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Issue theme: Transboundary Groundwater

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This issue of *Water Resources IMPACT* covers an increasingly important and potentially contentious resource: transboundary groundwater. Seven authors introduce the panoply of scientific, management and governance issues that permeate the field of transboundary groundwater resources. Shaminder Puri sets the stage by asking, "Why do we care whether an aquifer crosses political boundaries?" He reflects on his lifelong transboundary groundwater studies and shares lessons learned. Sharon B. Megdal presents the Mexico - US Transboundary Aquifer Assessment Program (TAAP), advancing it as a model for collaborative groundwater studies across international boundaries. Farther north, Alfonso Rivera examines Canada's approach to understanding and managing its interprovincial groundwater resources and discusses Canada-US interactions. Back in the USA, Noah D. Hall highlights the first interstate groundwater dispute to reach the U.S. Supreme Court. At issue: is Tennessee 'stealing' Mississippi's water to slake Memphis' thirst? Rosario Sanchez adds to hydrogeology jargon with a new term - *Transboundariness* - which attempts to describe the degree to which the boundaries are impacted when the aquifer crosses political borders. Todd Jarvis proposes serious gaming facilitation to enhance cooperation over transboundary groundwater resources. Finally, Michael E. Campana takes a brief look at the *Winters* Doctrine and ownership of pore space.



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# The Value of Governance



**Brenda Bateman**  
**President, AWRA**  
**president@awra.org**

“Good governance of AWRA relies on the active participation of the members.”

**SEVERAL OF US** have just returned from the World Water Forum in Brazil, where the world's youth, once again, have displayed a well-informed and eloquent approach to activism, questioning the practice of unsustainable water resources management and calling for improvements in water governance.

Governance is the process by which we make and implement decisions. “Good governance” involves concepts like transparency, accountability, inclusivity and participation, and the AWRA Board is committed to these same concepts as we go about our work. In the spirit of transparency, accountability, inclusivity and participation, we are pleased to offer you the following updates.

First is the search for AWRA's next Executive Vice President. By recruiting an executive who is also committed to good governance, we continue to ensure a strong professional association that is well-positioned to grow and innovate in the coming years. Visit AWRA's homepage ([awra.org](http://awra.org)) for executive search updates as they become available throughout the summer.

Second, the board wants to increase leadership development within the water resources profession by actively recruiting members to the board of directors, technical committees and conference committees, and other volunteer positions in the association. To demonstrate this renewed effort and emphasis, we propose to rename the “Nominating and Awards Committee” to the “Leadership Development and Recognition Committee.” (See proposed Bylaws change on pg. 32 of this issue.) This committee will also continue its commitment to recognize and reward excellence in the field of water resources.

A third focus area is to develop participation models appropriate for the emerging generation of water resources professionals. Although presentations, publications, state sections, student chapters and technical and conference committees have long been a good way to make connections and share knowledge within AWRA, the question is whether this type of involvement still works well for all of the generations represented by our members. Please visit [conversations.awra.org](http://conversations.awra.org) and describe what opportunities for leadership and involvement you would like to see AWRA offer in the future.

A fourth effort will grow AWRA's National Leadership Institute in scope and reach. For the past three years, the Institute has issued invitations to state leaders who are responsible for developing state water plans. In a workshop environment, they have a chance to share with peers their experiences creating both process and content. Last year, the Institute also held an invitation-only workshop for well construction regulators from five Pacific Northwest states, allowing them to compare programs, rules, and challenges they face. Led by board member Scott Kudlas, the Institute continues to grow and reach more leaders in the water resources profession.

The final effort underway is a series of public policy statements adopted by the Board. Originating with the technical committees, these statements are meant to give members and observers a set of well-informed, common sense public policies to put to use in the water resources profession. In January 2018, the AWRA board adopted a groundwater policy statement that calls for sustainable—or at least thoughtful—management and protection of the earth's groundwater resources. See the “about us” tab at [AWRA.org](http://AWRA.org) for this and other policy statements of the association.

Building on this groundwater policy statement, AWRA Past Presidents Michael Campana and John Tracy have curated this issue of *IMPACT* with a collection of articles on transboundary groundwater. From July 9 through 11 they will also host AWRA's summer specialty conference on “The Science, Management, and Governance of Transboundary Groundwater” in Fort Worth, Texas.

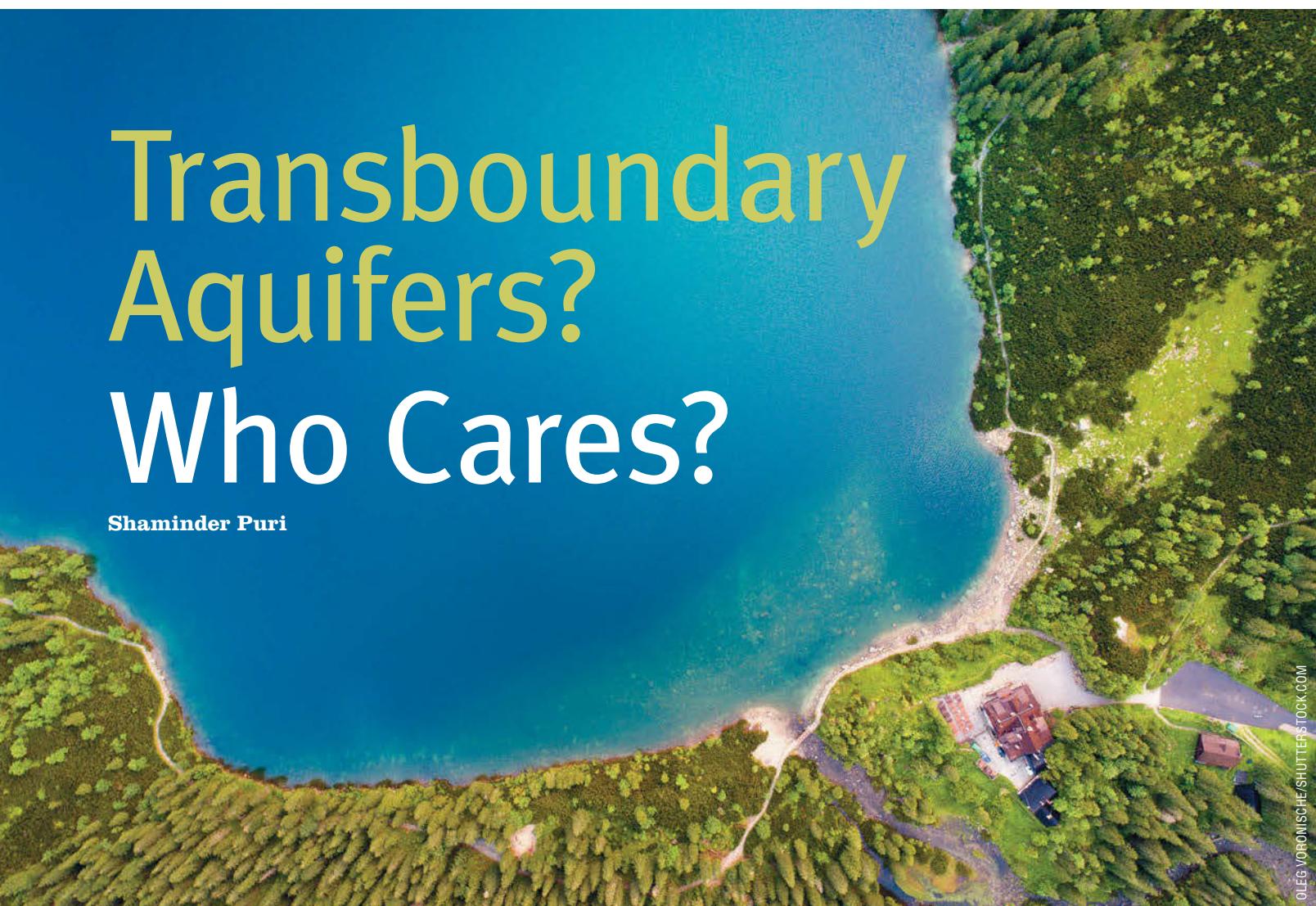
Good governance provides no guarantee that we'll all agree with the outcomes; far from it. However, it does contribute to the health of the organization and the strength of its relationships. Good governance of AWRA relies on the active participation of the members. If you have been waiting for your invitation to participate in this association, consider yourself invited! We need your perspective in the committees, conferences, webinars, workshops, publications—and governance—of AWRA. ■

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Brenda O. Bateman can be reached at [president@awra.org](mailto:president@awra.org).

