, and Singapore PUB to evaluate the ability of online sensors to ensure that advanced treatment of reclaimed water before potable reuse eliminates chemical and microbial contaminants. Specifically, the researchers sought to determine if real-time sensors could be used for process control of advanced treatment systems to ensure the safety of potable water for the community. Monitoring for Reliability and Process Control of Potable Reuse Applications (Reuse-11-01) is the research title.

Real-time monitoring offers the opportunity to engage in potable reuse with the ability to detect failures quickly and greatly reduce the response time needed to rectify upsets in a treatment system.

The team conducted the research in four phases:

- Comprehensive literature review
- Laboratory evaluations
- Pilot-scale utility evaluations
- Full-scale utility evaluations

Real-time detection of trace organic compounds was evaluated through sensors for surrogate parameters such as UV254 or fluorescence. For microbial contaminants, techniques such as multi-angle light scattering or measurements of adenosine triphosphate (ATP) were used. Advanced treatment technologies that were evaluated included advanced oxidation, reverse osmosis, and activated carbon.

From Lab To Pilot-Scale

Laboratory evaluations at the University of Arizona Sensors Lab tested eight different advanced treatment methods to determine their efficacy in removing chemical and microbial contaminants. The pilot-scale evaluations involved going beyond bench-scale testing and into monitoring and sensor validation at pilot-scale facilities. The facilities sampled at various critical control points in the system using existing online monitoring systems to monitor the surrogates and indicators proved to be the most useful based on the results of the laboratory evaluation. The last phase conducted full-scale evaluations at facilities that currently implement potable reuse to determine the effectiveness of online monitoring systems.

The pilot-scale evaluations occurred at the Beenyup Wastewater Treatment Plant in Australia, Sacramento Regional Wastewater Treatment Plant, and the Tucson Water Sweetwater Recharge Infiltration Systems. Each facility tested advanced treatment options and identified solutions to improve their process control. Overall, the pilot-scale studies demonstrated that select online sensors were able to provide effective process control. Specifically, ozonation more effectively reduced total microbial load and bacteriophage MS2 levels, indicating that total microbial load may be an effective surrogate for pathogen reduction in treatment trains. Real-time detection methods specific to microorganisms were also shown to have potential

to monitor pathogen reduction in treated water.

The Beenyup Wastewater Treatment Plant and Advanced Water Recycling Plant (Perth, Australia) pilot trial identified two key solutions that could improve their process control. First, the implementation of UV254 and fluorescence online sensors may be useful additions to their system. Second, the implementation of a microbial assay like LuminUltra would allow for rapid detection of potential microbial contaminants.

The Sacramento Regional Wastewater Treatment Plant (Sacramento, CA) trial found sensors useful in evaluating the treatment performance and incremental failure events during membrane filtration. The addition of a fluorescence online sensor would also potentially provide additional online process control.

The Tucson Water Sweetwater Recharge Infiltration Systems (Tucson, AZ) pilot found ozonation more effectively reduced total microbial load and MS2 levels over UV-AOP. This implies that total microbial load is an effective surrogate for pathogen reduction in treatment process trains, as it includes a broad spectrum of microorganisms that are more resistant to inactivation than human pathogens typically found in wastewater.

University of Arizona Sensors Lab

Full-Scale Findings

The full-scale evaluations occurred at facilities that currently implement potable reuse to determine the effectiveness of online monitoring systems. When combined with the laboratory and pilot-scale evaluations, recommendations for the full-scale facilities were developed to suggest ways to improve their monitoring practices. The facilities that conducted full-scale demonstrations included West Basin Municipal Water District and Orange County Water District.

The results of the full-scale evaluations demonstrated that online sensors can be effective strategies for monitoring process control, and real-time monitoring can detect failures in potable reuse treatment schemes quickly and reduce the response time to rectify the problem.

Based on the laboratory, pilot-scale, and full-scale evaluations, online sensors were shown to be useful for monitoring process control. Overall data from the pilot- and full-scale utility evaluations show that utilities in the U.S. and abroad do use online sensors successfully to monitor for the presence of chemical contaminants in real time, but not microbial contaminants. Currently, utilities rely heavily on sensors for turbidity, conductivity, and total organic carbon (TOC) to act as real-time triggers to alert operators of treatment failure. These sensors could usefully be augmented by an online fluorescence sensor and a real-time assay for microbial contaminants.

