Intelligent Water Systems

THE CHALLENGE

As with other industries, new technologies drive water utilities to adapt their day-to-day operations. Water networks have been a special focus, with new instrumentation options for water production, transmission, distribution, wastewater collection, and consumer endpoints coming to market. These technologies can improve the efficiency and reliability of water networks, but with myriad options, utilities need guidance on which technologies are most worthwhile and how they should be implemented.

THE RESEARCH

The Water Research Foundation (WRF) advances science and innovation for the use and management of sensors, networks, and data to improve utility decision making, efficiency, and reliability. Focuses include big data, the internet of things (IoT), analytics, and workforce skills needed to meet the demands of a digital future.

WRF has led the way on IWS research to benefit water utilities. A recent project, *Intelligent Water Networks Summit* (4714), gathered information about experiences with intelligent water networks and facilitated the distribution of this information to interested organizations. Three regional workshops were held, followed by a 2018 summit where water utilities presented case studies addressing topics such as managing wastewater overflows, non-revenue water reduction, water quality monitoring, and source water monitoring. An intelligent water utility maturity model framework was developed to assess a utility's technological maturity and support the development of strategies, budgets, and implementation plans for improving the utility's efficiency and customer service. A maturity model tool was also developed to assist utilities in conducting self-assessments using the maturity model framework.

Sensors and Meters

In the last few decades, online sensors have evolved into sophisticated units that can be integrated into computerized control systems and remotely monitored. As regulatory requirements increase and the potential for water system disruptions takes on greater importance, more utilities are relying on sensors and meters to optimize their treatment processes and mitigate potential system risks. WRF research is advancing the science of technologies to monitor, collect, and transfer measurements in real-time—helping utilities proactively solve critical water problems.

Many utilities operating sanitary sewer and combined storm sewer systems are faced with water quality and quantity challenges related to collection system management. These challenges are primarily related to the control of industrial/commercial wastewater inflows and wet weather flows that affect the viability of treatment and water reuse operations and the frequency/pollutant loading into the environment from system overflows. With the recent emergence of low-cost, reliable water quality and quantity sensors and the exponential increases in computing power, the promise of real-time monitoring and operation of collection systems to address these challenges is being realized. *Designing Sensor Networks and Locations on an Urban Sewershed Scale* (SENG6R16/4835) identifies sensor technologies through a survey, workshop, and interviews to develop use cases and IoT strategies for improving operations and management of urban sewersheds. These insights will be consolidated in a phase 2 demonstration project (IWS-17-07/4797).

Potable reuse is typically achieved through multi-barrier treatment trains, consisting of technologies such as microfiltration, reverse osmosis, advanced oxidation, and/or granular activated carbon. To ensure treatment efficacy, water quality must 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. *Monitoring for Reliability and Process Control of Potable Reuse Applications* (Reuse-11-01/1688) develops an operations support tool that integrates sensors and data generated within the treatment process for immediate feedback and alerts. The tool integrates existing sensors as an early warning system to support real-time decision making.

"As the North American water market transitions toward intelligent water systems, we are very excited to partner with WRF. Their outstanding research expertise will bring invaluable knowledge to our membership as we continue to promote critical discussions and cutting-edge research tools needed to advance the water sector."

AMIR CAHN, EXECUTIVE DIRECTOR, THE SMART WATER NETWORKS FORUM

Published in 2020, *Demonstrating Real-Time Collection System Monitoring for Potable Reuse* (WRF-17-30/4908) demonstrated at full scale the ability of use monitoring technology to identify, alert, and trigger responses to harmful discharges within a sewer system. The report examines the deployments led by three utility partners, which investigated the real-world capability of a commercial monitoring system to detect pollutant spikes and react to the detection.

But once utilities gather data, how do they best use it? *Integrating Management of Sensor Data for a Real Time Decision Making and Response System* (Reuse-14-01/4759), completed in 2019, developed a framework for an overall decision support system (DSS) to aid operators and managers of direct potable reuse facilities in making appropriate real-time actions based on anomalies and events at critical process control points to ensure regulatory compliance. The researchers developed an Excel-based decision support tool (DST) which can be configured based on specific facility characteristic and monitoring requirements. The DST, in conjunction with other decision support system components, can help facility operators and managers monitor process performance and identify and respond to process upsets or failures.

A growing number of drinking water utilities are implementing advanced meter reading (AMR) and advanced metering infrastructure (AMI) to capture detailed information from customer meters. With this information, utilities can better respond to customer billing questions, enforce policies for water usage and conservation, and better quantify and ultimately reduce the level of non-revenue water in their distribution systems. Published in 2020, *AMI-Meter Data Analytics* (4741) investigated how water utilities can use AMI data to realize benefits beyond just reading meters. Seven utilities shared practical application of AMI meter data analytics for benefits beyond customer billing. The project results support the use of AMI data analytics in developing and improving leading practices for customer interactions, water accounting, and meter management.

Data and Security

IoT technology and the need to process data from multiple and often disparate sources are becoming very important in the water and wastewater industry. Findings indicate that the water sector has not embraced big data analytics and IoT as rapidly as other industries. While utilities are collecting significant amounts of data, data quality is an issue that hampers data utilization. Generally, the technology solutions available address only single water industry uses. This leaves the onus on utilities to provide the integration capabilities when multiple applications are implemented. *Leveraging Other Industries—Big Data Management* (SENG7R16/4836) captures the state of knowledge on IoT and big data processing in the water sector and key non-water sectors. This knowledge will help to improve operations efficiency, asset investment decisions, and regulatory compliance, all while reducing environmental impact.