# Transboundary Aquifers? Who Cares?

Shaminder Puri



OLEG JORONISCH/SHUTTERSTOCK.COM

**I**t was in September 1997 that I had the temerity to stand up in the International Association of Hydrogeologists (IAH) Congress of Hydrogeologists and ask of my several hundred gathered peers, "What do we know about the transboundary aquifers of the world?" That was after five years of grueling work in the deserts of southern Jordan, close to the borders of Saudi Arabia, on the hydrogeological exploration of the Rum-Saq aquifer. So this question was high on my mind. Our final report, prepared with my excellent team, had included a chapter on transboundary aspects. Imagine my annoyance and irritation when the United Kingdom government's technical supervisory team, (who had financed the whole study worth £ 8M), instructed me to remove the chapter from the report! That text still sits somewhere on my hard disk and looking back at it from the perspective of the past two decades, I marvel at the shortsightedness. Today, no water resources assessment is complete without reference to aquifers that cross international or intra-national boundaries (see Photo 1). It was not so in 1997.

# The Cooperative Framework for the Transboundary Aquifer Assessment Program: A Model for Collaborative Transborder Studies

**Sharon B. Megdal**

**M**embership on the Transboundary Aquifer Assessment Program (TAAP) team continues to be gratifying. The late 2016 publication of the *Binational Study of the Transboundary San Pedro Aquifer* (San Pedro Study) by the International Boundary and Water Commission (IBWC) marked a milestone. This study is noteworthy in that it is a first-ever binationally prepared, fully bilingual aquifer assessment along the border shared by the United States and Mexico, and because it was subject to peer review on both sides of the border.

Also noteworthy is the framework for cooperation that has guided the team's multi- and trans-disciplinary collaborative assessment work. Signed on August 19, 2009, IBWC's "Joint Report of the Principal Engineers Regarding the Joint Cooperative Process United States-Mexico for the Transboundary Aquifer Assessment Program" (Cooperative Framework) took considerable time to develop. The successful ongoing collaboration confirms the value of the time spent at the front-end to develop the Cooperative Framework. The team was able to persevere despite uncertain and very limited funding and the challenges of working in different languages and across an international border. I believe strongly that the Cooperative Framework can serve as a model for transboundary water studies across the globe, whether or not focused on groundwater.

By way of background, TAAP got its start on the U.S. side with the signing, late in 2006, of U.S. Public Law 109-448,

the Transboundary Aquifer Assessment Act. I had the honor of serving as the sole non-federal witness at the May 2006 U.S. House of Representatives subcommittee hearing on the proposed legislation. The Act articulated U.S. interest in engaging in binational aquifer assessments of specified priority aquifers. While the Act indicated that IBWC would be consulted "as appropriate," it soon became clear that IBWC involvement would be central to development of the type of assessment authorized by the Act.

The Cooperative Framework establishes that the binational program will be called the Transboundary Aquifer Assessment Program and that the IBWC will serve as the Binational Coordinating Agency. It confirms that the United States and Mexico are aware of the value of developing an understanding of the aquifers used by both countries. The Cooperative Framework acknowledges the need to develop a team of binational experts to assess aquifers, exchange data, and if necessary,

develop new datasets. The document states, that the "IBWC, under this joint cooperative process, will provide the framework for coordination of binational assessment activities conducted by U.S. and Mexican agencies, universities, and others participating in the program," ... "to improve the knowledge base of transboundary aquifers between the United States and Mexico." Additional key provisions include: assuring that both countries concur on transboundary aquifer assessment activities and specifying binational technical advisory committees for each identified transboundary aquifer. The IBWC was named as the official repository for binational project reports to be published in Spanish and English. Figure 1 shows the four aquifers that have been established as aquifers of focus for the TAAP.

Importantly, IBWC is responsible for developing a joint program and for determining whether a proposed aquifer study is in the interest of both countries. The IBWC also coordinates with agencies for both countries in defining the scope of the assessment and facilitating agreement on work plans. However, the Cooperative Framework specifies that "each country will be responsible for any costs on projects conducted in its territory, in addition to selecting the participants and consultants to carry out the studies in that country. Each country may contribute to costs for work done in the other country, and the IBWC will coordinate any flow of funds across the border." The six principles of agreement, which appear toward the end of the three-page document, make it clear that each country is free to undertake its

# Transboundary Groundwater Issues within Canada and between Canada and the U.S.

**Alfonso Rivera**

*"Humankind has not woven the web of life. We are but one thread within it. Whatever we do to the web, we do to ourselves. All things are bound together. All things connect."*

– Chief Seattle

When I received an invitation to give a conference on water to the Blood Tribe of the Blackfoot Confederacy in 2014, little I knew of the impact that my work on aquifer mapping had had on one of the most important First Nations in Canada. I was invigorated, inspired and heartened by the Tribe's reception and the way they look at science and at water within their vision of life. I humbly learned a very valuable lesson that day.

In brief, I learned that their vision of humans and nature is centered on relationships and ideas that will ultimately translate to sustainable planning and management of their natural resources and ecosystems through fostering dialogue among youth, elders, community members, academics and Chief and Council. They work toward positive approaches and solutions to take care of their land, where everyone profits. Their vision is an intertwined ensemble, one where water is not a separate element of the community; rather it is one integral part of a communal ensemble, which includes water, air,

soil, environmental health and cultural knowledge. They do not separate the other elements when dealing with water issues.

I learned that this philosophy could be applied—and I actually try to use it—in any aspect of the sharing of natural resources, particularly groundwater resources, be they between counties, provinces or countries. I refer here to transboundary water issues.

The Great Chief Seattle, a Suquamish Tribe chief, strongly influenced the First Nations of North America since he delivered his famous speech from 1854. In that speech/letter, Chief Seattle wrote: "The

*Great Chief in Washington sends word that he wishes to buy our land. The Great Chief also sends us words of friendship and goodwill. This is kind of him, since we know he has little need of our friendship in return. But we will consider your offer. For we know that if we do not sell, the white man may come with guns and take our land. How can you buy or sell the sky, the warmth of the land? The idea is strange to us. ....*

These thoughts beg the questions: Whose land is it? And, who owns the water sources located in that land? These questions are very relevant to groundwater in particular.

At the time of my conference, the Blood Tribe was interested in learning about the Milk River transboundary aquifer, which, they had learned, crossed the boundaries of Alberta and Montana and Canada-U.S. Since they shared lands in between the two countries with the Blackfeet Nation in Cut Bank, Montana, they were interested to know how the "great Chiefs" were dealing with these shared waters. They were pleased to learn

# U.S. Supreme Court to Decide First Interstate Groundwater Dispute

Noah D. Hall



Over a century ago, the U.S. Supreme Court established a rule of sharing—called “equitable apportionment”—between states for transboundary rivers and lakes. In short, this legal doctrine settles disputes over state interests in shared waters by determining the best overall utility for the water supply, with no state having absolute ownership based on geography or any other factor. With equitable apportionment as the background principle, states often avoid litigation and negotiate cooperative interstate water management agreements for shared resources.