Sensor-ability

These research findings provide meta-data on a variety of different sensors including parameters such as working range, accuracy, precision, response time, and detection mechanism. In addition, the researchers evaluated the ability of different sensors to detect incremental failure of advanced treatment and the efficacy of various sensors in waters with differing water quality. Finally, the team characterized the current status of the use of online sensors at utilities nationally and internationally by evaluating operational pilot and full-scale treatment trains.

Real-time monitoring offers the opportunity to engage in potable reuse with the ability to detect failures quickly and greatly reduce the response time needed to rectify upsets in a treatment system. The research indicates that at the same time, the need for engineered storage in direct potable reuse would be reduced due to the faster response time in monitoring.

The variety of evaluations also identified some gaps and issues in sensor technology:

- Enhanced sensitivity of contaminant detection and removal via surrogates
- Further development of an online sensor for bacterial microbial contaminants
- Development of an online sensor for human pathogenic viruses, perhaps via aptamers or immunoassays coupled to microfluidics
- Enhanced ability to detect minimal incremental failure
- Development of superior software for data maintenance and setting of constantly operational alarm thresholds
- Development of online courses to train utility personnel with respect to new real-time technologies, including sensor maintenance

These topics are among many that may be tackled by the WE&RF water reuse and desalination issue area team in future research efforts. ■

About The Author

Justin Mattingly is a research manager at the Water Environment & Reuse Foundation focusing on treatment systems for potable reuse, industrial reuse, and water economics and finance. Prior to joining WE&RF, he completed a four-year fellowship at the U.S. EPA in the Clean Water State Revolving Fund program, working with states and communities to develop innovative financing tools and strategies to fund a diverse array of water quality projects. Justin has a bachelor's degree in biological sciences from the University of Delaware and a master's degree in environmental science from American University.

Identifying Risks For Sewer Conveyance Asset Management

If risk analysis isn't in the pipeline, your asset management plan needs updating. Arcadis shares best practices to launch or update your program.

By Celine Hyer

Done right, asset management delivers savings, risk reductions, and efficiency. But getting there involves important trade-offs and decisions with serious financial and service implications.

We will explore ways that utilities can identify the most critical and vulnerable risk points, even in enormous and complex systems, and use this information to tackle rehabilitation and replacement while making a solid case for funding.

Given the substantial effort and cost of renewing sewer conveyance systems, especially those nearing the end of their economic and service lives, it helps to be able to make the case that any investment should have maximum effect. Therefore, every program should start by determining the best approach for everything, from overall asset management to risk-based pipe replacement.

Reframing The Approach To Asset Management

Effective asset management is crucial to ensuring the right work is done at the right time. Using outdated or incorrect approaches can result in underperformance and loss. Fortunately, we are in the midst of an asset management revolution, opening avenues to improved planning, budgeting, and efficiency.

No longer solely a technical discipline primarily driven by the need to improve capital investment forecasting, today's business-driven mindset considers the entire asset life cycle, inherently transforming the way utilities operate. In fact, utilities that can break the functional silos can create a plan that is truly sustainable, now and across the life of the whole water or wastewater system.

But getting such an enterprising program off the ground starts with single steps. It helps to identify first the elements of the program that can jumpstart the desired changes, while recognizing that the data required to fully realize the benefits may not be available right away. Taken from the Arcadis paper "Improving the Current State of Water and Wastewater Buried Infrastructure for a More Sustainable Future," the following list of five critical elements of a successful asset management program can help anticipate and overcome the inevitable challenges.

Expert Resource: The Virginia Tech Sustainable Water Infrastructure Management (SWIM) Center — Blacksburg, VA

The SWIM Center was created to help utilities build asset management programs rooted in research, innovation, and practicality, with access to a network of expert professionals. Knowledge centers like the SWIM Center have been proven to provide a foundation of needed industry data, training, and best practices to advance asset management programs.

