WATER RESOURCES IMPACT

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VOLUME 25 • NUMBER 5

INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) REDUX

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Credit: Alabama Tourism Department, Chris Granger

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IWRM Redux

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AWRA has invested much effort into promoting the concept of integrated water resources management. For example, this issue is at least the third *Water Resources IMPACT* devoted to IWRM. And we've had at least two conferences dedicated to the subject. The article by Mike Antos—an IWRM guru who's been "doing this" for 20 years—promotes relationships. I see more of that lately. Dan Sheer and Jay Lund note that IWRM is a "broad and vaguely defined concept." That's what some find appealing. Harry Zhang focuses on sustainability. Of note: the Tennessee Valley Authority (TVA) dealt with navigation, flood control, and power generation as early as the 1930s—an early example of IWRM. But my introduction to IWRM came in 2014, when I became a member of the Steering Committee of the Global Water Partnership (GWP.org). Importantly, the GWP supported the adoption of the UN's Sustainable Development Goals (SDGs). Goal 6 is Support Clean Water and Sanitation. Harry Zhang must be enthused about SDG6! Stephanie Ishii and her colleagues focus on what IWRM can do for a small city, Plant City, in Florida. Megan Van Ham, Sarah Marshall, and Pamela Duncan focus on a much larger city—Calgary is Canada's fourth largest and still growing. Calgary is also very keen on diversity, equity, and inclusion. Can IWRM handle that? I suspect it will. Jenny Bywater and Kimberly Chanslor look at the development of a forecasting model for Georgetown, a suburb of Austin, Texas. And Simone Williams deals with groundwater issues in the USA's arid Southwest. We know that elevating groundwater quality through IWRM is essential for safeguarding water supplies, ecosystems, and economies

After reading the aforementioned articles, I am optimistic about the future of IWRM. After all, its "official" definition reads: "Integrated Water Resources Management is a process that promotes the coordinated development and management of water, land, and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." Beware—I might even be around for more!

– Michael Campana, Editor-in-Chief

Messages

FEATURE ARTICLES

About the cover: These three images capture key elements of IWRM as well as three of the projects discussed in this issue. In the American Southwest, careful management of water resources is essential, as is cooperation among states and municipalities. In Calgary, Canada, stormwater keeps the grass green, saves energy, and helps prevent drought. In California, author Mike Antos and colleagues gather for a coastal cleanup, cementing the relationships that support IWRM. Sources: Simone A. Williams, City of Calgary, and Ryanna Fossum

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PRESIDENT'S MESSAGE

Rabia Ahmed, AWRA 2024 President

Past-President Jason Zhang hands off the gavel to incoming President Rabia Ahmed at the 2023 AWRA Annual Water Resource Conference. Source: Rabia Ahmed

DEAR AWRA MEMBERS,

My name is Rabia Ahmed, and as the 2024–25 president of AWRA, I am excited to welcome you to a new era of AWRA. While not the first from the great state of Washington, I am the first Pakistani American woman president in the association's 60-year history. I am indeed humbled and honored in this capacity. 2023 was a year of strategic thinking and planning for AWRA, with the completion of extensive bylaws revision and strategic planning processes. Special thanks to Jason Zhang, the outgoing 2023 president, for leading us through this last year, and for staying with us as president emeritus to guide and advise us this year. While we implement the strategic plan during 2024, we are mindful that we continue our mission of providing the quality experience you have come to expect from AWRA as an environmental professional. We hope that you will join AWRA for our 60-year celebration at the AWRA, UCOWR, NIWR 60th Anniversary Joint Water Resources Conference from September 30 to October 2, 2024, in St. Louis, Missouri.

This issue of *Water Resources IMPACT* is my first as AWRA board president. As we head into 2024 together, allow me to extend my heartfelt thanks to the readership of this magazine, and even more for the kind welcome I have received from the AWRA community. I look forward to bringing new perspectives to all of you in print, online, and in person in the coming year.

I am so pleased that this issue centers on integrated water resources management (IWRM), a field with a long history and one that has grown exponentially in recent years, to the betterment of local planning efforts as well as the global effort to ensure collective water needs are met. As our expert authors show, when done well, IWRM can transform communities and set us on a course for an inclusive, sustainable, and equitably resourced future.

In these pages, we dig into just what that future can look like. We feature reports and voices from on the ground in several communities: Plant City, Florida; Georgetown, Texas; Calgary, Alberta, Canada; and the Southwest region of the United States.

We also look back on the last several decades of water resources management, seen through the lens of IWRM. Mike Antos argues for the inherently relational nature of IWRM, and Dan Sheer and Jay Lund tease out the roles that have emerged as essential to ensuring IWRM runs smoothly. Meanwhile, Harry Zhang argues for IWRM, and especially "One Water," as the ultimate systems approach that can solve climate, business, and social issues in one fell swoop. I am excited about 2024, and look forward to this journey with our wonderful community of environmental professionals, practitioners, and students. In this new year, I wish that all our membership and broader community may find hope in the future and joy in one another. I expect the stories recorded here will help in that endeavor. ■

Kind regards,
Rabia Ahmed

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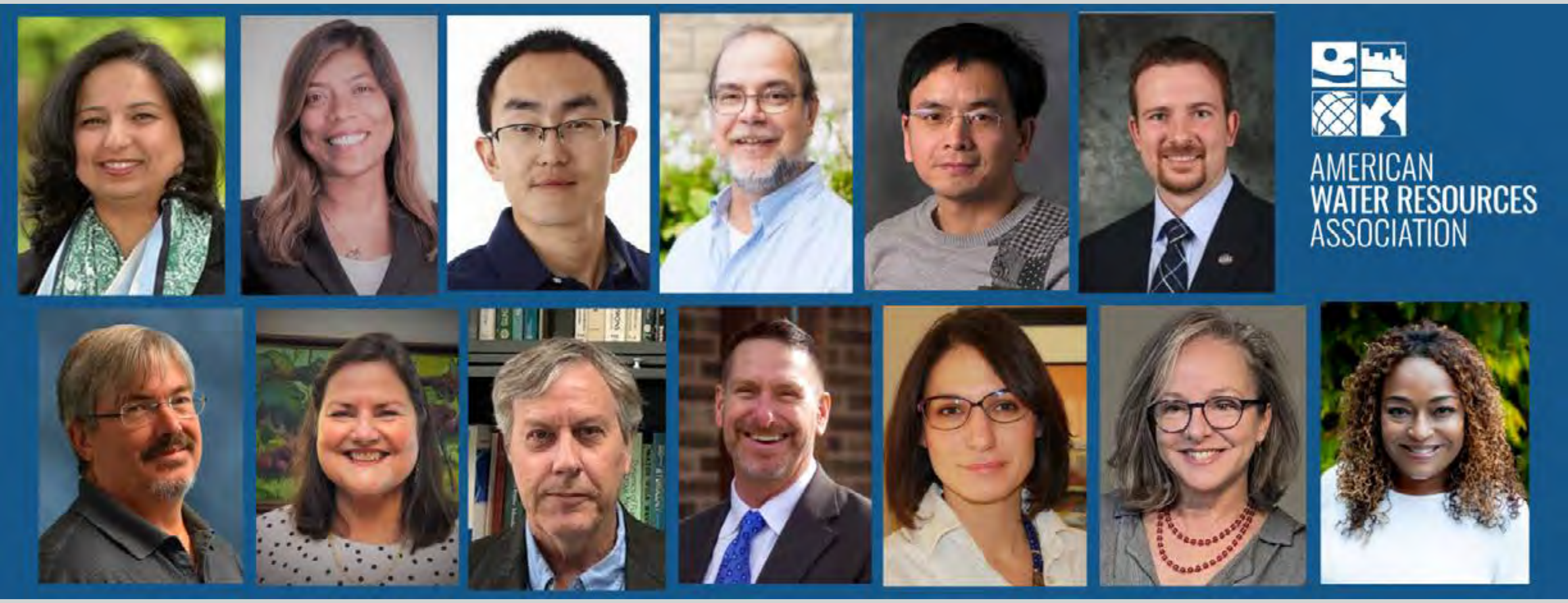

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FEATURE

Facilitator, Analyst, and Planner—Three Critical Professional Roles in IWRM

Daniel P. Sheer and Jay R. Lund

A great blue heron looking out over Lake Okeechobee in Florida. To illustrate the role of the analyst, discussed below, the authors use the example of the development of a performance metric for the survival of wading birds in Lake Okeechobee. Image source: Norm, Adobe Stock

PUTTING THE ROLES IN CONTEXT

Integrated water resources management (IWRM) is a broad and vaguely defined concept. Individual applications of IWRM are very different. IWRM doesn't occur by itself. Sometimes a "kaiser," a judge or regulator implementing a legal or regulatory directive, provides motivation. Sometimes system failures or stressors, experienced or from a simulation exercise, provide impetus.

Whatever the motivation, effective management requires an understanding of objectives. There are many stakeholders, each with multiple objectives. Each has relative preferences for their own objectives, and their preferences are dynamic. Preference for an apple or an orange differs if you have one apple and nine oranges or nine apples and one orange. Preferences change over time, especially with additional knowledge. It is generally impossible for any one person or group to fully understand the objectives and preferences of all stakeholders.

Implementing IWRM usually requires at least the acquiescence of the large majority of stakeholders, any one of which can typically block or postpone implementation. Stakeholders will generally acquiesce if they perceive that they will be better off accepting a management strategy rather than fighting that strategy. IWRM increases the likelihood that acceptable strategies can be identified and implemented. IWRM helps resolve what is essentially a political problem, allocating the benefits of a public resource.

Throughout the senior author's 50-year-long career, he was engaged in developing and instituting IWRM. Based on that experience, he believes three critical professional roles are needed in developing and implementing IWRM—facilitator, analyst, and planner. This article offers some hopefully helpful pointers, with examples on how practitioners can best perform those roles, alone and with others.

Facilitators: The Glue

Facilitators hold IWRM processes together. It's a very challenging role. Usually they are primarily responsible for several tasks and are invaluable for others. Their first primary task is scheduling people and resources, making sure people are in the right place at the right time. In multiparty, multiobjective efforts, this is a good deal of work. This sets the pace of the process, and timing (not too fast, too slow, too rigid, too lackadaisical, or too performative) is essential for success.

The facilitator's second primary task is moderating discussions. Keeping discourse civil and productive is rarely easy. Keeping meetings moving can be even harder. IWRM processes that lack good moderators generally go nowhere fast. To be effective, a moderator must have a basic understanding of the subjects being discussed and/or be a quick study willing to do homework. It is essential to build productive and effective communication, especially when there is a history of conflict.

Stakeholders often speak different "languages"—using different words, or worse, the same word with different meanings. Good facilitators are sensitive to this and serve as "translators" so participants understand what was meant, even if it is not what they heard. Many, many heated arguments can be avoided by good translators.

Translation must be done gently; it involves people skills. The facilitator must have a basic knowledge of at least most of the languages in use. Making sure discussion keeps moving in a mostly productive direction without suppressing newly relevant ideas, topics, or information also requires an interest in and understanding of what's being said.

The third task for facilitators is to make sure that other team members, including analysts and planners, understand what stakeholders are saying—particularly about stakeholder objectives and their perspective on how the system works. Too often, facilitators assume that having been party to the stakeholder discussions, their analytical and planning colleagues have the same understanding as the facilitators. That assumption is rarely correct. It is useful for all three groups to debrief after discussions with stakeholders. Different perspectives on what was meant can be discussed. What was meant can be quite different than a literal interpretation of what was said. Analysts (in particular) are often not the best communicators. Often facilitators must translate analytical results and feedback among analysts, stakeholders, and planners.

IWRM helps resolve what is essentially a political problem, allocating the benefits of a public resource.

Analysts: The Evaluators

Analysts must develop and usually operate the analytical tools to evaluate and compare alternatives. Their first and most important task in that development is defining and formatting performance metrics (PMs) to be used in the evaluation. It is stakeholders, and not analysts, that define the PMs. Analysts often assume that those PMs are, and should be, the same as their own. Facilitators must be on the watch for this tendency, and analysts must be open to correction.

Analysts can suggest PMs to the stakeholders. They must, however, refrain from insisting that their own objectives be included. Analysts are responsible for ensuring that PMs proposed by stakeholders can be evaluated in a scientifically credible and reproducible way, using credible data, within the time and budget constraints of the IWRM project. When a proposed PM cannot be credibly evaluated, it is the analyst's responsibility to help find a surrogate. Formats for PMs can be very important. Analysts must confer with stakeholders to choose the most meaningful and easily interpreted format.