However, the settled law of interstate sharing and equitable apportionment that motivates cooperative management is being questioned in the U.S. Supreme Court’s first major case over transboundary groundwater. The Sparta-Memphis Aquifer (sometimes called the “Memphis Sand Aquifer”) straddles the Mississippi-Tennessee border and is the primary water supply for the city of Memphis, Tennessee, along with Memphis and its municipal utility Memphis Light, Gas and Water (MLGW), would apply the doctrine of equitable apportionment to the groundwater. This would most likely allow Memphis’ continued pumping for municipal supply, given the minimal harm to Mississippi’s interests.

# Transboundariness, or the End of Aquifer Boundaries as We Know Them

Rosario Sanchez

**D**efining aquifer boundaries can be difficult, even under the best conditions. However, when it comes to delineating the boundaries of an aquifer that happens to be located between two or more countries, the science and its methods get involved in a complex and multidimensional negotiation process where every aspect of an aquifer's hydrogeology is overshadowed by various social, political, cultural and economic variables.

The first time I thought about the term "transboundariness" was during a conversation with a colleague trying to explain how the boundaries of an aquifer acquire a different value, dimension and scale when it is located in the borderland. I was trying to find a term, concept or approach that could measure why and how the treatment and attention to those shared aquifers vary depending on those interrelated variables. These variables can affect how we: identify an aquifer; define an aquifer's boundaries; recognize an aquifer as transboundary; and prioritize an aquifer over other aquifers.

This reality takes place in the border regions at different levels and scales, but it has neither been weighted nor evaluated in terms of the variables involved, or in the level of attention and prioritization given to any particular transboundary aquifer. The "transboundariness" approach attempts to measure precisely those variables, which turns a supposedly simple technical task (defining the

boundary of an aquifer), into a blurry and indefinite process into which the strategic and political values of an aquifer expand its physical boundaries into a complex spectrum of needs and priorities.

Sanchez & Eckstein introduced the tranboundariness concept in 2017, and later, Sanchez *et al.* 2018a applied it to the hydrogeological units between Mexico and Texas. The questions that transboundariness tries to answer and that led to its development are:

1. Why have only 11 transboundary aquifers been recognized officially as *transboundary* when there is evidence that at least 16 are potentially transboundary?
2. Why have only four aquifers been given priority over the remaining aquifers in the border region between Texas and Mexico?
3. What criteria are used to identify, define and prioritize one transboundary aquifer over another?

Whatever the answers, the relevance of this approach is that the physical features of the aquifers become just additional variables among the broad spectrum of considerations of the transboundary nature of an aquifer: social (population); economic (groundwater productivity); political (as transboundary); available research or data; water quality and quantity; and other issues governing the agenda (security, trade, immigration and so on). The discussion changes from the traditional question of "is the aquifer transboundary?" to "how transboundary is the aquifer?" The socio-economic and political contexts effectively overwhelm the aquifer's physical features adding its corresponding geostrategic value—its transboundariness.

The criteria proposed by this approach attempt to encapsulate and measure all potential variables that play a role in defining the transboundary nature of an aquifer and its multidimensional *boundaries*. However, given the complexity and differences in contexts and local regimes, transboundariness should not be understood as a metric strictly speaking, but only as an indicator of differences in treatment, attention and prioritization among different transboundary aquifers. Today, these differences are usually underestimated or neglected when addressing the nature of transboundary aquifers and assume that such aquifers should be treated equally as those that are circumscribed to a geographic jurisdiction. This false assumption is

# The Science, Management and Governance of **Transboundary Groundwater**

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# Scientific Mediation through Serious Gaming Facilitates Transboundary Groundwater Cooperation

**W. Todd Jarvis**



*Scientific mediators attempt to tread the path between Merchants of Doom and Merchants of Doubt as Merchants of Discourse using multiple working hypotheses and multiple ways of knowing as their moral compass.*

(Moore et al., 2015)

Conflicts related to groundwater and aquifers manifest certain peculiarities not frequently experienced in other water conflicts. Groundwater is inconvenient to water law and water diplomacy because it is hidden and is many times referred to differently than surface water; however, groundwater also can sometimes be considered part of the “unitary whole” of an international watercourse.

Scientific mediation is used by groundwater scientists and engineers in matters where the technical jargon and

high levels of uncertainty lead to a stalemate on decision making. Scientific mediation is also used to resolve disputes between groundwater scientists and engineers who live and work across boundaries, including the urban-rural divide, county-to-county, state-to-state, province-to-province and international.

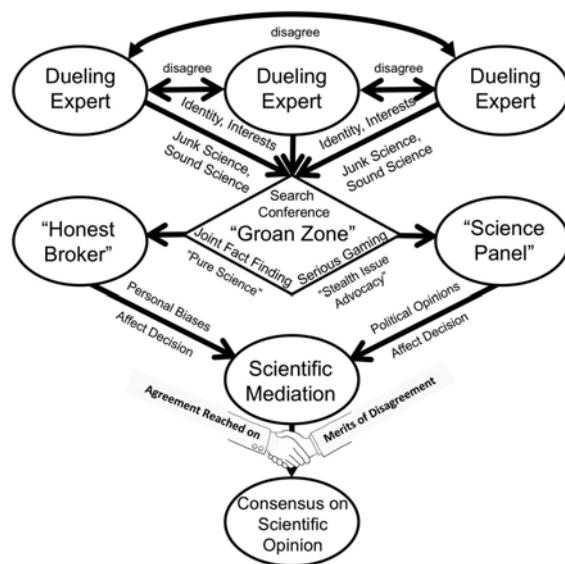
It seems silly that groundwater professionals cannot get along, but, as is human nature, groundwater scientists and engineers bring their personal and political biases to their work. Likewise, conflicting conceptual hydrogeologic models are also part of the formal training of hydrogeologists. The intellectual method of multiple working hypotheses was introduced in the late 1890s by U.S. hydrogeologist Thomas Chamberlain to explain observed phenomena. This theory allows for creativity and imagination in the practice of the profession. The antithesis of multiple

ways of knowing is a ruling theory. Ruling theories are many times promoted by individuals who consider the geology and hydrology of where they live and work as so complex and unique that only a local professional would understand how their hydrogeology works. As a consequence, groundwater professionals also have a strong personal affinity and identity to their work given that imagination and creativity are key parts of developing their working hypotheses.

This can lead to dueling experts. The danger of not addressing a dueling expert situation in an effective manner leads to distrust in groundwater science and engineering by the public, policy makers, as well as the courts as groundwater-related disputes are increasingly being heard by the highest domestic courts and the International Court of Justice.

The Scientific Mediation framework depicted in Figure 1 attempts to reach agreement on the merits of the disagreement as opposed to having personal and political biases cloud the scientific process. While scientific mediation is a process that sounds rather utopian, it is garnering much interest by conflict resolution practitioners because it moves beyond the tired and overused cliché of agreeing to disagree.