Tapping into the SWIM Center lets utilities create and share infrastructure data, tools, and cases to set asset management programs in a positive direction. It also offers the most comprehensive source of water infrastructure asset management information and innovative research available through the PIPEiD and WATERiD national databases, conferences, workshops, training courses, publications and reports, and SWIMeD online certification programs.

However important, these are foundational activities for the main event: assessment and risk analysis for rehabilitation and replacement planning.

Sewer Pipe Condition Assessment For Rehabilitation And Replacement Planning – New Castle County, DE

Arcadis developed an asset management program to identify the nature, extent, and sources of infiltration and inflow (I/I), cross-connections, and structural failures for New Castle County, DE. This provided valuable information to set priorities and

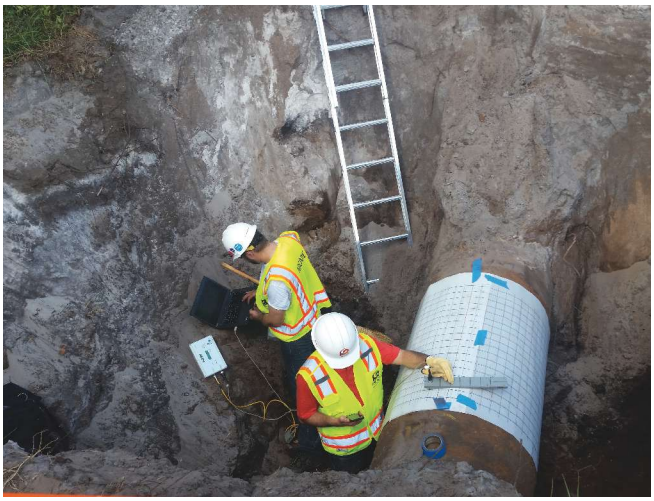
budgets for a program of capacity, management, operations, and maintenance (CMOM); replacement; and expansion.

New Castle County owns and operates wastewater collection and conveyance facilities comprising about 1,600 miles of gravity sewer and interceptors, 40,000 manholes, and more than 150 pump stations. This also includes the Brandywine Hundred Sewer System, encompassing four sewersheds with more than 420 miles of the oldest and most problematic sewers, located in some of the county's most densely populated areas. The system includes a number of structured sanitary sewer overflows (SSOs) that combine untreated sewage with stormwater for discharge in the Delaware River and tributaries. The Brandywine Hundred Sewer System Rehabilitation and Capacity Assurance Program aimed to:

- reduce groundwater and rainwater entry from I/I into the collection system to achieve a significant

Five Recommendations For Successful Asset Management

Recommendations for a successful asset management program	Greatest challenge utilities face when executing this recommendation	Tips for overcoming this challenge
Truly understand and communicate the goals of the asset management program, ensure strong leadership, and engage stakeholders to win support.	Establishing concise goals that are tied to your overall strategic objectives and will resonate with your internal and external stakeholders.	Network with other utilities that have comprehensive, long-term asset management programs to gain perspective and lessons learned that can increase your chances of implementing a program that is successful and delivers sustainable outcomes.
Recognize the organizational implications of an asset management program to ensure long-term success.	Identifying the necessary roles and responsibilities that touch all levels of asset management within your utility (i.e., IT, engineering, operations and maintenance, and finance) and understanding that it may require implementing a change in management strategy.	Perform an organizational assessment specific to asset management implementation to gain a thorough understanding of your workforce and their roles, responsibilities, capabilities, and expertise. Map where each person brings value to the program and where there may be talent gaps that inhibit long-term program success. Network with other utilities regarding their asset management staffing and change management strategies to learn how they set up their programs for success and why they did so, and what's working and what's not, to help accelerate the implementation of your program.
Implement a framework that integrates all asset-related functions, activities, and financials to achieve true ownership across all levels of the organization.	Deciding how to begin and which framework to adopt and roll out to the organization.	Adopt industry standards and utilize proven gap analysis tools (e.g., ISO 55000 or the Water Environment & Reuse Foundation's Strategic Asset Management Research Area) to define the elements of your framework and learn where you stand today. Stay up to date on the most innovative, research-based asset management trends, strategies, and applications by participating in training and continuing education opportunities that will give you the perspective, knowledge, and tools to implement and manage your program with clarity and confidence.
Strike the right balance between financial performance, risk management, and operational performance.	Defining effective service levels and key performance measures to target capital and maintenance decisions.	Leverage existing performance measures, such as those published in AWWA's "Benchmarking Performance Indicators for Water and Wastewater Utilities: 2013 Survey Data and Analyses Report," to develop measurements that deliver financial returns, manage risk, and enhance operational performance.
Leverage IT to enable organizational change, optimize business processes, and support informed decision making.	Determining where to start, what products to use, and how to effectively tie existing systems together.	Conduct a review of your existing systems relative to asset management best practices.