In addition to the ability to evaluate all PMs, analysts must build toolsets that can evaluate all alternatives that might be considered, especially alternatives proposed by stakeholders. Infeasible alternatives often must be evaluated so discussions can progress. Operational and physical alternatives need to be considered—water trading, water markets, forecast-based operations, water-use restrictions, water rates changes, insurance, etc., depending on the problem at hand.

Analysts in IWRM are a human interface to the analytical tools. Facilitators also may be vital in this function. By making the tools available to the stakeholders, individually and collectively, and allowing the stakeholders to test their own ideas and intuition, analysts can help build trust and confidence in the analytical tools they develop and improve the group's exploration of already proposed and new alternatives.

Planners: The Creatives

The planning (or engineering) role in IWRM involves crafting alternatives that are "better" in terms of performance measures. Such alternatives may modify or combine previously evaluated alternatives or may be the creation of the planner (partially or completely). To create

An example PM, for survival of wading birds around Lake Okeechobee, near the Everglades in South Florida, including some endangered species.

The initially proposed PM was expected population of wading birds. Available science was inadequate to predict future population changes based on changes in the complex water management system. A surrogate was needed to help assess if changes would benefit or harm the birds. Discussions with stakeholders showed that an important hydrologic factor for spawning success was the nature of the seasonal drawdown in the lake. The birds feed along the shallow areas at the edge of the lake. As the lake comes down, new forage area is exposed to provide additional food. If the drawdown reverses by more than about six inches during the nesting season, there is insufficient food for the fledglings. Identifying years with reversals would be straightforward using available analytical tools. Historical data was analyzed—showing many years with reversals. Reversals also could be expected under pre-development conditions. During discussion of the results, it was shown that consecutive years of reversals were particularly damaging to populations, with three consecutive years being catastrophic. The PM developed showed the number of good years, the number of bad years, the number of two-consecutive bad years and the number of three-consecutive bad years. Not only was this clear to the stakeholders interested in wading birds, it was easily explained to others; it was a broadly effective PM.

acceptable alternatives, planners must recognize that IWRM is driven by stakeholders' multiple objectives—in particular, those represented by the PMs. The planner's role is to develop alternatives that balance the achievement of those objectives in a way that is satisfactory to all (or as many as possible) stakeholders. These alternatives are sometimes called satisficing alternatives. The planner can more convincingly discard alternatives that are inferior—that is, where another alternative exists that does at least as well on all the objectives and is better on at least one of them—in favor of non-inferior solutions that can be refined and improved.

Creativity is vital for this role, as is an overall familiarity with the problem. The planner needs to learn specifics of the problem by working with the stakeholders (assisted by the facilitator) and the analysts (sometimes assisted by the facilitator). Planners should be ready to explain to stakeholders the rationale for the alternatives they create. Planners need to especially note the merits of alternatives developed by stakeholders.

Effective IWRM efforts require people who can fulfill several external and internal roles. If any of these roles are filled inadequately, IWRM processes can linger and wither and not take advantage of opportunities provided by external stimuli to make improvements. ■

Jay Lund (jrlund@ucdavis.edu) is a professor emeritus of civil and environmental engineering at the University of California, Davis.

Dan Sheer (DSheer@gmail.com) is one of the pioneers in the field of collaborative modeling and led the team that developed OASIS, one of the most widely used tools in that field. The firm he founded and led, HydroLogics—now a part of Hazen and Sawyer—helped manage water in basins containing approximately 20% of the U.S. population, as well as basins internationally. He is now retired but working part time on several water resources projects.

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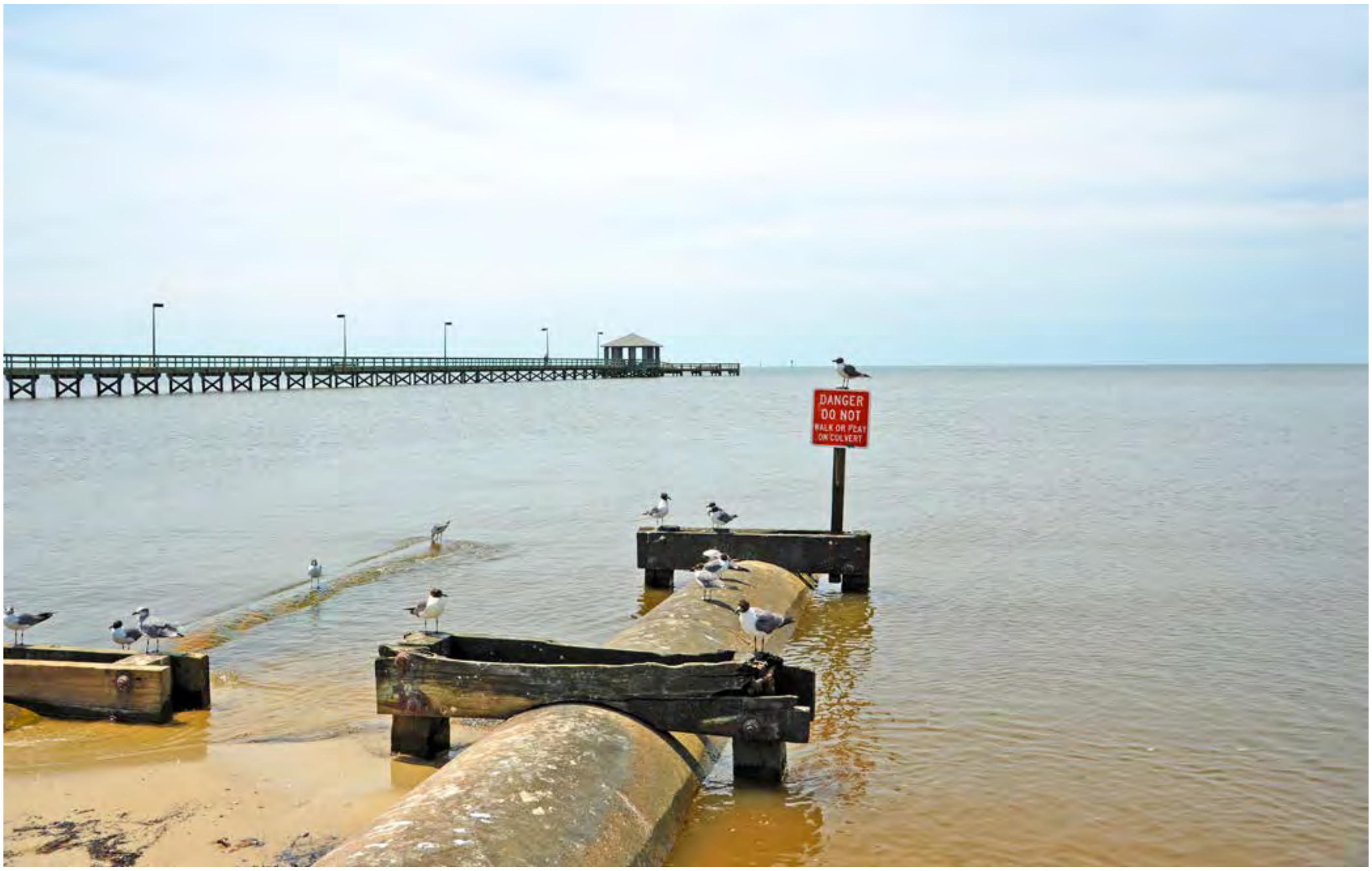
FEATURE

Integrated Water Resources Management: The Key to Making Water Systems Sustainable over the Long Term?

Harry X. Zhang



A stormwater culvert juts out from a beach. The future of integrated water resources management depends on the field's ability to adapt to climate change, among other evolving concerns. Source: EyeMark, Adobe Stock

SUSTAINABILITY HAS BECOME A WIDE-RANGING TERM that can be applied to almost every facet of life from a local to global scale and over various time periods. Integrated water resources management (IWRM) has a close connection with sustainability. IWRM has been defined by the Global Water Partnership (GWP) as a process that promotes the coordinated development and management of water, land, and related resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

In order to advance IWRM as a concept and as a practice to tackle evolving challenges, we need to apply a systems analysis approach, for example, by using a holistic framework that considers environmental, economic, and social interrelationships for tracking and understanding changes to the full water cycle. The water system, climate system, and related climate-water nexus are essentially good examples of complex systems. Complex systems are systems where the collective behavior of their parts entails emergence of properties that can hardly, if at all, be inferred from the properties of the parts alone. The 2021

Nobel Prize in Physics was awarded "for groundbreaking contributions to our understanding of complex systems," with one-half awarded jointly to Syukuro Manabe and Klaus Hasselmann "for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming" and the other half to Giorgio Parisi "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales." Given the complexity and interconnectedness among water, climate, energy, and other systems, the underlying science advancements for IWRM have been and will continue to be supported by rigorous multidisciplinary research.

The Birth and Evolution of Research on IWRM

Over the past 10 to 15 years, The Water Research Foundation (WRF) has been actively conducting research on the topics of "One Water Management" and "Integrated Water Management" (IWM). It started in 2010 when WRF's predecessor organization launched a program called "Sustainable Integrated Water Management" (SIWM). The SIWM program takes a holistic approach to wastewater, stormwater, drinking water, and recycled water to achieve the goal of "One Water," including consideration of projected climate impacts. The SIWM program has defined its research challenges in dedicated statements, with an overall goal to advance a paradigm shift in water management toward next-generation, integrated, sustainable systems. These systems would: (1) integrate wastewater, stormwater, drinking water, and other water resources; (2) maximize energy, materials, and water recovery; (3) be safe and resilient to external impacts; (4) protect water quality for designated uses; (5) maximize triple-bottom line benefits; (6) leverage existing and emerging models for service delivery; and (7) incorporate integrated and comprehensive water planning and smart growth planning at the national, regional, and watershed/local level.

The journey toward sustainable and integrated water resources management begins by determining the most important water issues and related indicators.

Through years of collaborative efforts, WRF published a report titled "Pathways to One Water: A Guide for Institutional Innovation" in 2015. Continuing further with follow-up research, WRF published a report titled "Blueprint for One Water" in 2017, which sought to advance the adoption of a One Water approach through the development of a user-friendly blueprint for the practical application of One Water planning. Realizing the importance of interconnection between the One Water approach and other more focused topics, WRF completed several additional studies in recent years. Further drawing the connection with an integrated planning framework, WRF published "User's Guide for Integrated Stormwater and Wastewater Planning" in 2020. Subsequently, the research products "Holistic Nutrient Management" and "One Water and Pretreatment" were published in 2023. All these projects are connected to WRF's "One Water Cities" research, which aims to help utilities and municipalities identify effective strategies and viable technological, policy, institutional, and financial pathways toward One Water Cities.

In collaboration with the U.S. Environmental Protection Agency, national organizations, and several universities, the WRF research team developed a decision support system called "Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs" (CLASIC) in 2021 to advance holistic stormwater and wet weather management. The three main outputs from the tool are (a) performance (both hydrology and water quality), (b) life cycle cost, and (c) triple bottom line (TBL) benefits. This integrated decision support tool enables municipalities to analyze risk tolerance for stormwater services and consider associated costs for holistic solutions while also addressing climate resilience at the community level.

Approaches to Climate Change and Business Solutions

Regarding IWRM in the context of the changing climate, it is possible that the future may not be a good representation of the past. The impact of a changing climate is expected to make certain aspects of water availability and water quality estimation more uncertain. Nonstationarity (e.g., constant change) presents many challenges to the water managers who are dealing with a complex system in a real world. Currently, many types of analyses are integrally linked to stationary concepts (e.g., hydrologic statistics such as high-flow flood frequency and low-flow drought frequency). While research proceeds, efforts can be made to bring knowledge advancements into planning and analysis to better accommodate nonstationarity and enhance integrated water management.

In facing these challenges, WRF has recently launched several IWRM-related research projects that consider a changing climate. For example, these projects include "Navigating One Water Planning through Municipal Water Programs: Meeting Multiple Objectives and Regulatory Challenges" and "Integrating Climate Change Impacts with Wet Weather Management, Capital Improvement, and Stream Network Enhancement." More IWRM-related research will evolve in the years to come.