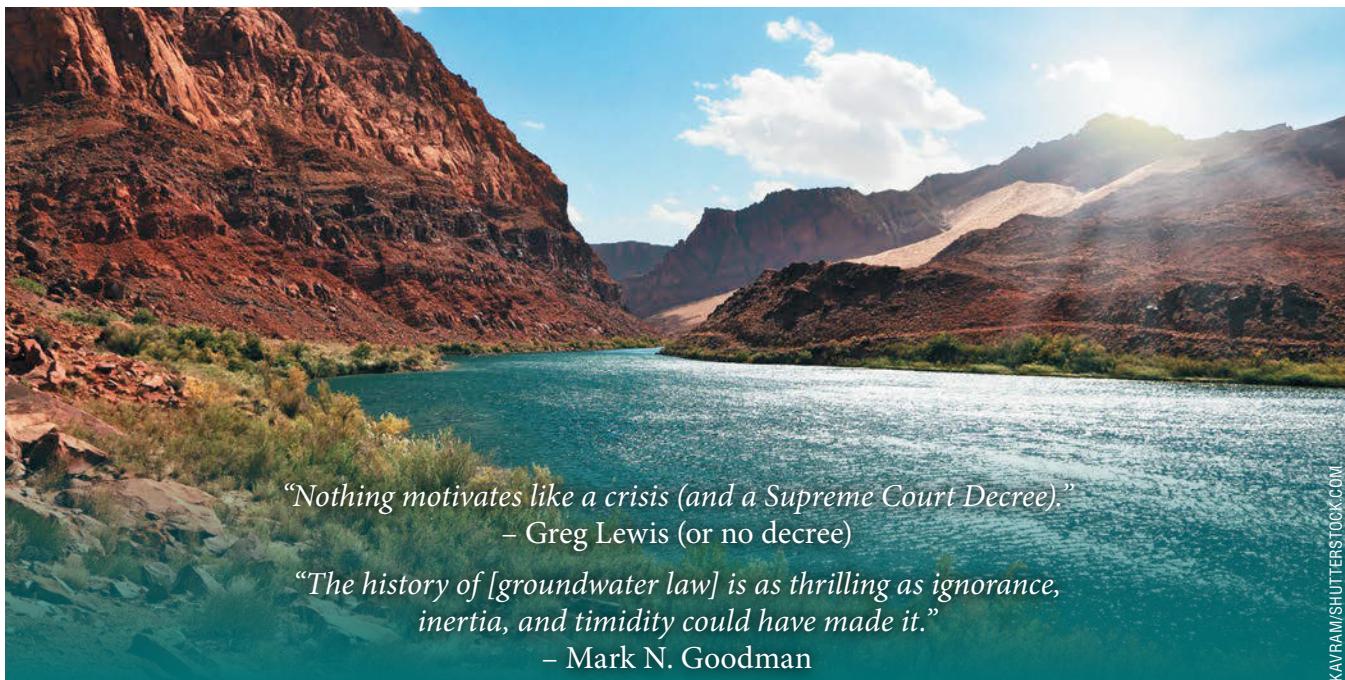
What are the best approaches to negotiations regarding groundwater



**Figure 1.** Scientific Mediation Framework. Modified after Moore et al. (2015).

# The *Winters* Doctrine Goes Underground

**Michael E. Campana**



*"Nothing motivates like a crisis (and a Supreme Court Decree)."*

– Greg Lewis (or no decree)

*"The history of [groundwater law] is as thrilling as ignorance, inertia, and timidity could have made it."*

– Mark N. Goodman

Mention the *Winters* Doctrine to a certified WaterWonk and you're likely to get this response: 'Oh, yeah, I know that one. It's the Supreme Court decision that reserved water rights for federal reservations even though the rights were not specifically granted when the reservation was created.' That's a pretty good definition, although I suspect a few of my legal friends are no doubt rolling their eyes. Many people interpret the word 'reservation' to mean 'Native American reservation' but the term refers to any federal 'reservation' such as a national monument, park, etc.

So how does an article about the *Winters* doctrine and its promise of water rights find its way into an issue on transboundary groundwater? Let me explain, starting with a little bit of repetition.

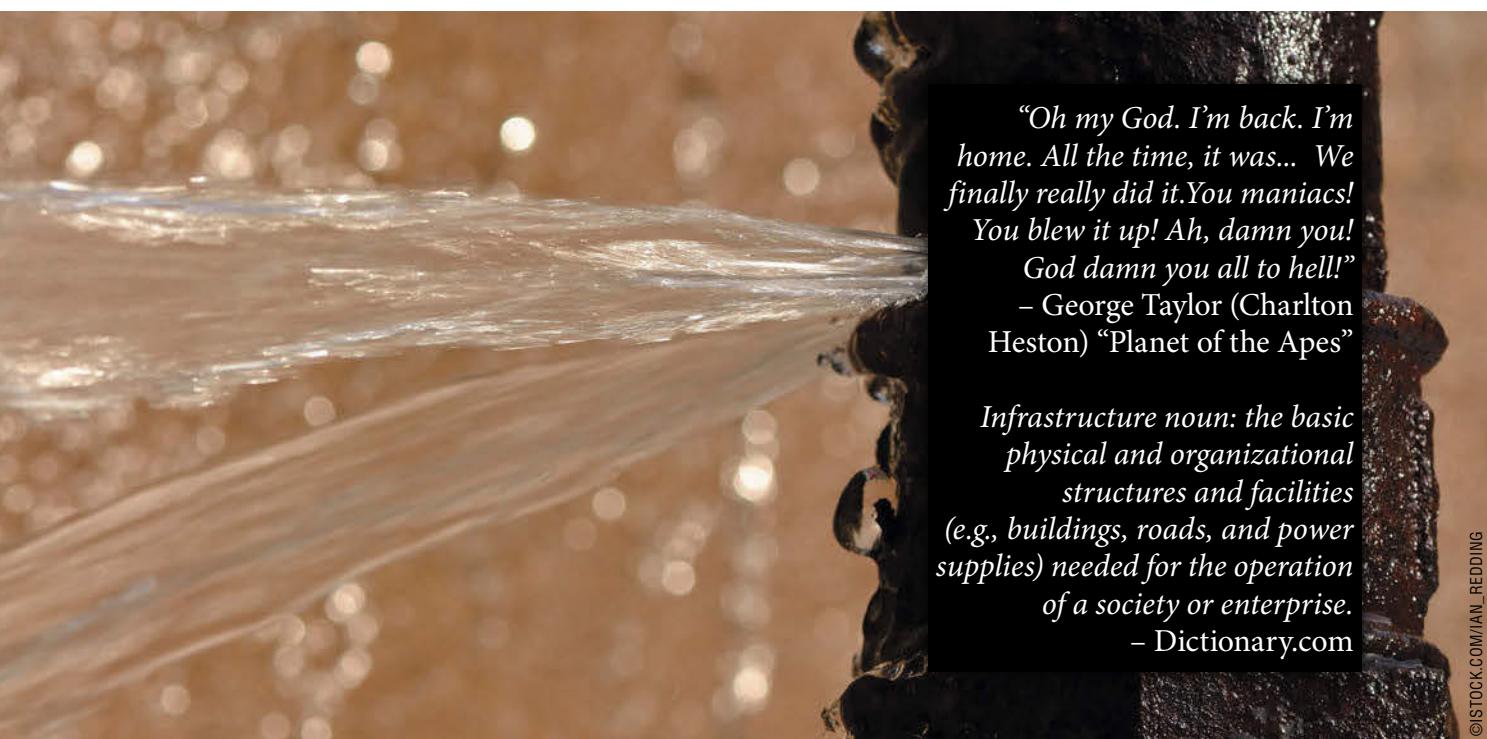
One of the most important U.S. Supreme Court water decisions is the 1908 *Winters v. United States* decision in which the court established the federal reserved water rights doctrine. This doctrine, often associated with Native American

reservations but also applicable to other federal lands such as national monuments, holds that when the federal government set aside lands, it implicitly reserved sufficient water to enable the reserved lands to be used as intended. These reserved rights, or *Winters* rights as they are frequently called, have traditionally pertained to surface water and not to groundwater. That is about to change.

In the *Agua Caliente Band of Cahuilla Indians v. Coachella Valley Water District* case, the tribe sued a number of California water agencies for adversely affecting the quality and quantity of its groundwater by over-pumping a shared aquifer. The tribe further asserted that it had *Winters* rights to the groundwater beneath its reservation. The Ninth Circuit Court of Appeals ruled in the tribe's favor, stating that the *Winters* doctrine applies to groundwater as well as surface water. Furthermore, the U.S.