Condition assessment of a sewer force main using broadband electromagnetic technology to measure the pipe wall thickness

reduction in basement sewage backups, the occurrence of hydraulics-related sanitary SSOs, and interceptor surcharges; and
- reduce infrastructure failures that contribute to combined sewer overflows (CSOs) and SSOs.

The program included:
- hydraulic condition assessment, data review, and modeling to understand the extent and nature of chronic problem areas
- physical condition assessment, using CCTV, pole-mounted zoom camera inspections, and sanitary sewer evaluation technology
- smoke testing and basement sump inspections to identify inflow contributions in each subbasin, subsequently used to develop a program to reduce illicit connections
- sewer modeling to determine existing level of control and needed I/I removal requirements for regulatory compliance
- maintenance and inspection program development.

The rehabilitation and prioritization work helped identify, budget, and frame a capital plan for replacement, expansion, and clearwater elimination projects implemented in three phases over 15 years. As of 2017, much of the Phase 1 work is complete.

Planning For Sewer Conveyance Damaged By Hurricanes In Florida

Risk assessment has been critical for a sewer rehabilitation and replacement program for the Emerald Coast Utilities Authority (ECUA) in Florida. The system serves almost 300,000 people in Escambia County and the City of Pensacola, with 915 miles of gravity sewer and three wastewater treatment plants with a total combined permitted capacity of 33 MGD. Damage from Hurricane Ivan in 2004 had significantly increased I/I flows the years following. The risk assessment is helping to determine priorities and set the agenda for future work.

To ground this comprehensive sewer rehabilitation program with actionable information, Arcadis conducted extensive data collection, including covered flow metering studies and sewer system evaluation surveys (SSESs) of 207 miles of gravity sewers in four major project areas. The flow metering included 12 long-term flow meters, four rain gauges, and 31 short-term meters. Smoke testing for cross connections and nighttime flow measurements using V-notch weirs to evaluate groundwater infiltration was completed in September 2009. A total of 1,500 manholes have been inspected to date. Initial CCTV investigations were completed in mid-2008.

The hydraulic and physical condition assessments identified key areas of sewer rehabilitation needed for 21 miles of sewer damaged by hurricanes. Because this sector experienced the most serious problems with I/I flows in the service area, this rehabilitation construction work was completed first. Other work includes open-cut replacement of sewer mains and laterals as well as cured-in-place lining. Through investigative processes, it was found that in some areas more than half of the existing laterals were determined to be inactive and have been eliminated from the system, thus reducing both potential inflow and groundwater infiltration.

Program tasks are accomplished through flow metering networks, nighttime weiring, above-grade storm inflow observations, smoke testing, and in-pipeline inspections using digital, state-of-the-art CCTV. The resulting information has been incorporated into the hydraulic model. As the program progresses, the entire service area will be prioritized for rehabilitation based on the size of the contribution of I/I, the anticipated failure period, and other criteria.

A related phase of the project includes the evaluation of the condition and risk of failure of the force mains. Condition assessments such as transient pressure monitoring, in-pipe inspection, and other nondestructive techniques are being used to evaluate the current conditions and make recommendations regarding replacement needs.

Risk-based planning brings down the total cost of sewer pipe rehabilitation and replacement. Integrating this work with asset management across the whole system for the complete asset life cycle will pay off many times over the years. But starting from a base of knowledge and using industry resources will help make the most of all needed risk assessment and possibly reduce the effort needed to identify critical weak points. The assessment then becomes a powerful data set to drive funding, planning, and execution. ■

About The Author

Celine Hyer, senior vice president and conveyance lead at Arcadis North America, is a recognized expert in advanced rehabilitation and replacement planning for pipelines as well as treatment and pumping facilities, with over 17 years leading the implementation of asset management programs nationwide.