The IWRM concept is now embedded in business water sustainability as well. For instance, a report titled "Vision 2050" released in 2010 and a subsequent report titled "Vision 2050: Time to Transform" released in 2021 by the World Business Council for Sustainable Development (WBCSD) address three main questions: "(a) What would a sustainable world look like in 2050? (b) What are the pathways and solutions for achieving sustainability? (c) What are the roles business can play in ensuring more rapid progress toward that world?" WBCSD promotes the concept of circular economy, which aims to help the business sector start the transition toward a circular economy to unlock more value with fewer resources, including water resources. In practice, there are already established sets of key water performance and risk indicators for water consumption, efficiency, and intensity. These metrics can then be used for communication with internal and external stakeholders and reporting under corporate disclosure initiatives like the Global Reporting Initiative (GRI), CDP Water, Dow Jones Sustainability Indices, and Bloomberg Environmental, Social, and Governance (ESG) Indices.

Going forward, to create truly sustainable and integrated solutions, businesses and those who support them need to address the interconnectedness of issues such as water, food, and energy, approaching them in a holistic way, with a better understanding of trade-offs that need to be balanced.

Systems Analysis into the Future

To address the challenges presented by evolving water issues through IWRM, we will need to continue adopting a systems approach, with a good balance between innovative thinking and practical solutions. The holistic water management and "One Water" approach envision managing all water in an integrated, inclusive, and sustainable manner. The journey toward sustainable and integrated water resources management begins by determining the most important water issues and related indicators. We must take a holistic view of watersheds and ecosystems by simultaneously considering water quality and availability; freshwater and coastal waters; surface water and groundwater; reuse; water and land use; and physical, chemical, and ecological characteristics. By taking environmental, economic, and social interrelationships into account, an integrated framework for the full water cycle will provide a thriving opportunity for a sustainable future for many, many years to come. ■

Harry X. Zhang (hzhang@waterrf.org) is research program manager on integrated water and stormwater at The Water Research Foundation (WRF) in Alexandria, Virginia. In addition, Harry is WRF's climate change topic lead. Harry holds a Ph.D. in civil and environmental engineering (water resources) with a minor in systems engineering from the University of Virginia, and is a registered professional engineer.

IWRM: Can You Relate?

Mike Antos

The author (right) and colleagues at the site of a Coastal Cleanup Day in the Arroyo Seco, a tributary to the Los Angeles River. Source: Ryanna Fossum

AS SOMEONE WHO NOW HAS 20 YEARS (!) EXPERIENCE with "integrated water resources management," I am constantly fascinated to hear, often within the course of one coffee break at a conference, that IWRM is both passé and central to everything we are currently doing. About four years ago someone at an AWRA meeting told me, "Our projects would never get through a city council if they weren't integrated and providing multiple benefits." And I often share an apocryphal summary of a community conversation:

Consultant: "For you, how important is it that the different water management agencies plan and work together?"

Community member: "You mean they don't?"

At the 2019 AWRA specialty conference in Omaha, my co-chair and I encouraged everyone to think about "setting the conditions for the success of IWRM." We edited an *IMPACT* magazine using that same theme. My professional experience and academic research had led me to observe that practitioners had mostly sorted out how and why to work in integrated ways when managing water. However, in most cases the policy structures that empower (or restrict) how water managers work had become the primary challenge. If the concern is that IWRM takes 20% more time and 20% more money, it is because everyone is stretching slightly outside their authority, requiring special permits and clearances, and having to triple-check that they are spending money in approved ways. Seeing "20% slower and more expensive" as a sign that the system is either a luxury or a dead end had become a self-fulfilling loop, as policy makers who should empower IWRM were instead viewing it with skepticism. Empowering further integration to achieve economies of scope is necessarily a mission of policy and governance.

I remain confident that we were on to something and, more importantly, that real-world progress is being made. Today, public agencies are more likely to have a sustainability office and a resilience mandate, for example, and both those concepts recognize integrated challenges and opportunities. Climate risk is driving more integrated thinking, with water, health, and prosperity

Flooding on the South Fork American River in California, near Henningsen Lotus Park, on New Year's Day 2023. Heavy snow and rain across the Sierra Nevada resulted in deadly flooding and mudslides. Flood-MAR promises to curb the negative impacts of such flooding, saving the water to be used in times of drought. Source: Lisa, Adobe Stock

seen as interconnected and within the responsibility set of water managers. When economic tides ebb and flow, the need to make smart investments pushes toward greater integration—solving two or more problems with the same dollar.

Investing in Social Infrastructure

For me the truth about IWRM has always been hiding in plain sight: relationships are the actual topic that should be made central to our discussions. Maybe it should be integrated water relationship management. Whether it be relationships between agencies, or between agencies and the communities that created them, or relationships between the people and their representatives, relationships of trust and mutual understanding are what is needed to be effective at integrated management of anything. Relationships are the social infrastructure that results when the "extra" 20% investment of time and money is made. Those relationships, once created and nurtured, are a persistent benefit across projects and over time.

A remarkable example to share is the Disadvantaged Community and Tribal Involvement (DACTI) Program in California. This program is a $51 million investment in relationships and engagement statewide, produced by an act of the voters in 2014. As a component of the State's Integrated Regional Water Management Program (IRWM), the DACTI Program was explicitly designed to build capacity and empower the voices of marginalized, tribal, and overburdened communities to be prominent if not in the lead of planning for more resilient and integrated water management.

California's IRWM had long held a mandate that 10% of the funding provided by the State in a 1:1 cost-share for local projects had to be supportive of disadvantaged communities. However, in the five years after the 2002 creation of IRWM, advocates and community members

> "Economies of scope" was coined in the 1970s to describe "a situation where it is less costly to combine two or more product lines in one firm than to produce them separately." The application of this framing to public infrastructure has been explored in peer-reviewed literature on and off since and I believe remains fertile intellectual territory for resilience, integration, and remediation scholars and practitioners.

alike shared how projects that were being located within communities were not what the community itself would have chosen. The DACTI Program was aimed directly at this reality, putting another 10% of the available funding aside for efforts that would "ensure the involvement of" members of overburdened and tribal communities.

This policy success—an investment in strategic listening and building relationships with the time and resources necessary to do it properly—is the "setting conditions for success" that has been central to my thinking for more than a decade. This program demonstrates that engagement must not be a self-referential requirement (we are engaging because the funder says we must engage) and instead is a fundamental part of achieving equity, resilience, and sustainability. In the DACTI Program, supporting and listening to the voices of all those who will be impacted by water management decisions is the integration.

Another example to share from California is the ongoing adaptation effort driven by climate change switching the winter precipitation in the Sierra Nevada from snow to rain. Much of California's water supply infrastructure was built to use the slow snowmelt to sustain supplies through the summer. With climate change, more frequent and more deeply dry years will be punctuated with years that bring much more winter rain to the mountains, meaning California faces drought and flood. A collective and collaborative effort has gained steam over the past five years to adopt Flood-MAR (managed aquifer recharge using flood waters) within the Central Valley. Solving one climate-related challenge with another climate-related challenge is quite elegant.

> *For me the truth about IWRM has always been hiding in plain sight: relationships are the actual topic that should be made central to our discussions.*

Moving from not doing Flood-MAR to doing lots of Flood-MAR is a deeply integrated challenge. To name but a few specific challenges, it requires changes in policy, regulation, and law, and it requires adoption of new financial models and new thinking about private property. It also ties to groundwater dependent ecosystems and in-stream flows, and it accentuates concerns about groundwater quality. Into these puzzles came the Flood-MAR Network—a group of people who are each tackling their own piece of the puzzle, sharing with one another, looking for synergies, sorting out turn-taking, resolving conflicts before they can start, and helping teach and learn what works and what does not. Here again, the integration is the people and the relationships they have established. Any one Flood-MAR project may be relatively single-purpose—but the transformation to the widespread use of Flood-MAR is an integrated effort benefitting from people recognizing their interdependence and shared purpose.

Learning the Lessons of IWRM 1.0

This magazine is considering what comes next for IWRM—do we need to rebrand or create a 2.0 version? I would say the first step to answering that question is to reflect on some of the key things that changed because of IWRM 1.0. First, we saw fewer lawsuits as water managers began partnering with one another to alleviate shared burdens instead of ignoring externalities until they got out of control. Second, water management became home to not just technical people with engineering and hydrology degrees; this period saw the planners, policymakers, engagement specialists, community organizers, ombudsmen, and community groups all join in. If you look across the AWRA IWRM award winners since 2012, you find that the celebrated integrated efforts always stem from groups of people with different roles in the community coming together.

"Disadvantaged community" has several policy definitions in California and is often abbreviated "DAC" and pronounced "dack." I bristle at this shortening, and welcome opportunities to help people see how using "dack" further dehumanizes and de-peoples the communities whose burden is almost always no fault of their own. It also suggests a uniformity that falsely smooths over the often very complex set of opportunities and challenges that are held uniquely by every community. Regardless of economic capacity, all people and all communities have pride, hope, things they would sustain, and things they would change. Investing in capacity, engagement, and listening to all voices is both humane and a key resilience strategy, and doing so in a way that respects all people is necessary.

These projects all achieved economies of scope—spending a little more time and a little more money to achieve a lot more outcomes.

Seen this way, I argue that what we actually learned during IWRM 1.0 is that our challenges are integrated, which means our solutions must be integrated. The only way to do this is through many diverse and diversely skilled people building lasting relationships of respect and common purpose. I'm not sure about you, but I absolutely treasure that my work lets me strive together with people who are different from me and who hold different skills and perspectives. Integrated water resources management is rewarding for its processes and its outcomes in equal measure.

I encourage the IWRM community to recognize all that it has achieved, and to consider if the "brand" was ever the most important part for us. Learning how to connect with others, how to think together at the scale of complex systems, and how to overcome the allure of planned externalities—these skills never were constrained to only the IWRM projects. IWRM is a practice, a skill, a discipline. We are IWRM practitioners, and every project needs at least a couple of us. We don't need IWRM projects—all projects need to practice IWRM. ■

Mike Antos (Mike.Antos@stantec.com) is a principal watershed social scientist at Stantec and a fellow of the Robert & Patricia Switzer Foundation.

AWRA 2023 Annual Water Resources Conference Student Paper Competition Winners

AMERICAN WATER RESOURCES ASSOCIATION

UNDERGRADUATE DIVISION

Nathan Hewitt (Winner)
"Using Remote Sensing and Spatial Data Analysis to Quantify Impact of Hurricane Ian Storm Surge on Sediment Buildup and Shoreline Changes on Southwest Florida Barrier Islands"
Florida Gulf Coast University
https://www.linkedin.com/in/nathan-hewitt01/

Nathan Hewitt is a dual major undergraduate student at Florida Gulf Coast University studying marine science and environmental studies. He is a lab assistant at the university and currently analyzing the impacts to Southwest Florida barrier islands caused by Hurricane Ian. He has also worked on a project investigating the spatial temporal dynamics of eastern oyster spat and larval density in a local estuary. He is also an avid scuba diver and loves exploring new dive sites!

Haylie Fine (Runner-up)
"Difference in Part-Time Versus Permanent Residents' Beliefs Regarding Willingness to Participate in Remediation of a Local Body of Water"
Jupiter High School

Haylie Fine is currently a senior at Jupiter High School in Jupiter, Florida. She joined the Jupiter Environmental Research and Field Studies Academy when she was a freshman during Covid-19. Growing up in South Florida has allowed her to foster a love for the environment. She is hoping to study sustainable consulting at the University of Florida. Interacting with her community and raising awareness about water quality have been her favorite parts of her project. She has been attending the AWRA for the past years and is very thankful for the connections she has made, all due to her outstanding teacher Dr. Teresa Thornton.

GRADUATE DIVISION

Jacob Taggart (Winner)
"Development of a Micro-Fractionation Method for Studying Phosphorus Bound to Suspended Sediments"
Bringham Young University
https://www.linkedin.com/in/jacob-taggart-695526164/

Jacob Taggart is a Ph.D. candidate in Civil & Construction Engineering at Brigham Young University with a sponsorship from the Wasatch Front Water Quality Council to conduct research on phosphorus geochemistry in Utah Lake. Prior to pursuing a Ph.D., Jacob received a master's degree in hydrological science & engineering from the Colorado School of Mines in 2021 and a bachelor's degree in geological science from Brigham Young University in 2017. Upon completing his doctoral degree, Jacob hopes to build a career tackling water-related issues throughout the Intermountain West in order to help find ways to better preserve and utilize this valuable resource.