# The Infrastructure Crisis and a Paralysis of Leadership

**Eric J. Fitch**



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**THE GROWTH AND** emergence of America as a great country and power can to some degree be measured by the development of an integrated, technologically sophisticated physical infrastructure. From the development and promotion of the building of canals and wagon roads, through development of transcontinental railroads and even the successful opening of the Panama Canal, the United States went from a middle-of-the-road regional power to a continental power. Massive investment in infrastructure development via the Works Progress Administration and other New Deal Programs helped to integrate the nation's infrastructure and lift the country out of the Great Depression.

Mobilization for WWII and eventual victory left the country as a global power with an intact and powerful industrial, research and infrastructural base. In subsequent decades, federal programs such as the Eisenhower Interstate Highway System, urban renewal/community

development, and heavy investment in and subsidization of the development of water-related infrastructure (locks and dams, levees, water treatment and distribution systems, wastewater treatment facilities, etc.) helped continue this progress.

As the nation entered the 1980s, growing concern about the size, scope and cost of government led to a reconsideration of its roles and a retrenchment in the scope. One critical area of this retrenchment was the investment in creating new, and maintaining existing, infrastructure. Without such support, to create and maintain, rot has set into our basic infrastructure across the nation. If Frederick the Great is credited with saying, "an army travels on its stomach," then a nation rises or falls on the strength of its infrastructure.

During my teen years, one of my favorite television series was the "Six Million Dollar Man." A classic example of a Joseph Campbell hero's journey, an

"Oh my God. I'm back. I'm home. All the time, it was... We finally really did it. You maniacs! You blew it up! Ah, damn you! God damn you all to hell!"  
— George Taylor (Charlton Heston) "Planet of the Apes"

*Infrastructure noun: the basic physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) needed for the operation of a society or enterprise.*  
— Dictionary.com

American astronaut—the quintessential American hero of the day—suffers near-fatal injuries in the crash of an experimental lifting body aircraft. In the introduction to the weekly show, the situation is summarized for the audience. First the narrator (Harve Bennett) intoned; "Steve Austin, astronaut, a man barely alive." Then Oscar Goldman (Richard Anderson) continued the narrative, "Gentlemen, we can rebuild him. We have the technology. We have the capability to build the world's first bionic man. Steve Austin will be that man. Better than he was before: Better, stronger, faster." Cue the stirring theme music with image of Steve Austin running at incredible speed right into the end of the opening credits.

America's infrastructure today is Steve Austin right after the crash; on life support waiting for government decisions to spend the time and resources to restore and even improve him or let him die.

# Generating More Hydropower Using Weather Forecasts

**Shahryar Khalique Ahmad and Faisal Hossain**

**THE OPERATION FOR** almost all hydropower dams in the United States is guided by water control manuals that were developed when the dams were constructed many decades ago. Reservoir control manuals are often defined in terms of ‘Rule Curves’ that specify the storage targets the reservoir needs to meet at specific time intervals of the year. The dam operator releases water as necessary and as close to the recommended levels in the manual to achieve the respective targets for each stakeholder need [Loucks *et al.*, 2005]. Actual releases vary depending on the storage and dynamic inflows that actually occur.

However, these rule curves do not account for the change in inflow patterns that have resulted due to changes in climate and land cover conditions. Furthermore, releases in the rule curves are specified independently of the future inflow forecasts. In fact, release guidelines are typically based only on existing storage volumes and within-year periods using a climatology of historical flow observations. Now that weather forecasts are widely available in real-time, such archaic use of rule curves misses the opportunity to operate hydropower dams more dynamically at a higher level of efficiency.

For instance, in a weaker-than-average flood-prone month during the flood season, lowering the pool to rule-curve recommended level will result in significant loss in hydropower generation through non-powered release through spillways. This otherwise could have been avoided if inflow forecasts were made ahead of time to maximize the flow through the powerhouse [Miao *et al.*, 2016]. This is just one of the many scenarios where the static and traditional rule curves could be made more adaptive for real-time operations to harvest more hydropower.

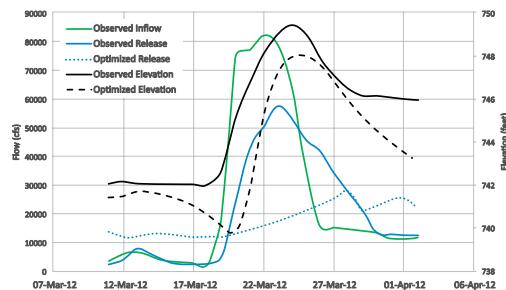
Current numerical weather forecasting models can provide reasonable accuracy

over short-term period of 5-10 days, which may be sufficient in many cases to forecast, for instance, a peak flood event and adjust the dam operations accordingly. Not only can the weather forecasts provide an emergency flood warning, but incorporating that forecast information to adjust reservoir operations can often result in two-fold benefit of maximizing hydropower production without sacrificing downstream flood safety. A term we introduce here is called “flood-safe hydropower,” which we believe can be maximized by making little tweaks to reservoir operations using widely available weather forecasts.

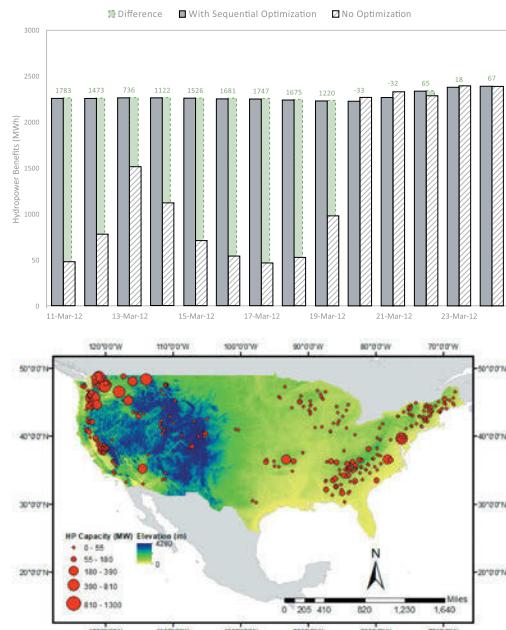
## Flood-safe hydropower benefits: A proof of concept for a U.S. dam

We considered two competing benefits of hydropower and flood control for a dam in the United States (Pensacola dam in Oklahoma) to demonstrate the concept of how weather forecasts can be leveraged to generate more ‘flood-safe’ hydropower. We used NOAA’s Global Forecast system (GFS) of weather forecasts up to 15 days lead time. These forecasts were applied to a hydrologic model to forecast inflow into the Pensacola dam that receives unregulated flow. Finally, we applied a sequential optimization routine with all known constraints defined by hydrologic/hydraulic limits of spillway, turbines and downstream flood safety, environmental flows. The downstream flood safety defined the upper bound of total flow that can be released from the dam via turbines and spillways. We also sought input from the dam operating agency, U.S. Army Corps of Engineers (USACE), and existing public records to make sure the optimization problem was set up as realistically as possible using real-world data.

For a flood event that occurred during March 2012, the flood-safe hydropower



**Figure 1.** (a) Optimized releases and elevations for Pensacola dam along with the respective observed values using real-time sequential run, updating forecasts every alternate day from 11 March to 17 March (b) Daily comparison of hydropower benefits (MWh) obtained using observed operations (without optimization) and from sequential optimization (Ahmad, 2017).