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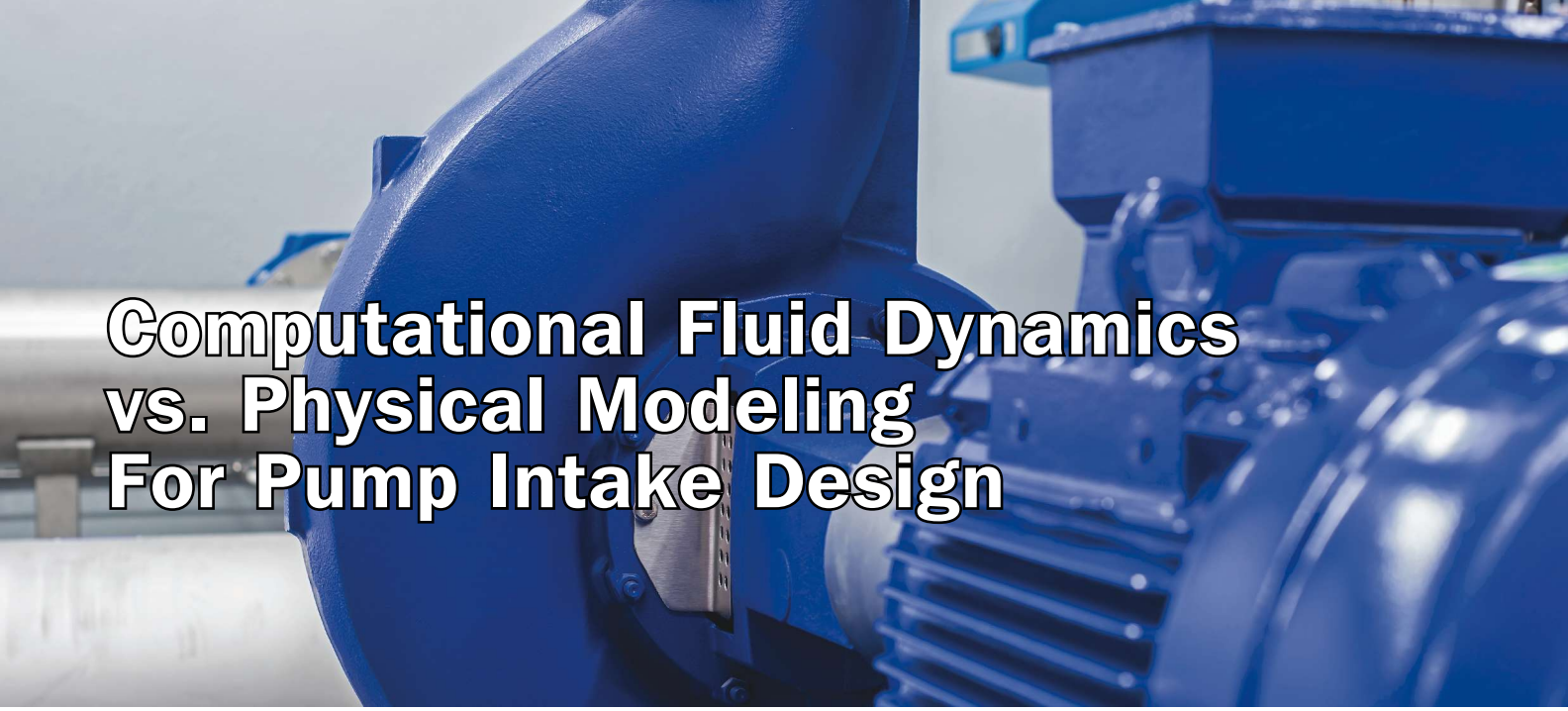

Computational Fluid Dynamics vs. Physical Modeling For Pump Intake Design

The past, present, and future of pump intake modeling is examined, highlighting the progress and value of computational fluid dynamics compared to tried-and-true methodology.