Layla El-Khoury (Runner-up)
"Estimating Nutrient Loads to Falls Lake from Streambank Erosion."
North Carolina State University
https://www.linkedin.com/in/layla-el-khoury-186487197/

Layla El-Khoury is a PhD student in the Biological and Agricultural Engineering department at North Carolina State University (NCSU), where she works with Dr. Barbara Doll. She conducts research in improving methods for identifying, predicting, and quantifying streambank erosion to better target restoration efforts. She conducted research for her master of science degree, from NCSU, that focused on validating a USGS geospatial data layer where the results indicated it could be used to identify locations of erosion. This enables identification of potential stabilization/restoration sites prior to field assessments, maximizing the use of limited time and resources.

AWRA 2023 Annual Water Resources Conference Student Poster Competition Winners

UNDERGRADUATE DIVISION

Isabel Kacprowski (Winner) (Not pictured)
"Vertical Removal of Brevetoxins in Southwest Florida Coastal Waters"
Florida Gulf Coast University

Dylan Gresch (Runner-up)
"Quantification of Human Waste in Surface Waters Affected by Septic Systems, Jupiter Farms, Florida"
Jupiter Academy

Dylan Gresch is a junior at Jupiter Community High School in Jupiter, Florida. He is a part of the Jupiter Environmental Research and Field Studies Academy at Jupiter High School. Living in Florida prompted Dylan's love for the environment and encouraged him to engage in field work. He also loves playing guitar, running, and traveling.

GRADUATE DIVISION

Rebecca Ryan Butters (Winner)
"Nutrients in Utah Lake Behave as a Buffered System: Suspended Sediments and Sorption Impacts on Water Column Phosphate Concentrations"
Bringham Young University
www.linkedin.com/in/becca-butters

Becca plans to graduate with her master's degree in civil and environmental engineering from Brigham Young University Provo in April 2024. Her graduate work focuses on studying nutrient concentrations in Utah Lake to inform lake restoration efforts as part of the Utah Lake Nutrient Cycling Studies project under the direction of Dr. Gus P Williams. She has enjoyed many different roles as a member of the project, including managing laboratory analysis of water quality samples, designing and implementing experiments in the lab and in the field, and compiling and presenting reports to facilitate coordination with the principle investigators.

William Taylor (Runner-up)
"Assessing the Value of Forecast-informed Reservoir Operations for California Water Supply"
University of California-Davis
www.linkedin.com/in/william-taylor-p-e-abbb541b2/

Will Taylor is a second-year Ph.D. student in the civil and environmental engineering program at UC Davis, advised by Dr. Jon Herman. His research focuses include water resources planning and management, multi-objective optimization, decision support, system dynamics, and sensitivity analyses. Will is a registered Professional Engineer in the state of Oregon and is an active-duty US Air Force Civil Engineer. His time at UC Davis will prepare him for a follow-on instructional role at the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

FEATURE

What's in a Name? The City of Calgary's Municipal Journey in Integrated Water Resources Management

Megan Van Ham, Sarah Marshall, and Pamela Duncan

A park in Calgary, Canada, where IWRM solutions are at work. IWRM in Calgary is bolstered by collaboratively created models that enable The City to plan for the effects of climate change and ensure its practices support equitable and just outcomes. Source: City of Calgary

YOU MAY ASK, WHAT IS IN THE NAME

You may ask, what is in the name "integrated water resources management," aka IWRM? What does it really mean? If you ask 100 people that question, you will probably get 100 different answers. We work for the municipal government in Calgary, the fourth largest city in Canada, which provides water, wastewater, and stormwater management services to over 1.3 million citizens and customers in the province of Alberta. Located on the edge of the Canadian prairies at the confluence of the Bow and Elbow rivers that rise in the Rocky Mountains—we are a big city on a small river. Here is our answer.

At its most basic, water resource management can be described as worrying about "too much water, too little water, and too dirty water." As a city committed to social, economic, and climate resilience, we take our role as one of the stewards of this precious, enjoyed, and

Glenmore Dam improvements mean less flooding and more drinking water for Calgary residents. Source: City of Calgary

shared watershed seriously and have relied on integrated water resources management in various forms since our inception as (what was then known as) the Waterworks Department at The City of Calgary in 1913.

We have witnessed the necessary evolution in municipal management of water resources. In a shared and changing watershed, this evolution has been necessary to accommodate growing population, regulatory constraints, and climate change pressure. Environmental protection was an early addition to the traditional business of reliable pipe and plant infrastructure. Then, customer service commitments and accountability broadened our perspective of what it means to be just one actor in a larger regional system. And as more people realized that every land-use decision is a water decision, water resource considerations were embedded earlier and earlier in the municipal planning system. Most recently, the reality of a changing climate has centered on water management as we pursue climate adaptation and resilience.

Modelling Our Shared Future

In the municipal roles that we hold in today's complex water resource system, we anticipate future risks and take future proofing actions as the "integrated" part of water resource management. One example is our support for the Bow River Operating Model, which was developed by a collaborative of regional water users in 2010 to represent the volume of water that moves every year through the Bow River Basin. It provides us a shared understanding of the snow and rainfall in the basin, the storage and releases from our many reservoirs, the withdrawals and returns of our various water users, and what flows out of the basin to our downstream neighbors. This data gave us a baseline on which we could test scenarios such as changes in population, agriculture irrigation, and climate. It enabled us to model options for new infrastructure, varying water uses, and different reservoir operations.

We contributed to the model as municipal representatives with our own interests, worries, and ideas, alongside colleagues from the irrigation, power generation, and recreation sectors, as well as from environmental groups and the provincial regulator. While we were focused on our municipal water systems and long-term water security, this model that we built together and trusted afforded us insight across the breadth of the water system and the many diverse groups that it serves. Perhaps more importantly, this collaborative, technical working group created the venue for and practice of shared solutioning.

The successes of this model and the shared solutioning that resulted include:

- 2016 saw the first ever agreement between the Alberta provincial government and the private reservoir operator on the Bow River upstream of Calgary for multiyear flood resilience and water supply operations. This agreement is a key underpinning in Calgary's river flood resilience.
- The continued update and refinement of the Bow River Operating Model has created the modelling platform we are now using to dive deeper into municipal water security. With the recent incorporation of climate change scenarios, this tool can support our development of a water security roadmap for our rapidly growing city.

Inclusion and Equity in IWRM—What Is Needed?

IWRM serves as a vital connection between people, land, livelihoods, and governance. IWRM practitioners have a responsibility to embed reconciliation and an EDIB lens into our everyday work and practice such that our future-focused resilience planning does not continue to reinforce structural inequities, and truly leads to transformative, sustainable, and just outcomes.

We must acknowledge our country's painful history of genocide, forced displacement of Indigenous peoples, and the systemic injustices perpetuated through government decisions and planning. These structural inequities have left Indigenous and equity-deserving communities disproportionately vulnerable to the impacts of climate change on water management.

Guided by actions taken at a federal level (for example, the Truth and Reconciliation Commission of Canada and the United Nations Declaration on the Rights of Indigenous Peoples Act), The City of Calgary has taken several important steps in this journey and today has a clear municipal policy framework for reconciliation and EDIB. This includes:

- Calgary's White Goose Flying Report and Indigenous Policy Framework—which commit the City as a municipal organization to engage in a sustained, shared, and active process of reconciliation.
- Calgary's Anti-Racism Strategy—which sets the foundation for unmasking and eliminating systemic racism in policies, programs, and plans.
- Calgary's Climate Strategy: Pathways to 2050—which acknowledges that the work of climate resilience must be advanced with Indigenous partnerships and equity-deserving communities leading the charge.

Having this municipal framework in place enables important actions like staff learning and new forms of engagement and collaboration to be prioritized across teams and projects.

• The Alberta Water Council's drought simulation, using the Bow River Operating Model and its counterpart for the neighboring Red Deer and Oldman river basins (collectively referred to as the South Saskatchewan River Operating Model), will produce a set of drought management recommendations. With that in hand, we have created Calgary's Drought Resilience Plan, which will catalyze the next and more advanced round of water conservation efforts and expand our supply-side portfolio.

As IWRM continues to evolve, the field must also address issues of inclusion and equity. The City's goal is to foster inclusivity, collaboration, and equity in our programs and services. IWRM practitioners have a clear role in responding to national and municipal policies that address Truth and Reconciliation and equity, diversity, inclusion, and belonging (EDIB). To ensure that our integrated water resource management is transformative, sustainable, and just, it is crucial to understand our past and prevent the reinforcement of discrimination or injustices in the governance systems, policies, and practices we shape and implement (see sidebar).

The Promise of "Integrated Water Resources Management"

It is essential that we aim to fulfill the promises made by the name "integrated water resources management." If we don't, we could stick to initial plans that do not adapt to our ever-changing context. We could take a short-term, narrow view that ignores the long-term, cumulative effects of our decisions and discounts the perspectives and needs of interested parties. We could be hampered by the limited bandwidth of our ever-busy staff, colleagues, and partners. We could be paralyzed by the depth and breadth of analysis desired to inform decisions laden with regulatory impacts and citizen responsibility. We could choose to avoid difficult discussions and shy away from confronting the impact

Newly installed steel gates at the Glenmore Dam provide an extra 10 billion liters in storage for greater flood protection along the Elbow River. As winter approaches and flows along the Elbow River slow, the gates allow the City to store double the amount of water in the reservoir, which helps meet the needs of a growing city. Source:

our profession has on Indigenous and equity-deserving communities.

When we can take a breath, we can come back to our fundamental question—what is in the name "integrated water resources management" and what does it really mean? This is what we discovered: First, we must pause to learn from history, and listen attentively and honestly to the agendas set by Indigenous communities and other historically underrepresented groups in our water resources management planning. Embracing new knowledge, perspectives, and planning approaches will only strengthen our journey toward a more resilient future.

Next, we must create and evolve the foundation of data, models, policy, and collaboration that will enable us and our future colleagues to make timely, well-informed water management decisions in our small part of the system, with confidence that we have an appreciation and understanding of the ripple effects they will have into the watershed (pun intended).

Then, with all this in mind, is there a better, pithier name that rolls more naturally off the tongue? Probably. But we'll leave that to our future colleagues to hypothetically ask another 100 people as IWRM continues to evolve and thrive. Until then we will continue to shape and advance IWRM through a lens of inclusive and equitable water management approaches that work toward ensuring universal access to clean and sustainable water resources for all. ■

Megan Van Ham (Megan.VanHam@calgary.ca) leads the Environmental Programs team at the City of Calgary. In this role and through prior work as a water management consultant, Megan has been actively involved in regional integrated water management initiatives in many of Alberta's major river basins for over 15 years.

Sarah Marshall (Sarah.Marshall@calgary.ca) is a senior water resources planner whose work connects watershed management objectives with city planning and policy. She is currently leading the Calgary River Valleys project, focused on climate and flood resilient land-use policy updates for Calgary's floodplains and river valleys.

Pamela Duncan (Pamela.Duncan@calgary.ca) leads the Resource Strategy team at the City of Calgary. Maintaining water security today and for future generations drives Pam's work in drought resilience, source water protection, and riparian management.