Today's water utilities utilize a wide range of information sources, including supervisory control and data acquisition (SCADA) systems, AMI/AMR systems, water quality monitoring systems, and security monitoring systems. Each of these information sources, along with the technologies used to transmit the associated data, has evolved largely independently. Utilities must deal with numerous communication platforms along with multiple communication protocols and cybersecurity measures. *Defining Optimum Security and Communication Methodologies for Intelligent Water Networks* (4670) inventories the types of information sources currently being used by water utilities along with the associated communication media and protocols. The security risks associated with each information source and its communication approach were assessed, and it was determined whether the current cybersecurity measures in use provide acceptable protection. In cases where the current measures appear inadequate, alternate approaches were recommended to improve security. An Intelligent Water Systems Matrix was developed to present general and security considerations for communication methodologies used by the most common information systems.

Workforce

The transition to an intelligent water system has obvious impacts on the utility labor force, eliminating functions

SOLUTIONS IN THE FIELD: OPTI

In recent decades, more green solutions have made their way into traditional stormwater systems, but managing these decentralized approaches hasn't always been easy. Additionally, most of these systems are operated in a passive manner, which doesn't optimize their performance. In 2011, WRF launched an effort with EPA that would help change that. The program, Innovation and Research for Water Infrastructure for the 21st Century, provided resources to advance water technologies, opening the door for Geosyntec and University of Massachusetts researchers to evaluate new stormwater solutions that incorporated recent advances in computer hardware and software. Up until that point, few truly "smart" stormwater systems that involved active, real-time control had been attempted.

The research examined highly distributed real-time control (DRTC) technologies for green infrastructure, such as advanced rainwater harvesting systems, dynamically controlled green roofs, and controlled under-drained bioretention systems. By and large, testing was successful, showing that technologies could be robust, low cost, and flexible. Now, stormwater flows could be monitored remotely on internet-connected devices and controlled in real time—a dramatic step forward. Next, Geosyntec wanted to demonstrate that the DRTC technologies they developed could play a key role in managing urban infrastructure. Results from this research, published in the 2014 report, *Transforming Our Cities: High-*

***Performance Green Infrastructure* (INFR1R11/1445), showed that technologies significantly lowered contributions to CSOs, reduced stormwater runoff, and retained stormwater for onsite use—helping to push the technology into full commercialization the same year.**

This led to the formation of the independent company, Opti, which focuses on delivering continuous monitoring and adaptive control solutions for stormwater applications. A second phase of research, through a partnership with LIFT, helped further accelerate this technology, demonstrating its use at scale. To date, the technology, a cloud-based platform for real-time monitoring and control of green stormwater infrastructure, has more than 130 installations, combining sensors with internet-based weather forecasts to make decisions that could help prevent flooding or combined sewer overflows—like whether to release stored water prior to rain events.

like meter or other remote instrumentation reading, but adding other functions such as data interpretation. Utilities must prepare to meet employee training needs and attract workers to fill more skilled positions. In addition to retraining the current water workforce, there is an urgent need to attract additional employees to this sector. These challenges offer an enormous economic opportunity: the water sector is well positioned to offer more durable careers to a wide variety of workers.

In 2018, WRF partnered with the Metropolitan Policy Program at The Brookings Institution, which published *Renewing the Water Workforce: Improving Water Infrastructure and Creating a Pipeline to Opportunity* (4751). This research provides insight on the nation's 1.7M water workers, including data on wages, skills, and demographics. The report also presents actionable strategies—a new water workforce playbook—that all types of leaders can use in future hiring, training, and retention efforts.

Published in 2019, *Building Workforce Skills for Intelligent Water Operations* (4663) helps prepare utilities for anticipated workforce changes as they implement increased automation and smart water technologies. Trends in the sector were identified, and recommendations were developed to guide utilities in addressing digital technologies and the changing workforce. In the short term, utilities must investigate and implement useful innovations in technology, develop data plans, identify staff responsible for managing data, investigate the utilization of simulation for system optimization and training, make training and standard operating procedures available on-demand, and update and modify hiring processes.

INNOVATION

The Intelligent Water Systems Challenge, a partnership between WRF and the Water Environment Federation, asks participants to demonstrate the value of intelligent water systems to utilities, thereby fostering the adoption of smart water technologies. The Challenge, held yearly, also gives students and professionals the opportunity to showcase their talents and innovation. Winners of the 2021 Challenge were Clean Water Services (Oregon) and Princeton University.

WHAT'S NEXT?

In spite of advances in intelligent water systems, there is no coherent definition of what a data-driven or digital utility is. In 2019, WRF funded *Definition, Framework, and Maturity Assessment for Intelligent Water Systems* (5039) to outline the definitions and elements of an IWS, particularly related to technologies, skill sets, culture, and workforce. The project will also investigate ongoing advancements in sensor, data management/analytics, and digital communication technologies for optimal management and operation of a complex IWS/data-driven digital water utility.

The American Water Works Association's *State of the Industry Report* cited deteriorating infrastructure as the top concern among utilities, and pressure has contributed to pipe failure in several studies. In several case studies, pressure reductions apparently correlated with reduced pipe breaks, and many times major pressure surges in a distribution system could be followed by a series of pipe breaks. Lowering pressure may provide significant reductions in pipe breaks, leakage, and energy costs—and certain smart water technologies are applicable for managing pressure with the direct result of reduced water loss and less stress on pipes. *Utilizing Smart Water Networks to Manage Pressure and Flow for Reduction of Water Loss and Pipe Breaks* (4917) will provide best practices for implementing smart water technology to manage pressure and flows in distribution networks, with a step-by-step approach for planning, design, technology selection, and operations and maintenance to extend pipe life and reduce water loss.