By Dan Gessler, Andy Johansson, and Becca Hall

In today's world of computational fluid dynamics (CFD), there are some applications where physical models remain as the only analysis tool that can provide reliable engineering design results. Pump intake design is one such area. The cost of physical models can be significantly higher than CFD; therefore, the temptation to use CFD is considerable. CFD can provide insight to the flow patterns approaching the intake, but is unable to consistently provide information about the vortex strength and temporal variation. For this reason, the Hydraulic Institute Standards (ANSI/HI 9.8-2012 and ANSI/HI 9.6.6-2009) do not recognize CFD as an acceptable means to predict flow patterns at the pump inlet or to show compliance with the acceptance criteria presented in the pump intake testing section of the standard.

The Hydraulic Institute (HI) was founded in 1917 and is a value-adding resource to member companies, engineering consulting firms, and pump users worldwide. The Hydraulic Institute develops and delivers comprehensive industry standards and tools for the effective application, testing, installation, operation, maintenance, and performance optimization of pumps and pumping systems.

The Hydraulic Institute Standard for Intake Design (ANSI/HI 9.8-2012) provides guidelines on when pump stations should be tested with a physical model and the model scaling requirements. Some of the criteria for pump stations that require physical model testing include individual pump flows or total station flow greater than 40,000 gpm and 100,000 gpm, respectively, intake or piping geometry that deviates from the standard, pump stations with nonsymmetrical or nonuniform approach flow, and/or pump stations where operation is critical or the cost of a prolonged outage for repairs is significant. For those pump stations that require testing, minimum model scales based on Reynolds number, Webber number, and absolute minimum model dimensions are given. The following paper provides information about the past, present, and future of pump intake modeling.

The Past

The performance of a pump can be negatively impacted by adverse flow conditions entering the pump. Adverse flow conditions including free and subsurface vortex formation, non-uniform velocity distribution, or preswirl can result in reduced pump efficiency, reduced pumping capacity, or vibrations that can damage the pump or require premature maintenance. Vortex formation has been studied by several investigators, including Alden staff members. An example of vortex identification in a physical model is included in Figure 1. These investigations led to the development of minimum model scale requirements that provide hydraulic similitude between the model and prototype. Standard testing methods were developed to measure the swirl and the velocity distribution approaching the pump

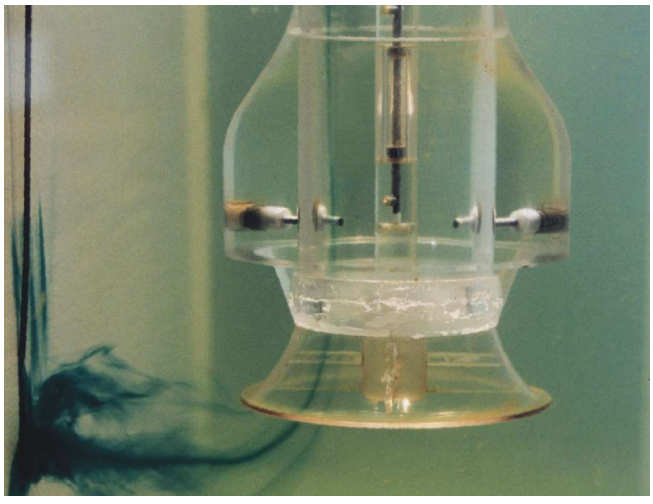

Figure 1. Vortex identification in a physical model

While CFD is considered a valuable and important tool for enhancing the value of physical model studies, it is still far from being able to replace physical models for pump intake modeling.

impeller. A standardized system was also established to classify free and subsurface vortex activity. Acceptable preswirl, velocity distribution, and vortex activity were defined based on experience gained over many years comparing physical models and prototype operation. A physical model study conducted in accordance with the HI criteria by laboratories experienced with pump intake modeling should provide the same results, regardless of the organization.

About 15 years ago, Alden and others started experimenting with the use of CFD for pump intake modeling. CFD is unreliable at predicting the time-dependent unstable vortices that can be characteristic of pump intakes; however, the allure of a faster and more cost-effective modeling approach was significant. In the ensuing time, computers have become much more powerful, and CFD model codes and methods have improved, albeit at a slower pace.