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FEATURE

The Benefits of Integrated Water Resources Management Extend to Small and Medium-Size Communities

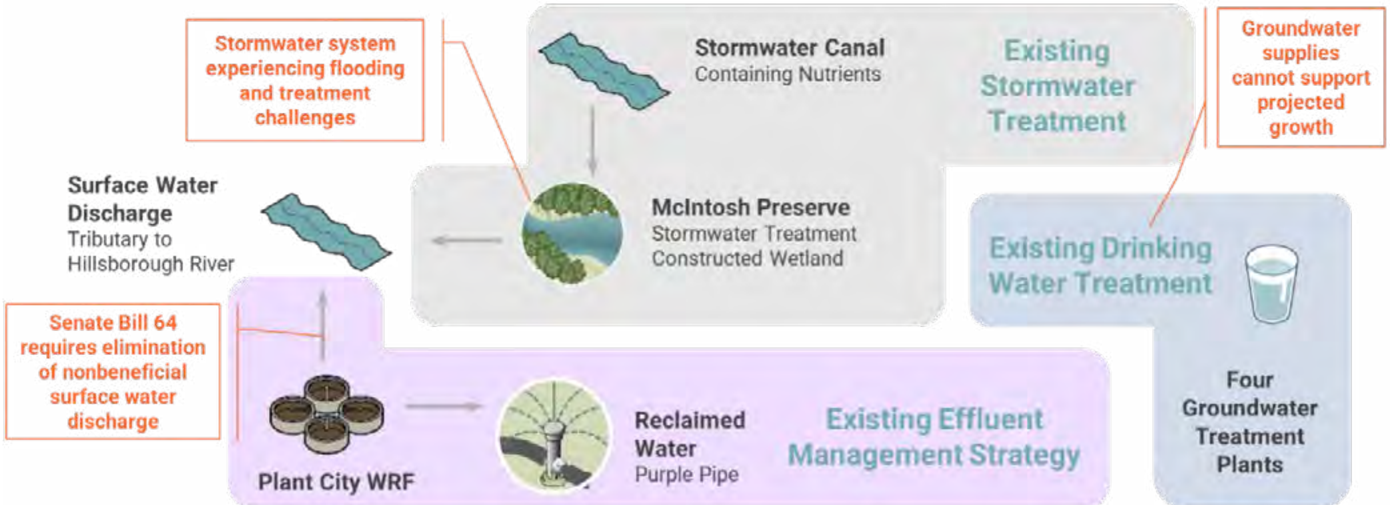
Stephanie Ishii, Carlyn Higgins, Paul Biscardi, Cole Anderson, Sarah Dominick, Andre Dieffenthaller, Lynn Spivey, Patrick Murphy, Mike Darrow, and Jay Kwag

The population of Plant City, Florida, will likely double in coming years. The City is turning to IWRM to address increased drinking water, wastewater, and stormwater needs. Source: City of Plant City

IWRM COMES IN ALL SHAPES AND SIZES, SPANNING comprehensive plans for the cities of Denver and LA to backyard reuse installations that protect neighborhood parks. The unifying factor across IWRM projects is, in fact, that each project is unique because they specifically address alignments between site-specific objectives. Take the City of Plant City, for example. This City's population of 65,000 is expected to nearly double, and they need to find resource efficient ways to simultaneously address increasing drinking water demands, environmental discharge restrictions, and stormwater management. Are these challenges related? Yes. Should the solutions also be related? Yes!

Welcome to the City of Plant City, Florida

The City of Plant City, Florida, is a medium-size, agricultural-based community on the eastern outskirts of the greater Tampa Bay area. The City is named after the railroad developer Henry B. Plant and is known



The City of Plant City's current water resource management practices and associated challenges. Source: Hazen and Sawyer

as the Winter Strawberry Capital of the World. Plant City's population is expected to increase by more than 65 percent in the next 25 years, yielding up to 109,000 residents by 2045. The combination of population growth, increased development, environmental restrictions, and regulatory/legislative changes has resulted in the City simultaneously facing challenges that span public water supply, wastewater management, stormwater management, and environmental protection. The City opted to use an integrated resource management approach, also known as a "One Water" approach, for developing solutions due to the concurrent and interrelated nature of these challenges.

Current Practices:

The City's current water resource management practices include the withdrawal and treatment of groundwater for drinking water supply, the use of stormwater canals and the McIntosh Preserve for stormwater collection and treatment, and advanced wastewater treatment with discharge of treated water to a non-potable, public access reuse system or to surface waters. As shown by the orange callout boxes in the figure below, these practices are unsustainable due to the limited nature of groundwater supplies relative to population growth, challenges in stormwater quantity and quality control, and recent legislative changes that require the elimination of non-beneficial surface water discharges from water reclamation facilities in Florida by 2032 (Florida Senate Bill 64).

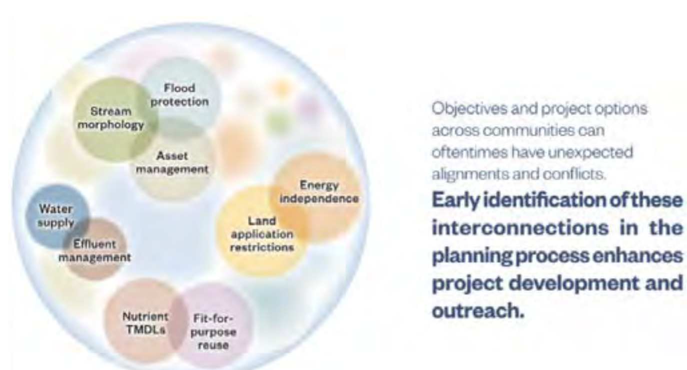
Why Plant City Chose Integrated Resource Management

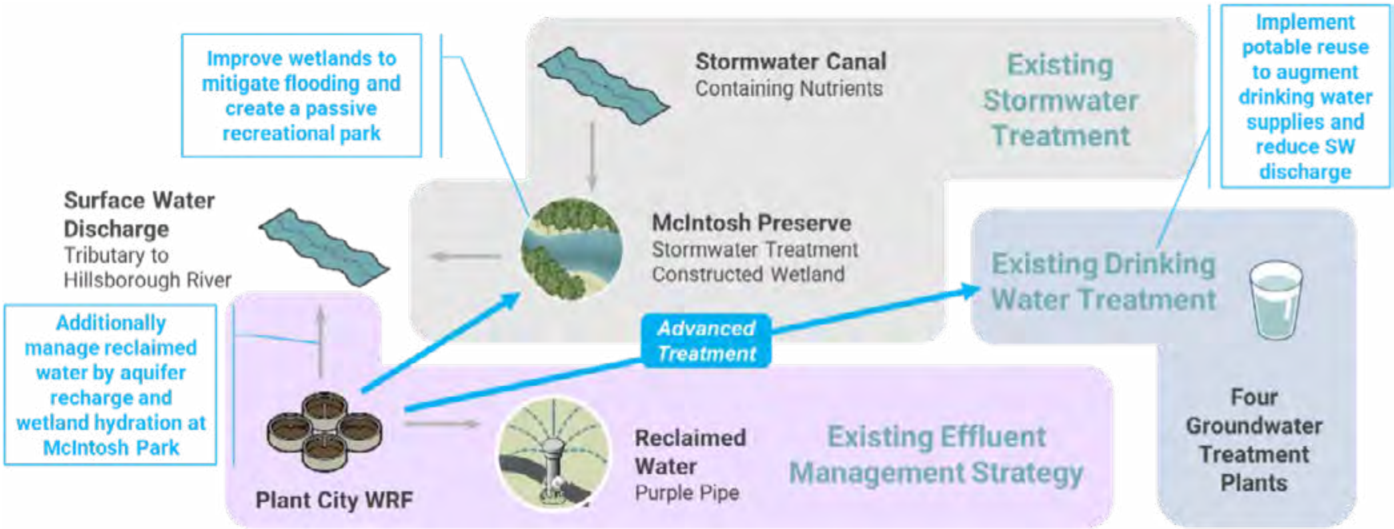
The City recognizes that the adoption of integrated resource management has resulted in tangible benefits for many communities. Integrated resource management enables one project to be developed with multiple objectives in mind, oftentimes leading to more efficient use of resources, streamlined schedules, avoidance of unintended conflicts, and broadened opportunities for funding.

PLANT CITY WATER
OUR WATER • OUR FUTURE

Potential Future Practices:

Instead of addressing each of their challenges in drinking water, stormwater, and wastewater individually, the City opted to put all objectives, needs, and constraints on the table at the same time to enable an integrated approach to solution development. The result was a series of interrelated projects that benefit one another. To begin, the City is implementing new beneficial uses of highly treated reclaimed water for wetland hydration and groundwater recharge at the McIntosh Preserve, as well as evaluating advanced treatment of reclaimed water for augmentation of public water supply. The City's integrated resource management plan includes the mitigation of flooding through increased stormwater capacity at the McIntosh Preserve, in part through the expansion of natural and engineered





Ongoing and potential future improvements included in the City of Plant City's integrated resource management plan. Source: Hazen and Sawyer

wetlands that provide additional water quality treatment to stormwater and reclaimed water. McIntosh Preserve improvements also expand the natural passive park amenities, preserve critical habitat, and provide an educational opportunity for visitors to learn about Florida's beautiful wetlands.

The City is currently wrapping up design for the 175-acre expanded-treatment wetlands at the McIntosh Preserve and recently completed a year-long pilot program to evaluate the reliable production of safe and aesthetic drinking water from reclaimed water. Project details are provided below.

McIntosh Preserve Improvements:

The McIntosh Preserve is a 365-acre natural habitat located in the City, originally purchased in 1998 by the Florida Communities Trust and Hillsborough County Environmental Land Acquisition and Protection Program. In 2015, the City opened the habitat facility as a passive

The City of Plant City hosted over 25 public tours of the advanced treatment pilot system. Source: City of Plant City

Plant City pilot system (microfiltration, reverse osmosis, UV/chlorine advanced oxidation process shown top to bottom). Source: Hazen and Sawyer

recreational park, with amenities that include walking and hiking trails and picnic facilities. The current design for the 175-acre expanded-treatment wetlands further enables a mutually beneficial relationship between habitat and reclaimed water at the preserve. The wetlands will improve stormwater and reclaimed water quality and minimize discharge to surface waters, and consistent reclaimed water flows will reestablish a proper hydroperiod to support wildlife habitat. Additionally, the new wetlands will include walking trails, boardwalks, an observation tower, and a 50-foot elevated event space for the public to enjoy.

Advanced Water Treatment:

The advanced water treatment pilot system was fed by reclaimed water from the existing water reclamation facility and included the following unit processes: microfiltration, reverse osmosis, and UV/chlorine advanced oxidation. This treatment train was selected after an extensive review of existing reclaimed water quality, drinking water regulations, health guidelines, and aesthetic targets. The design of the pilot program was comprehensive. It met regulatory requirements, established preliminary design and operating criteria for full-scale implementation, engaged the public in discussions of water resource management and the use of alternative water supplies, and provided operator training for advanced treatment.

The pilot system demonstrated that this treatment train can reliably yield water quality that complies with primary and secondary drinking water standards, health guidelines, aesthetic targets, and potential future drinking water standards.

Over 25 tours of the pilot system were conducted; the approximate 250 tour attendees included students, community groups, regulatory agencies, elected officials, and neighboring utilities. The utility also hosted a City-wide branding and communication campaign to develop a logo, tagline, signage, and brochures to ensure the approachability of program information and build alignment across departments.

Although not everyone should expect their advanced treatment facility to become a tourist

See the full Plant City story here!

attraction (25 tours of a pilot system was surely a surprise to managers!), Plant City exemplifies the type of novel solution an IWRM framework can provide. The City is committed to preserving the past while looking toward the future, and integrated resource management is a critical component of that commitment. The City's integrated, One Water resource management plan achieves multiple benefits: it incorporates stormwater treatment, mitigates localized flooding, rehabilitates a natural habitat park, reduces surface water discharges, and increases water supply through potable reuse. If the City had attempted to solve each problem individually, it would undoubtedly have missed out on the opportunity to streamline schedules and optimize funding, perhaps ending up with a hodge-podge of standalone solutions, as opposed to a unique point of pride. Plant City's approach to solution development is a model for future integrated resource management initiatives within and outside of the City. It shows that the articulation of needs and interconnectivities across sectors is the first step to simultaneously achieving objectives with a purposeful and collaboratively developed plan. ■

Stephanie Ishii (sishii@hazenandsawyer.com) is director of integrated resource technologies at Hazen and Sawyer and a regional leader for the firm's Water Reuse Practice and Sustainability Services groups. She specializes in the development and evaluation of water supply and treatment projects to achieve benefits across different sectors and service areas.

Carlyn Higgins (chiggins@hazenandsawyer.com) focuses on advanced drinking water treatment technologies at Hazen and Sawyer. She has led field operations and water quality and data analysis for numerous facilities. Carlyn served as the lead operator for Plant City's One Water Demonstration Facility.

Lynn Spivey (lspivey@plantcitygov.com) is director of utilities for the City of Plant City, Florida, with over 30 years of experience in a wide range of areas related to water management, water and wastewater treatment, potable reuse, and reclaimed water treatment and beneficial use. She is a recent past president and is currently on the board of trustees for WateReuse Florida.

Andre Dieffenthaller (adieffenthaller@hazenandsawyer.com) is vice president at Hazen and Sawyer, with over 32 years of experience in the planning, design, permitting, and construction management of water treatment improvements.