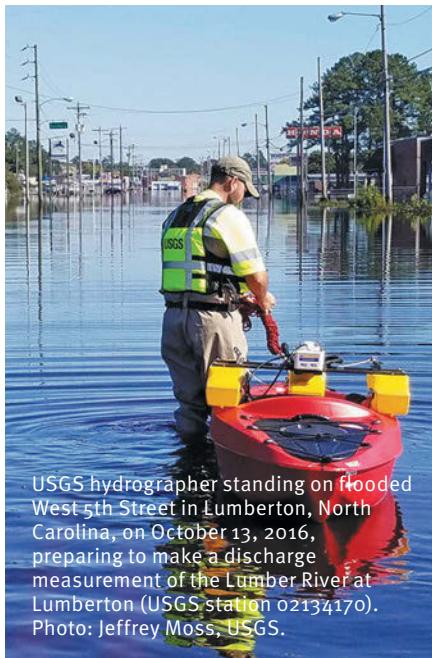


**Figure 2.** Distribution of small to medium hydropower dams in the US that receive unregulated inflow at upper catchments of river basins. The circle represents turbine capacity.

optimization strategy revealed a *net benefit* of 13,048 MWh, in addition to what operations without optimization would have yielded. With an average retail price of 7.90 cents/kWh, this benefit amounts to \$1,030,792. For the competing objective of *continued on page 34*

# Bulletin 17C: National Flood Flow Frequency Guidelines for the 21st Century

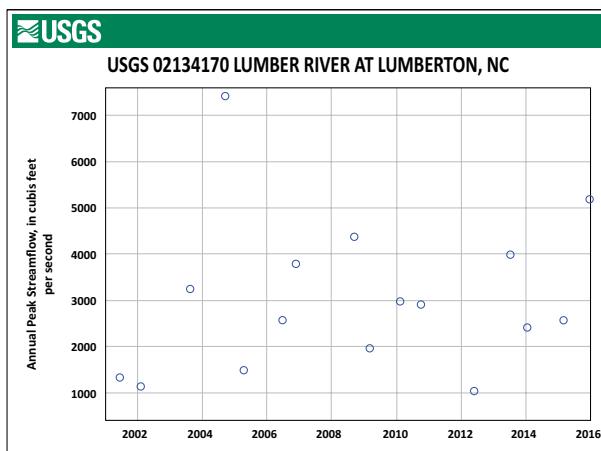
**Andrea G. Veilleux, Jery R. Stedinger, Julie E. Kiang, Wilbert O. Thomas, Jr., Robert R. Mason, Jr., John F. England, Jr., Beth A. Faber**



**FLOWING WATERS IN** meandering streams may be calming, but their beauty can mask the dangers that flood waters pose to communities along their banks. These waters fill channels and cover the floodplain—causing floods that can wash away bridges, houses, and even levees constructed to protect urban infrastructure and agricultural areas.

Infrastructure designers, civil and transportation engineers, floodplain managers, as well as various federal, state and local agencies require estimates of the frequency of large flood flows for a variety of reasons that include but are not limited to:

- support of risk-informed design of water management structures, such as dams and levees;
- support of economically efficient design of bridges, culverts and roadways; and,
- development of Federal Emergency Management Agency (FEMA) floodplain



Associated peak flow record.

maps under the National Flood Insurance Program to inform long-term land use planning.

Hydrologists employ flood frequency analysis to generate these estimates of the likelihood of various events, such as the 1% annual exceedance probability flood, often called the 100-year flood. It is imperative that different agencies and engineering organizations generate consistent, reproducible estimates of such design floods if those values are to be credible and in order to minimize potential legal challenges.

To provide a uniform statistical technique for estimating flood frequency for floodplain management, and for the design of hydraulic structures and their operation, national flood frequency guidelines for federal agencies titled, Bulletin No. 15—"A Uniform Technique for Determining Flood Flow Frequency"—were published in December 1967. Bulletin 15 was followed by Bulletin 17 and 17A in 1976–1977. The last update to the Guidelines was Bulletin 17B published in March 1982, 36 years ago. During those 36 years, major advances have

been made worldwide in hydrologic statistical methods. Moreover, the computational capabilities available to hydrologists today would have been almost unimaginable in 1982.

After a decade of work, the national guidelines for flood frequency analyses have been rewritten. The new guidelines capture those advances and improvements in

statistical hydrology, flood hazard estimation, data collection and the power of modern statistical computations. Hydrologists from different federal agencies, consulting firms and U.S. universities took on the task under the direction of the U.S. Advisory Committee on Water Information and its Subcommittee on Hydrology. The new "Guidelines for Determining Flood Flow Frequency"—Bulletin 17C—were released in March 2018 (England *et al.*, 2018). In conjunction with the release, the U.S. Geological Survey and the U.S. Army Corps of Engineers have designed and released user-friendly software for conducting analyses with the new algorithms. Those agencies and the U.S. Bureau of Reclamation have implemented the new methods.

Bulletin 17C retains many of the major features of Bulletin 17B, allowing consistency with previous studies. However, advances incorporated into Bulletin 17C address significant limitations of Bulletin 17B. Many were well known and are listed in Bulletin 17B as topics needing future study. Major advances in Bulletin 17C include:

## **Central Washington University Student Chapter of AWRA News**

The CWU AWRA student chapter enjoyed a tour of the water resources in the Yakima Basin with Tom Ring in April. Tom Ring is a knowledgeable water resources expert in the Yakima Basin. Students learned how annual spring discharge is managed in order to support water resource needs in the region. Finding a balance for seasonal distribution of water requires considering the importance of this water for environmental, municipal, and farming purposes. Tom detailed the challenges involved in this process by visiting important locations for water resource management such as the Rosa Dam and the Rosa Dam fish ladder, which highlighted water management challenges associated with the environment.



## **Indiana Section of the American Water Resources Association June 2018 Symposium**

The Indiana Section (IWRA) of the American Water Resources Association (AWRA) will convene on June 27-29, 2018, for the 39th Annual Indiana Water Resources Association Symposium at the Monroe Convention Center, in Bloomington, Indiana. “Ensuring a Sustainable Water Future for Indiana” is the theme for the Indiana Water Resources Association Symposium. IWRA will be soliciting symposium financial cosponsors and people to demonstrate field techniques for water-resource investigations at Flatwoods Park in Gosport, Indiana on Friday June 29. Please contact IWRA President Sally Letsinger, [sletsing@indiana.edu](mailto:sletsing@indiana.edu), 812-855-1356 if you have questions about the symposium, symposium sponsorship or field demonstrations.

We want to encourage participation this year with presentations on a wide range of topics. For more information about section events and the Call for Presentations, visit the Indiana Section website <http://iwra.info>. The IWRA provides economic incentive and assistance to students attending Indiana colleges and universities to present papers and posters at the Spring Symposium through the IWRA Student Scholarship Fund.



## **Washington State Section of AWRA News and October 2018 Conference**

AWRA-WA has kicked off 2018 with dinner meetings, an increase to our annual student fellowship award, a new young professional mentorship program, and substantial early action planning for our annual conference.

AWRA-WA's annual conference has become the venue in Washington State for timely, current and relevant discussion that connects water resources professionals across the state. This year's conference title is, "Hirst, Foster, Boldt, and Beyond: A New Era of Water Management?" and will occur on October 16, 2018 at The Mountaineers in Seattle, WA. The theme will revolve around the notion that historically, decisions on water management under prior appropriation were very closed, prescriptive, and narrowly defined under a statute primarily adopted in 1917. Modern desires for changes, flexibility and creativity on the use of water and water rights have been thwarted by the Washington State Supreme Court's application of a rigid code and case law framework. This conference will explore how the significant legal cases such as Hirst, Foster, Boldt and others are driving a New Era of Water Management. ■

# AWRA Approves Policy Statement on Fresh Groundwater

**IN A NEW** policy statement on fresh groundwater, AWRA proposes that groundwater will be managed according to the tenets of Integrated Water Resources Management (IWRM) and offers 10 IWRM-related actions groundwater users, water and land resource planners and managers, and decision makers can use to advance sustainable groundwater management. Below is the full text of the new statement.