Among civil engineering firms, Alden is one of the largest users of CFD in North America based on number of licenses in use. Alden also conducts 10 to 15 physical models of pump intakes each year, uniquely positioning Alden to conduct ongoing comparisons between CFD and physical model results. The research to date has failed to produce reliable CFD results for predicting pump intake performance.

The Present

In 2016, the HI invited leading CFD engineers from around the world to participate in a forum regarding the state of the art in CFD modeling of pump intakes. The modelers present all used a variety of CFD codes and turbulence models, including large eddy simulations (LES) run on

Figure 2. Swirl meter instrumentation

massively parallel supercomputers. Alden discussed a one-year modeling effort that compared physical and CFD modeling results using three different commercially available CFD codes (Fluent, CCM+, and FLOW-3D) with simulations conducted by three CFD engineers. Agreement among the experts was unanimous: While CFD is considered a valuable and important tool for enhancing the value of physical model studies, it is still far from being able to replace physical models for pump intake modeling. CFD was unable to predict vortex strength in accordance with the existing HI criteria, and in some cases the direction of rotation was incorrect.

A significant shortcoming of using the current HI Standards when interpreting CFD model results is that the measurement techniques and acceptance criteria outlined in ANSI/HI 9.8-2012 were developed specifically for physical models. The basis for acceptance is measurements that are readily made in a physical model, such as the swirl meter shown in Figure 2. A CFD model cannot report the number of swirl meter rotations because the swirl meter is not included in the model. Therefore, it is recognized that as CFD models improve, it may be necessary to develop standards specific to CFD modeling.

Additionally, CFD model results can be influenced by the individual modeler and the CFD code. For instance, different modelers will create different computational meshes, which in turn can affect results. To date there is no standardization for CFD modeling of pump intakes. When CFD is used to model a pump intake, it is important for the owner to realize that no accepted standards for the modeling exist.

The Future

An interesting topic for discussion is how the use of CFD in pump intake modeling will evolve in the coming years and decades. Crystal balls for predicting the future of CFD are hazy at best, but some information can be surmised with reasonable certainty. CFD models that use two-equation Reynolds Averaged Navier-Stokes (RANS) equation-based turbulence models are unlikely to be able to capture vortexing at pump intakes. The equations include simplifications that should preclude them from consistently predicting vortex formation. For example, the RANS equations assume that turbulent viscosity is isotropic (the same in all directions). While this assumption is valid for many situations, it does not apply to strong swirling flow, such as vortices, where turbulent viscosity is direction-dependent. LES models hold more promise, and while the models are too computationally intensive to be financially viable at this time, computers will continue to improve, and this limitation is expected to gradually diminish. In the near future, LES models will likely remain cumbersome to use and likely require vast amounts of output required to determine if a time-dependent vortex is forming. Despite these challenges, the use of CFD as a component of pump intake studies is expected to increase.

Extensive testing and comparisons between CFD results, physical models, and prototype performance are required to confirm that the CFD models can achieve a predictive reliability similar to that of physical models. The HI standards will need to be revised to include performance parameters that can be readily quantified in a CFD model. The original standards were based on many years of research, and it is reasonable that a similar amount of time may be required to develop and test standards written around CFD. Once the requirements for a reliable CFD model are established, it remains to be seen if a CFD model will be less expensive than a physical model.

Conclusion

While CFD is a useful and important tool in the pump intake designer's toolbox, at present CFD modeling cannot be used to show compliance with the acceptance criteria presented in the testing section of the Hydraulic Institute Standards (ANSI/HI 9.8-2012 and ANSI/HI 9.6.6-2009). A major research effort will be required to conduct the necessary testing required to develop standardized methods for the use of CFD in pump intake modeling. For additional information about the HI Standards, please contact Peter Gaydon (director, technical affairs, Hydraulic Institute, pgaydon@pumps.org). ■

About The Author

Dan Gessler, PE, Ph.D., DWRE, vice president of Alden Research Laboratories, has over 25 years of experience and is responsible for overseeing all of the hydraulic modeling completed at Alden. He provides technical expertise in numeric and physical modeling and also works on projects that combine large CFD and physical modeling efforts.

Andy Johansson, director of hydraulic modeling, is responsible for all physical hydraulic model testing performed in Alden Research Laboratories' Holden, MA, office. He provides technical and administrative supervision of Alden's Holden Hydraulic Modeling Department to ensure high technical standards are maintained. Mr. Johansson has been with Alden for over 27 years.