Paul Biscardi (pbiscardi@hazenandsawyer.com) of Hazen and Sawyer, specializes in drinking water quality and advanced treatment and is Hazen's drinking water practice leader for the Southeast.

Cole Anderson (canderson@hazenandsawyer.com) of Hazen and Sawyer, served as the assistant operator for Plant City's One Water Demonstration Facility.

Patrick Murphy (pmurphy@plantcitygov.com) is current president of FW&PCOA and the chief operator of utilities operations at Plant City.

Mike Darrow (mdarrow@plantcitygov.com) is immediate past president and legislative committee chair of FW&PCOA, and is currently the superintendent of utilities operations at Plant City.

Hye (Jay) Kwag (hkwag@plantcitygov.com) is CIP engineering manager for City of Plant City Utilities.

Sarah Dominick (sdominick@hazenandsawyer.com) is Hazen and Sawyer's director of integrated resource planning and the leader of the firm's Strategic Organization Planning efforts.

Meeting Water Needs under Unprecedented Growth in Georgetown, Texas

Jenny Bywater and Kimberly Chanslor

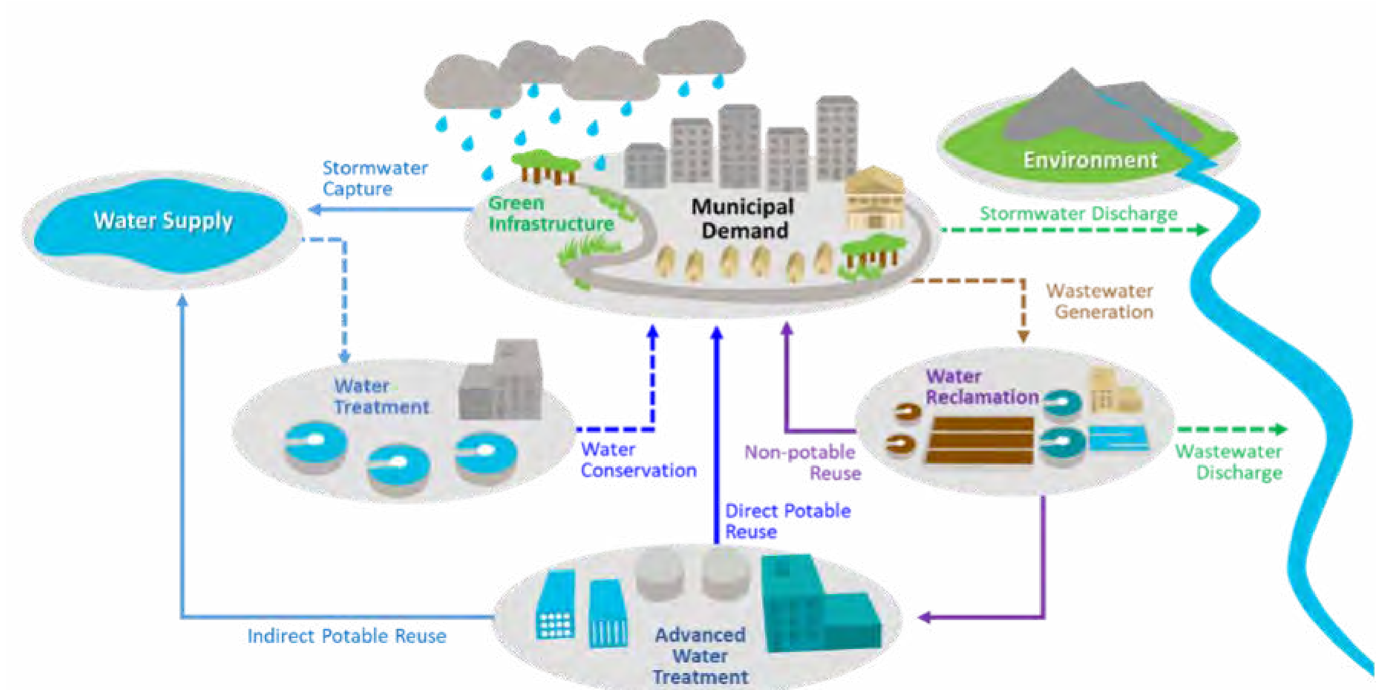


Figure 1. A One Water approach considers the full system. Source: CDM Smith, 2023, City of Georgetown Integrated Water Resources Plan

THE CITY OF GEORGETOWN, TEXAS, IS A GROWING suburb outside of Austin. Industrial growth in the area and population migration to Texas means that Georgetown has consistently been on the list of fastest growing cities in the United States. This increasing population has translated to unprecedented growth in water demand, while water resources have remained finite.

To identify new water supply options and ensure long-term reliability, the City initiated an integrated water resources plan (IWRP). When the City was developing their IWRP, they identified three principal objectives:

1. Construct and calibrate a systems model that forecasts water supply at a monthly time step
2. Identify and evaluate potential water supply alternatives that the City can implement
3. Evaluate the volume needed from, and timing for, each supply alternative out to 2070

The integrated systems approach has helped to answer critical questions for the City, including the ideal mix of supply alternatives to yield reliability at a reasonable cost. The IWRP looks at the interrelationships of the system as a whole to identify multipurpose and multibenefit projects (Figure 1).

The City has historically met approximately 70% of its water demand through a contract with the Brazos River Authority for surface water supply from Lake Georgetown. Groundwater from the Edwards aquifer is

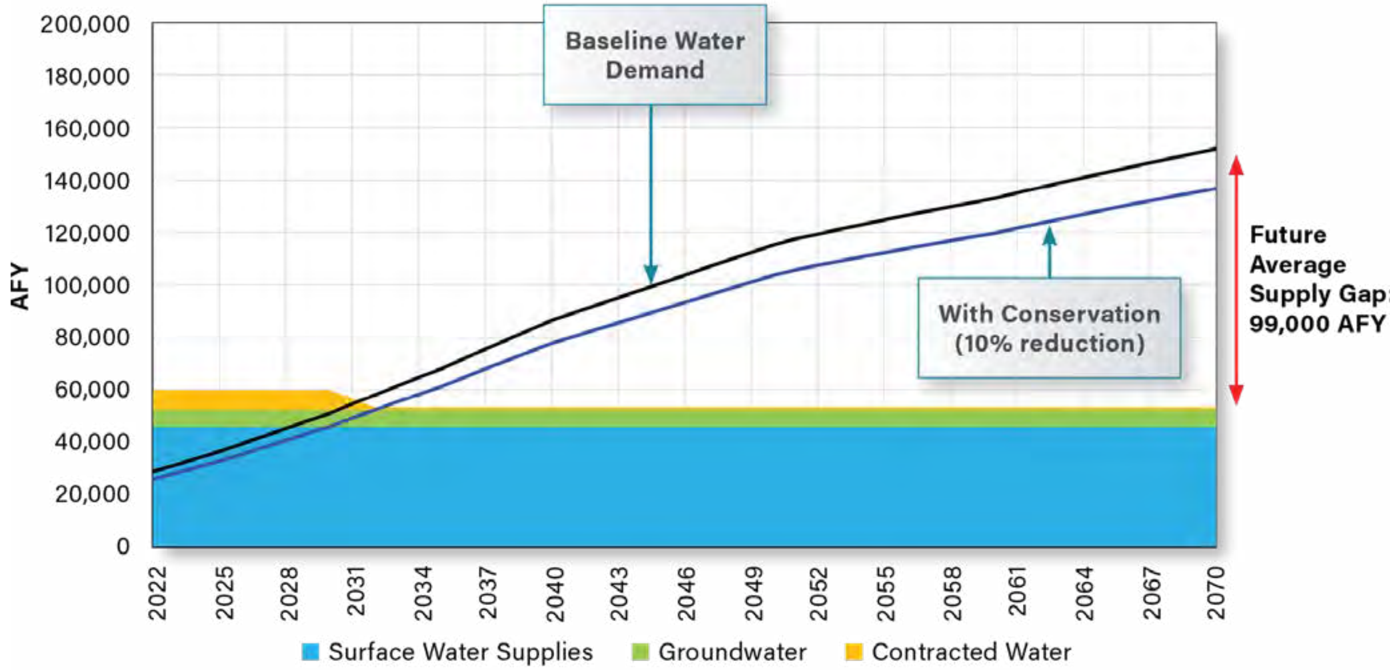


Figure 2. Comparison of existing water supplies to projected water demands. Source: CDM Smith, 2023, City of Georgetown Integrated Water Resources Plan

also used to meet demands, and the City has contracts for some additional supply from other local entities. However, these contracts will soon expire.

Comparing the existing supplies to projected future water demands (Figure 2), Georgetown may see a shortfall in supply as soon as the early 2030s if no additional water supplies are identified. The future supply need then grows to 99,000 acre-feet per year (AFY), or 88 million gallons per day (MGD), under the baseline conditions by 2070.

Expansion of the existing supplies is unlikely as surface water supply is already fully allocated and the Edwards aquifer is tightly controlled. With growth occurring throughout the Austin area, there is also competition for new supply sources. The supply sources evaluated as part of the IWRP include:

- **Additional Groundwater Supply:** A variety of new potential groundwater supplies were considered. These supplies are all largely to the east of the City and would require additional pipelines to convey the water into Georgetown.
- **Reclaimed Water:** The City could utilize water from their existing water reclamation plants to increase non-potable water service to meet growing irrigation and industrial demands. Additional advanced treatment could also be provided for indirect or direct potable reuse of this water.
- **Conservation:** Conservation efforts could reduce the City's annual demand by 10%.
- **Aquifer Storage and Recovery (ASR):** ASR involves seasonal recharge of surplus water. During times when there is spare water treatment capacity and supply, treated water is sent to a wellfield for recharge into the aquifer. Then during periods of high water demand or drought, the stored water can be recovered and utilized to meet demands.
- **Flood Flows:** During wet weather events, surplus unallocated surface water could be diverted to storage for future use.

Expansion of the existing supplies is unlikely as surface water supply is already fully allocated and the Edwards aquifer is tightly controlled.

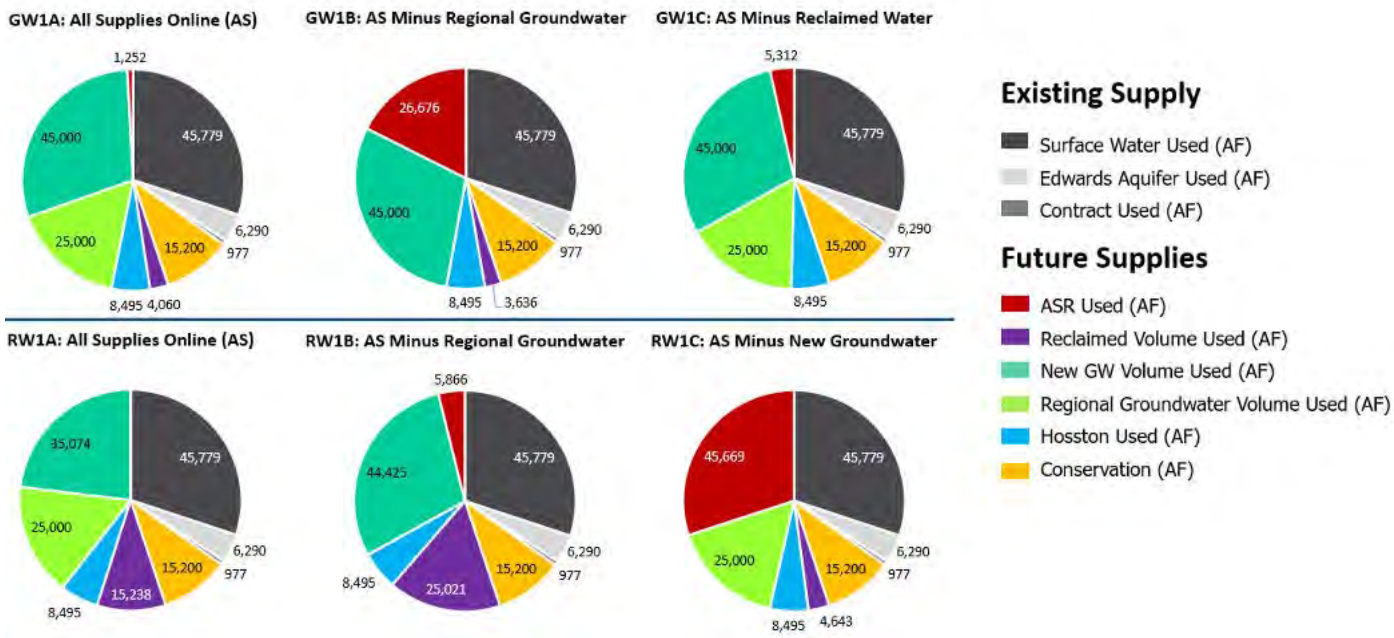


Figure 3. Average 2070 supplies for each portfolio. Source: CDM Smith, 2023, City of Georgetown Integrated Water Resources Plan

In completing the evaluation, it was identified that one single supply option is not sufficient to address the projected water supply gaps. Instead, groups of options were combined into supply portfolios. With such large projected supply gaps, the City will need to invest in multiple potential new supplies. Over 20 supply portfolios were evaluated, with six able to meet the long-term supply needs (Figure 3).