## AWRA Policy Statement on Fresh Groundwater

*Approved by the Board of Directors of the American Water Resources Association at its January 13, 2018 meeting.*

**Rationale:** About 40 percent of the U.S. population regularly depends upon groundwater for its drinking water, and groundwater constitutes about 43 percent of the nation's irrigation water. Groundwater also provides an important alternative water source in regions where surface water use is highly weather dependent.

**Policy Statement:** Given the critical importance of this water asset and given that groundwater and surface water are often interconnected resources that require full recognition of their ties to achieve sustainable water management, the American Water Resources Association recommends groundwater be managed according to the tenets of Integrated Water Resources Management (IWRM). Following are 10 IWRM-related actions groundwater users, water and land resource planners and managers, and decision makers can use to advance sustainable groundwater management.

- 1. Assess Resources.** States and related political subdivisions should assess their groundwater resources, including the health of their groundwater basins, to determine static and dynamic water budgets and to identify the nature, timing

and extent of water withdrawals each aquifer system can sustain over time. Working with groundwater users and other stakeholders, processes to measure/monitor the sustainability of withdrawals and inflows should be defined and implemented.

- 2. Build Partnerships.** The appropriate political subdivisions should work with groundwater users and other stakeholders to develop, or encourage development of, agreements and management/governance strategies to protect groundwater resources and fully acknowledge transboundary resources.
- 3. Legal Framework.** Groundwater law, and those policies and regulations based upon it, should stay aligned with the most current concepts and understanding of groundwater science.
- 4. Think Groundwater.** Policies for agriculture, energy, environment, land-use planning, economic and urban development policies should incorporate groundwater considerations.
- 5. Maintain Sustainability.** In those areas where groundwater use is unsustainable but necessary, efforts should be made to seek sustainable supplies and/or mitigate groundwater use.
- 6. Respect Ecosystems.** The role of groundwater as an essential component of ecosystems and freshwater systems should be respected in management actions and policies.
- 7. Engage Stakeholders.** Authentic stakeholder engagement should be incorporated in establishing and implementing groundwater management and governance.
- 8. Commit to Understand.** Congress, the states and all levels of government should make a commitment to

understand and improve governance of the nation's groundwater and its basins, and connected surface waters based on an understanding of hydrology and hydrogeology.

- 9. Protect the Asset.** Groundwater basins need to be managed with care. Users and managers should protect against the loss of capacity from subsidence, pollution or salt-water-intrusion. When a groundwater basin is polluted, remediation should be a top priority. Environmental and social considerations should be taken into account in the management of groundwater assets.
- 10. Utilize Interdisciplinary Approaches.** To achieve sustainability, groundwater users, managers, decision makers and other stakeholders should promote and utilize the best scientific, engineering, collaborative, and research practices available.

AWRA recommends the groundwater community, and its stakeholders and decision makers commit to advancing these 10 IWRM principles, recognizing that groundwater is an essential component of the world's freshwater supply.

National Ground Water Association (NGWA). Groundwater Use in the United States of America. <http://www.ngwa.org/Fundamentals/Documents/usa-groundwater-use-factsheet.pdf> [Accessed: 5 January 2018]

National Ground Water Association (NGWA). Groundwater Facts. <http://www.ngwa.org/Fundamentals/Pages/Groundwater-facts.aspx> [Accessed 5 January 2018]

*If you have questions about the above policy statement, please contact info@awra.org. ■*

# President Bateman Proposes Bylaws Change

**IN AN EFFORT** to modernize and reinvigorate AWRA's "Nominations/Awards Committee," AWRA President Brenda Bateman has proposed changing the committee's name to the "Leadership Development and Recognition Committee."

A name change for this committee signals a willingness and intent to actively recruit leaders and members of technical committees, conference committees and other volunteer positions in the association. The committee would continue to seek out proven leaders in our water resources profession for recognition and awards.

The committee is currently comprised of members Rafael Frias, Martha Narvaez and Kim Swan.

The change of name for this committee requires an amendment to the AWRA Bylaws, which falls under the purview of AWRA's Board of Directors upon notification to the AWRA membership. The intent is for the Board take up this issue during its August 2018 meeting.

Below is the proposed change to Article III, Section 8 of the AWRA bylaws:

## **ARTICLE III. Section 8—Administrative and Technical Committees.**

*In addition to the Executive Committee and the standing administrative committees listed below, the Board may appoint other special committees to advise the Board on matters of administration and policy, and the President may appoint other special technical committees to promote knowledge in all areas of water resources.*

*Standing Administrative Committees:*

1. *Finance*
2. *Nominations/Awards Leadership Development and Recognition*
3. *Tellers*

AWRA members may contact President Brenda Bateman at [president@awra.org](mailto:president@awra.org) with questions or concerns. The complete Bylaws of the American Water Resources Association may be found by visiting [www.awra.org](http://www.awra.org), click on About Us, then Bylaws. ■

# AWRA Announces Candidates for Officers and Directors 2019

**THE NOMINATIONS COMMITTEE** of AWRA, chaired by Past President Martha Narvaez, announces the following slate of candidates for terms commencing January 1, 2019:

## **PRESIDENT-ELECT:**

(1-year term)

Betsy Cody, Consultant, Arlington, VA

## **BOARD MEMBERS:**

(3-year term)

Zhenxing Zhang (Jason), Illinois State Water Survey, Champaign, IL

Claire Bleser, Riley Purgatory Bluff Creek Watershed District, Chanhassen, MN

## **TREASURER:**

(3-year term)

Jerad Bales, Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI), Cambridge, MA

As set forth in Article III, Section 5D of the AWRA Bylaws, "members may nominate additional candidates by submitting a written petition to the Association Headquarters signed by not less than 25 association members in good standing. A letter signed by the nominee expressing a willingness to accept the nomination and to serve if elected and a brief biographical sketch must accompany the petition. Such petition with the requisite signatures, the acceptance letter, and the biographical sketch must be received no later than June 15, 2018. Ballots for all contested positions will be sent electronically to all members in good standing no later than July 1, 2018. Ballots are not required for uncontested positions." ■

# AWRA Seeks Nominations for Prestigious Integrated Water Resources Management (IWRM) Award

## THE INTEGRATED WATER Resources

Management (IWRM) approach has been a hallmark of AWRA since its establishment in 1964. The AWRA Policy Statement on Integrated Water Resources Management in the United States recommends that water management goals, policies, programs and plans be organized around the concept. AWRA is committed to helping organizations throughout the nation and the world further the implementation of IWRM.

To recognize excellence in the use of the IWRM approach, AWRA established an award to recognize outstanding IWRM efforts.

**Eligibility:** IWRM planning processes, projects and programs are eligible for the award (and hereafter described as “projects”), though studies, technical papers and academic research are not. Any consulting, government, nonprofit or academic organization may submit projects for consideration.

**Criteria for Award:** This award recognizes outstanding IWRM teamwork on a complex water resources effort. The project chosen for this award will be conducted by a team representing multiple disciplines such as engineering, biophysical science, economics, social science, law, planning, political science, etc. The project team will have developed a common project mission with defined responsibilities, and collaborated to achieve a water resources management objective organized around IWRM principles. To that end, the project should include:

- Sustainable and community-directed economic goals
- Restoration and protection of environmental quality as an essential element and goal

- Advancement and protection of public health and safety
- Inclusive and robust participation of community members and stakeholders
- Enhancement of social equity and community values
- Coordinated and integrated planning, development, protection, and management of water and related resources

Projects worthy of this award should include all or most of the following elements associated with IWRM:

- Clean water and sanitation as basic human rights
- Planning for long term sustainability
- Participatory decision making
- Sound scientific principles
- Adaptive management and realistic measurement of results.
- Improvement of institutional capacity at all levels

Use of the IWRM team approach should have resulted in significant improvements in:

- Quality and sustainability of solutions
- Ability to build relationships and create consensus among diverse community members and stakeholders
- Acceptability, efficiency, and effectiveness of solutions

Not all the aforementioned elements will necessarily be present in any given project. The IWRM Awards committee is interested in rewarding adherence to and implementation of IWRM principles and not simply checking-off the bullet lists above.