Becca Hall, engineer II, is a project manager at Alden who specializes in conducting physical model tests with an emphasis on pump intake modeling. She has over 10 years of experience in physical modeling of hydraulic structures.

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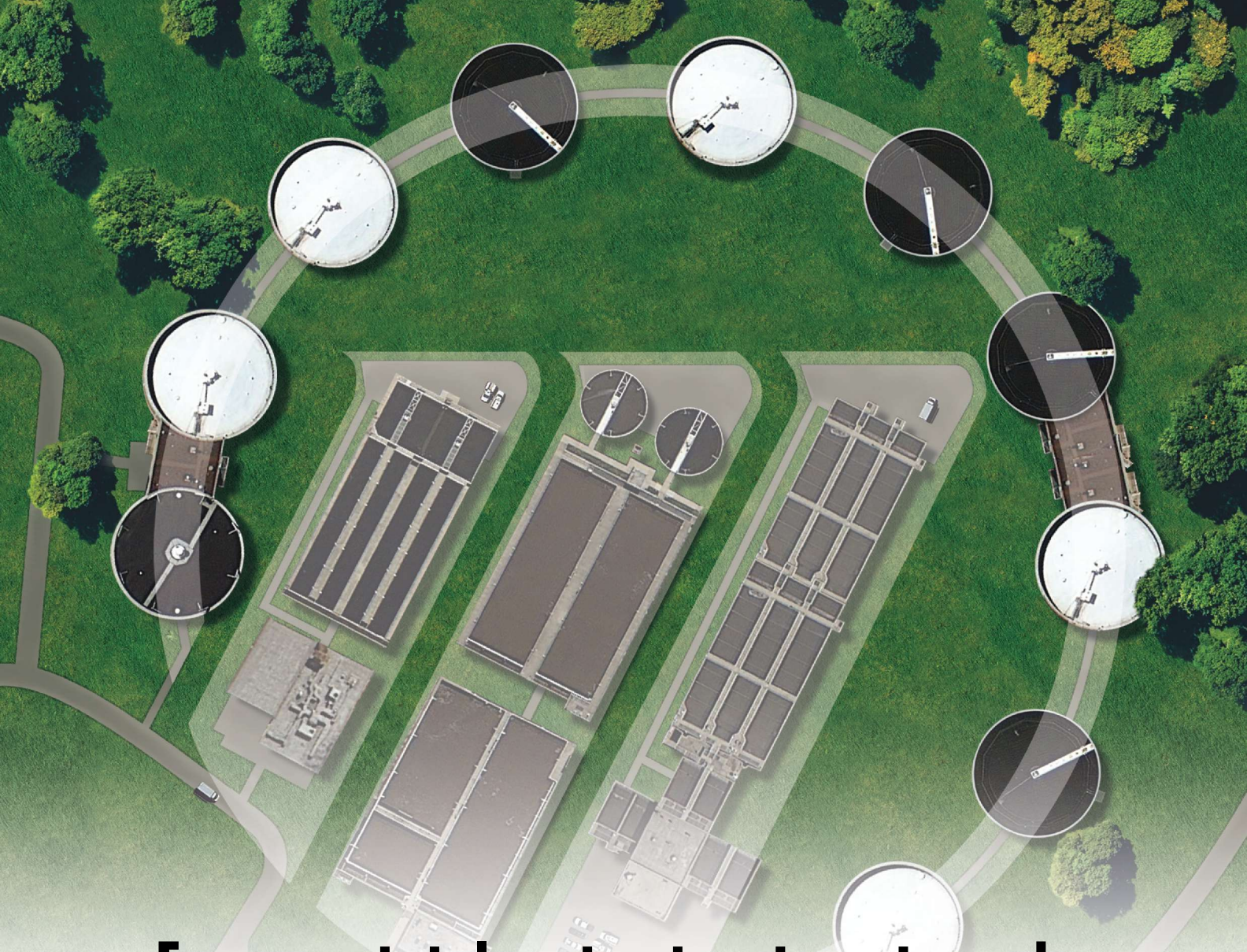

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