As part of the IWRP analysis, a systems model was created using the Water Integration Tool (WIT) model developed by CDM Smith. The WIT is designed to simulate changes to surface water, groundwater, and recycled water budgets with changing hydrology or new project implementation. The WIT systems approach is a high-level water supply simulation that is lower in precision but more comprehensive and integrated than models used in the master planning and capital improvements approach. Elements incorporated into WIT are shown in Figure 4.

The WIT model utilized historical hydrology from

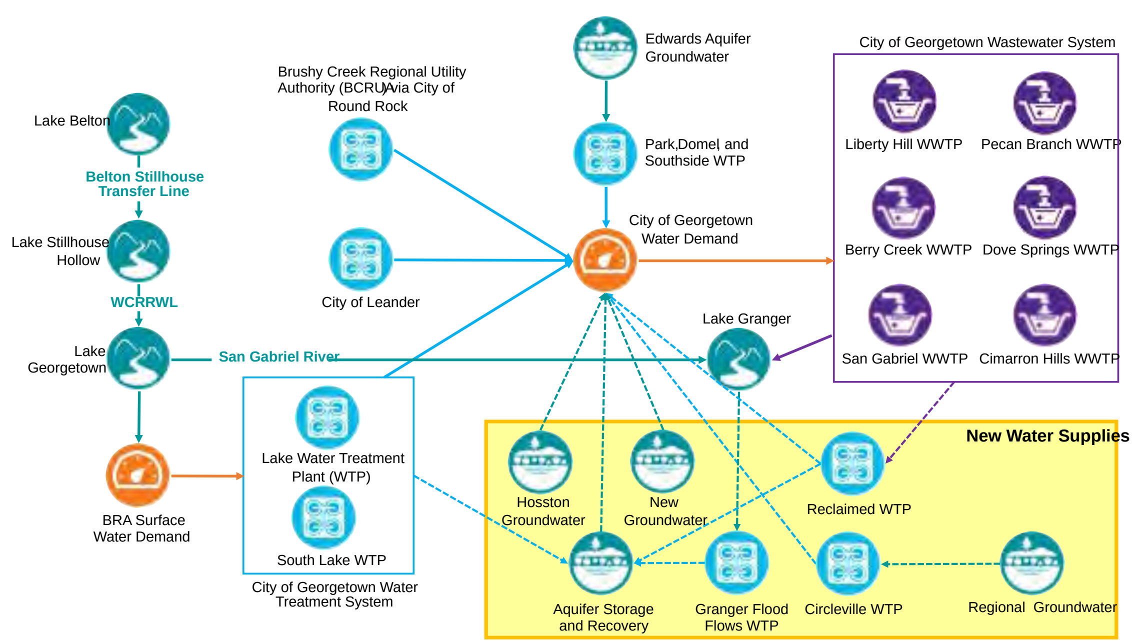


Figure 4. Water Integration Tool elements. Source: CDM Smith, 2023, City of Georgetown Integrated Water Resources Plan

Criteria	Metric	Performance	Source of Measurement	Metric Weighting
Reliability (40% importance)	ASR volume required to not have gaps	Lower score is better	WIT systems model	20%
	Dependability	1 to 3 score; Higher is better	Expert judgment	20%
Cost-effectiveness (40% importance)	Annual cost (amortized capital plus O&M) above baseline ($/year)	Lower $ is better	Engineer's estimate	40%
Public acceptance (10% importance)	Public perception	1 to 3 score; Higher is better	Expert judgment	10%
Permitting complexity (10% importance)	Partnership complexity	1 to 3 score; Higher is better	Expert judgment	10%

Table 1. Portfolio Performance Metrics

1941 to 2013 in its analysis of supply reliability. A 49-year planning horizon from 2022 to 2070 was examined, looping through different potential hydrologic sequences to arrive at a probability for supply reliability for any given forecast year.

A final ranking of the portfolios was completed using metrics (Table 1) to indicate how well certain IWRP criteria were achieved. The results showed that new groundwater and reclaimed water are required for all high-scoring portfolios. Because of the uncertainty in volume and cost of regional groundwater supplies, the City may need to aggressively pursue new groundwater and regional partnerships.

Each portfolio requires that in order to keep up with increasing demands, the City must have a new supply online by 2030. The City needs to move forward with constructing wells and conveyance infrastructure for Hosston aquifer supplies, as well as facilities that will treat and connect other groundwater to the distribution system. In order to achieve the targeted supply of reclaimed water, Georgetown is now completing a Reuse Water Master Plan to determine more specific potable and non-potable reuse projects.

Using the IWRP process, Georgetown has been able to effectively plan for its future growth. With estimates of water demands as high as five times the current values over the next 50 years, the City must significantly invest in multiple additional water supplies. The IWRP is one foundational step in ensuring future residents and businesses have the reliability and cost-effective water supply needed for Georgetown to continue to thrive. ■

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FEATURE

Data-Driven Sustainability: Closing Groundwater Data Gaps in the Arid Southwest

Simone A. Williams

Figure 1. Groundwater being pumped to an irrigation canal to supply field crops in Central Arizona. Source: Simone A. Williams

INTRODUCTION

In the arid Southwest United States, integrated water resources management (IWRM) is crucial for long-term water sustainability. Groundwater, which constitutes 43% of drinking water supplies and 46% of total withdrawals, provides a lifeline to communities and ecosystems. Policies often prioritize groundwater quantity (see Figure 1), but limited water resources and contamination risks necessitate a focus on quality. Contaminants like nitrates and heavy metals render groundwater unsafe, threatening public and ecosystem health. Therefore, elevating groundwater quality within policy and broader

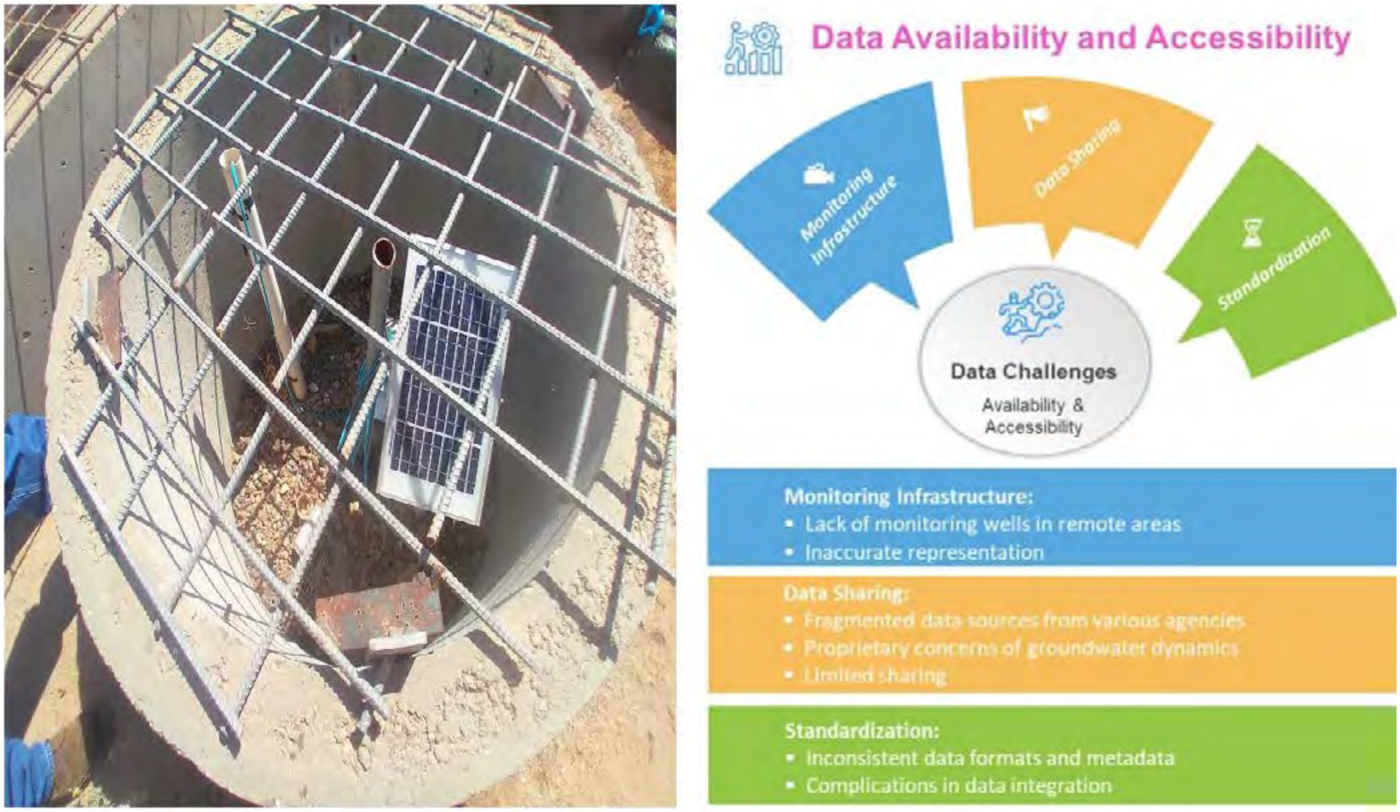

Figure 2. Groundwater well monitoring infrastructure, data availability, and accessibility challenges. Photo and figure source: Simone A. Williams

IWRM frameworks is essential for safeguarding water supplies, ecosystems, and economies.

Sustainable groundwater management requires reliable, accessible water quality data. This data is crucial for understanding aquifer dynamics, tracking contamination risks, and making well-informed decisions. Yet, limited access to comprehensive data hampers our ability to establish standards, ensure compliance, identify trends, assess impacts, and design mitigation measures. This article explores groundwater data challenges and offers short-, medium-, and long-term strategies to empower decision makers, researchers, and communities to address water issues, preserve human and ecosystem health, and unlock development opportunities.

Current Data Landscape

Groundwater vulnerability data is collected using methods like monitoring networks, well sampling, remote sensing, and modeling. Each method enhances our understanding of groundwater dynamics and quality. However, data availability varies in the Southwest due to hydrogeological conditions and human influences that drive monitoring requirements, data collection frequencies, parameters, and spatial coverage. In several states, available data primarily comes from area-specific studies and monitoring required by state regulatory programs. Notably, persistent groundwater quality data challenges (see Figure 2) include inadequate monitoring infrastructure, data sharing, and standardization, plus missing metadata. Overcoming these issues requires innovative approaches to data collection, sharing, and integration.

Groundwater Data Challenges

Groundwater data accessibility and availability challenges stem from inadequate monitoring infrastructure and limited coverage. In remote areas, insufficient wells and equipment can distort aquifer assessments. For instance, in New Mexico's remote communities and the Navajo Nation, scarce monitoring wells have led to inaccurate measurements and a dearth of water quality data. Expanding monitoring infrastructure is essential to capture hydrogeological variations, especially in Lower Colorado River karst aquifers. Furthermore, researchers can enable multisource data integration by increasing data collection frequency and density using technology like satellite monitoring, geographic information systems (GIS), and the statistical programming language R (see Figure 3) to improve our understanding of groundwater.