## Procedure for Nominations:

Credentials of projects for consideration for the award should be submitted to [info@awra.org](mailto:info@awra.org). Applications must be submitted electronically as one document

and limited to 10 Mb in size to ensure delivery. Inclusions of videos and/or other visuals (PPTs, Prezi, etc.), podcasts, etc., are welcomed and can be made using Dropbox, Google Docs (or other similar site) or links to a WWW site. These items do not count against the 10Mb limit.

**Applications are due electronically by 11:59 PM Eastern U.S. Time, June 11, 2018.** Please call 540-687-8390 or email [info@awra.org](mailto:info@awra.org) with any questions concerning the submittal process.

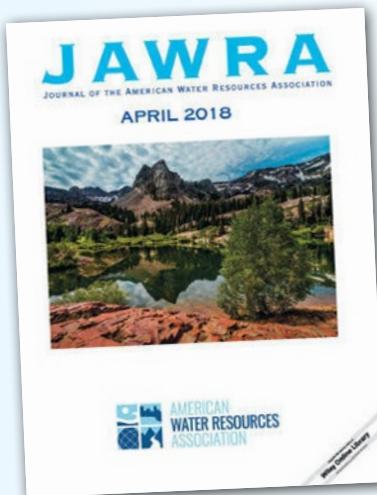
## Material submitted must include:

- Names and disciplines of team members
- A description of the issue/problem that was overcome by the project
- How the project used an IWRM approach to solve/address the water resource issue or problem, drawing from the criteria described above
- External validation, in the form of three endorsement letters from stakeholders or community participants describing the positive value and outcomes of their engagement with the project

The documentation must be thorough and address the nature of the attributes specified for the award so that the IWRM Award Committee can make valid judgments. AWRA reserves the right to make multiple awards that recognize and celebrate the application of IWRM principles in diverse settings and circumstances to include large, landscape-level settings, communities, small watersheds, etc. The award is presented annually, or at such time as there are qualified nominees. If no suitable projects are received in a given year AWRA reserves the right not to make an award. ■

# Highlights of the JAWRA Technical Papers

Volume 53, Issue 2, April 2018



## Featured Collection – Connectivity of Streams and Wetlands to Downstream Waters

This issue contains the Connectivity of Streams and Wetlands to Downstream Waters featured collection as well as several other technical papers. As described by Alexander *et al.*, the papers in the collection focus on types of waters whose protections under the U.S. Clean Water Act have been called into question by the U.S. Supreme Court cases. The collection answers

many questions related to the roles of streams and wetlands in sustaining downstream water integrity and presents emerging research on aquatic connectivity.

Leibowitz *et al.* present an integrated systems framework to understand hydrological, chemical and biological connectivity focusing on how headwaters and wetlands contribute to overall aquatic connectivity.

Fritz *et al.* review and synthesize existing evidence of the physical and chemical connections by which streams and associated riparian and floodplain wetlands influence the structure and function of downstream waters.

Lane *et al.*, based on a comprehensive literature review, conclude non-floodplain wetlands are hydrologically, chemically and physically interconnected with stream and river networks

though connectivity varies in frequency, duration, magnitude and timing.

Schofield *et al.* review the literature on movements of aquatic organisms that connect different types of freshwater habitats, focusing on linkages from streams and wetlands to downstream waters. They conclude that biological connections established by movement of biota are critical for ecological integrity of aquatic systems.

Goodrich *et al.* illustrate the hydrologic, chemical and ecological connectivity of ephemeral and intermittent streams throughout the stream networks in arid and semiarid landscapes of the Western and Southwestern United States.

## Additional Technical Papers

Bigham *et al.* present a study aimed to improve the empirically derived Bank Assessment of Non-Point Source Consequences of Sediments (BANCS) model application by evaluating repeatability between users and identifying sensitive and/or uncertain model inputs.

Esquivel-Hernandez *et al.* highlight the need for truly integrated water resources management plans that include water conflicts as indicators of hydrology-climatic changing conditions and water supply and sanitation status in Costa Rica.

Kendy *et al.* seek to understand how environmental water transaction programs (EWTPs) impact other water users and local economies. They develop a suite of environmental and socioeconomic indicators that help guide and design and track the implementation of water transition portfolios in EWTP programs in Oregon and Nevada. ■

*continued from page 27*

flood control, a maximum release of 1620 m<sup>3</sup>/s was limited to just 850 m<sup>3</sup>/s as a safe threshold to prevent flooding downstream. Thus, a 47.5% reduction in the peak outflow was achieved compared to the operations without optimization (Ahmad, 2017; Figure 1).

A low-hanging fruit is the development of better coupled hydropower-flood control optimization framework using weather forecasts for small-to-medium-sized hydropower dams that receive mostly unregulated flow. This can be done by integrating the present hydropower optimization strategy with more sophisticated flow forecasting techniques based on weather forecasts for dams similar to Pensacola and part of the regional energy infrastructure. Figure 2

shows a map of such dam sites that receive unregulated flow where the use of weather forecasts is likely to benefit optimized hydropower generation.

Because these weather forecasts are already available, the challenge now is to convert availability to accessibility so that dam operators have an additional option for decision-making that builds on the rule curves when increased energy production is required. ■

**Shahryar Khalique Ahmad** is a Ph.D. student in Civil and Environmental Engineering at the University of Washington. His current research uses satellite remote sensing and numerical weather forecasts for improving hydropower generation around the world. His vision is to use multiple satellites and

global numerical models for smarter reservoir operations to meet complex stakeholder challenges. Contact: skahmad@uw.edu.

## Co-author

Faisal Hossain, University of Washington, fhossain@uw.edu

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AMERICAN  
WATER RESOURCES  
ASSOCIATION

# 2018 Summer Specialty Conference: The Science, Management and Governance of Transboundary Groundwater

Worthington Renaissance Fort Worth Hotel,  
Ft. Worth, Texas

July 9 - 11, 2018

## Early Registration Discount

**Deadline: June 18, 2018**

[www.awra.org](http://www.awra.org)

To date, few treaties, decrees or formal agreements have been codified to manage groundwater as a transboundary resource, and there has been limited discussion on the manner in which these agreements could be effectively negotiated and what scientific information is necessary to support their development and implementation.

The goal of this conference is to stimulate conversations on innovative approaches for identifying the transboundary nature of groundwater resources and the methods that can be used to develop governance agreements to aid in sustainably managing groundwater resources that cross political boundaries.



# 2018 AWRA Annual Water Resources Conference

Baltimore Marriott Inner Harbor at Camden Yards Baltimore, MD

**November 4-8, 2018**

**SuperSaver Discount Registration**  
**Deadline: September 4, 2018**

[www.awra.org](http://www.awra.org)

AWRA's 2018 Annual Conference program will stimulate conversations on water resource management, research and education by addressing globally significant issues such as coastal resilience, fire effects on watersheds, communication and outreach strategies and integrated water resources, as well as locally relevant topics such as the Chesapeake Bay, the Delaware River watershed, and eastern water law.

Hosted by the Delaware Section, in partnership with members of the New Jersey and National Capital sections of AWRA, will convene water resource professionals and students from throughout the nation and will provide attendees the opportunity to learn about and engage in multi-disciplinary water resource discussions.

Photo Credit:  
Austin Kirk via Flickr