Across states, data challenges arise from fragmented

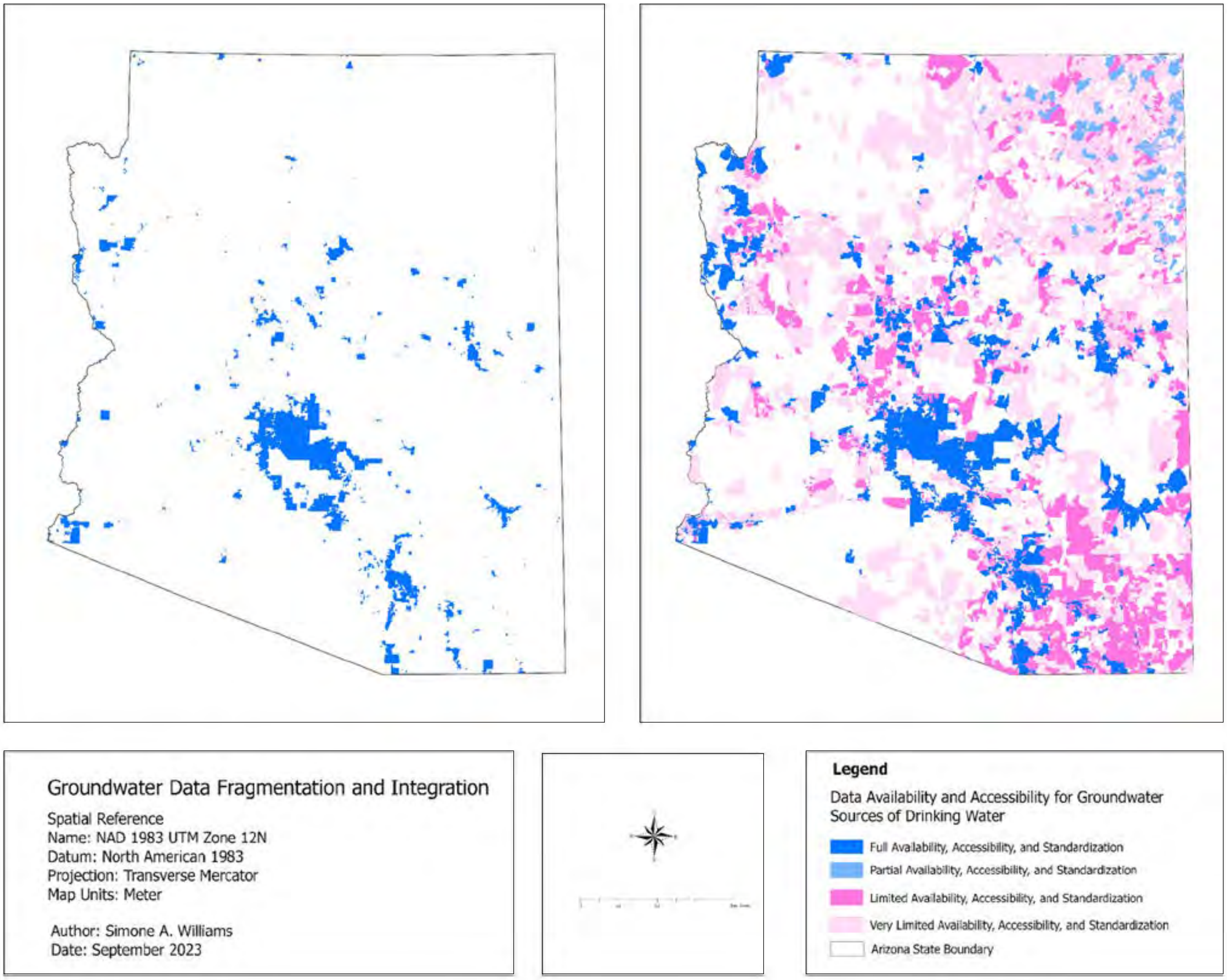

Figure 3. Illustration of groundwater data fragmentation and multisource GIS integration to examine drinking water quality.
Source: Simone A. Williams

sources, varied access protocols, structures, and terminologies. This is compounded by entities creating distinct datasets without integration standards, complicating the compilation and integration necessary for comprehensive analysis of statewide groundwater quality trends. To address this complexity, we should improve data management for cohesive sharing among stakeholders and integrate these efforts into an IWRM framework that considers the entire water cycle and different water uses. Aquifers store substantial freshwater through recharge processes, which helps sustain surface water flows, benefiting ecosystems, economies, and communities while mitigating drought impacts. Therefore, to ensure sustainable and resilient water supplies, addressing fragmented groundwater data is a necessary step, which requires collaborative platforms to enhance data sharing and understanding.

In groundwater vulnerability research, privacy, ownership, technical barriers, and data integration issues persist. Well data is often withheld by private landowners and tribal governments due to privacy and property rights issues. Lack of standardized data formats and metadata, coupled with varying requirements across states, counties, and basins, complicates integration, hindering data exchange, collaboration, and regional studies. A call to action to address these challenges requires standardized protocols, metadata frameworks, and streamlined data exchange to enhance information utility. Accordingly, to secure a sustainable water future, short-, medium-, and long-term IWRM strategies must prioritize enhancing groundwater data collection and sharing.

Short-, Medium-, and Long-Term Solutions

Enhanced collaboration is a key short-term strategy,

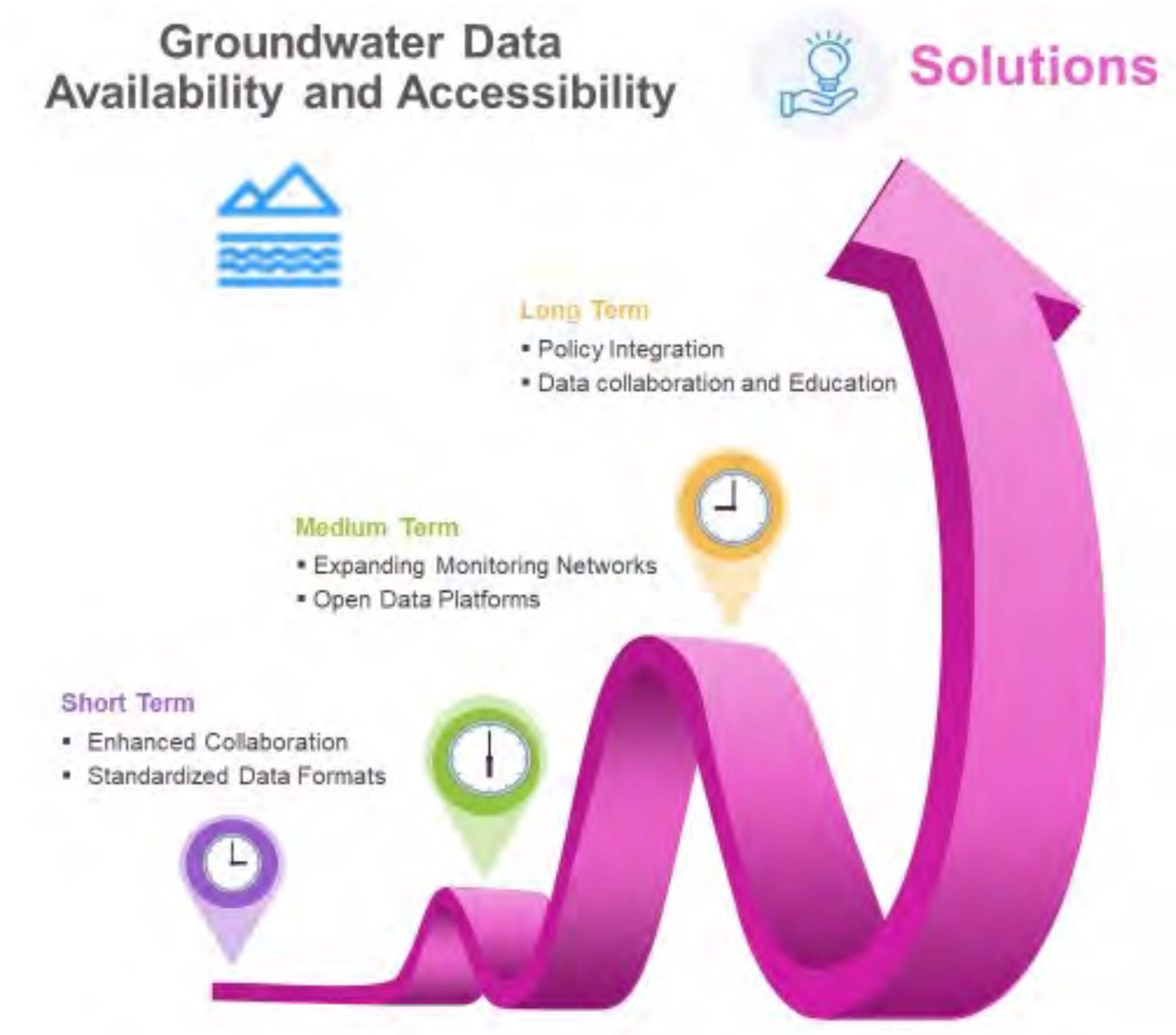

Figure 4. Groundwater data availability and accessibility solutions. Source: Simone A. Williams

fostered via coordination among governmental agencies, researchers, businesses, and communities. The U.S.-Mexico transboundary aquifer agreements highlight how groundwater quality drives cooperation. Collaboratively developed data-sharing agreements and protocols, often involving universities, have also shown promise. Agencies and universities have combined monitoring network data for joint research. For instance, data-sharing between Arizona State University and agencies has improved accessibility of crucial groundwater information through online platforms, encouraging public access and cross-pollination of ideas for more insightful research.

Another short-term solution is improving data standardization. Adopting uniform formats and metadata standards streamlines data management, exchange, and integration across agencies and regions. Nevada has articulated standardizing data collection and management as a goal within its water plan. Such adoption of standardized formats facilitates effortless integration of data across diverse projects and data sources. Similarly, Arizona Geological Survey's use of standardized geoscience data formats enhances integration, reduces technical barriers, maximizes data utility, and enables broader coverage and multifaceted analysis, thus strengthening sustainable groundwater management.

Strategically expanding monitoring networks is a potent medium-term approach for addressing data gaps. This approach entails augmenting monitoring network coverage in under-sampled regions and utilizing advanced sensors for real-time data collection. Arizona's push to invest in additional monitoring wells in rural areas improves data resolution and enhances groundwater contamination risk assessment. The U.S. Geological Survey's Water Science Center has coordinated establishing wells in rural and tribal areas within the Little Colorado River basin to close gaps in groundwater data.

To foster broader contributions to groundwater management and research, creating open data platforms is pivotal, especially in the medium-term. Existing platforms like the GIS portals of the Arizona Department of Water Resources and Maricopa Association of Governments (MAG) serve as centralized, user-friendly data hubs that increase engagement, transparency, and data-driven decision making. Adopting open data platforms, along with user training and guidance, is a proactive step toward bridging accessibility gaps and enabling more extensive participation in groundwater management and research.

Long-term solutions integrate data requirements into groundwater and land management policies and offer a transformative approach to resolve data challenges. Treating data collection and sharing as regulatory components establishes a robust framework that encourages consistent, comprehensive data collection and dissemination. Colorado and Arizona have already integrated groundwater data reporting into some permitting processes, enhancing data accessibility for informed water management.

Fostering data-sharing collaboration, awareness, and education is a crucial long-term solution. Partnerships like the Internet of Water Coalition seek to build water data infrastructure and create a network of individuals and organizations for enhanced decision making. Collaborative programs like California's local community groundwater workshops, Arizona's MAG web mapping workshops, and The Babbitt Center's scenario planning workshops educate and empower communities. These initiatives raise awareness about the importance of sharing data, cultivate collective responsibility, foster collaboration, and promote participation to underpin resilient Southwest groundwater management.

Conclusion

The tenets of IWRM suggest that resolving arid Southwest groundwater sustainability necessitates a collective commitment to short-, medium-, and long-term data solutions. Southwest states have experimented with different approaches to address specific challenges at state, county, local, or organizational levels. The complexities arising from monitoring limitations, data gaps, fragmented sources, and technical obstacles underscore the urgency of overcoming these issues. Yet, these challenges offer opportunities for transformative change. Immediate strategies include fostering collaboration, standardized formats, and expanded monitoring. Medium-term solutions involve developing accessible data platforms and expanded networks. Long-term strategies, like policy integration, data-sharing collaboration, and awareness, hold promise for systemic transformation and engagement. Achieving data availability and accessibility requires dedication from stakeholders ranging from policy makers to local communities. Therefore, a call to action resonates—champion efforts to surmount data challenges and forge enlightened, sustainable groundwater management and IWRM in the arid Southwest. This action is especially critical given that groundwater provides almost half of the region's water. ■

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