WATER RESOURCES

IMPACT

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TRANSBOUNDARY GROUNDWATER

AMERICAN WATER RESOURCES ASSOCIATION

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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

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> 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) 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 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 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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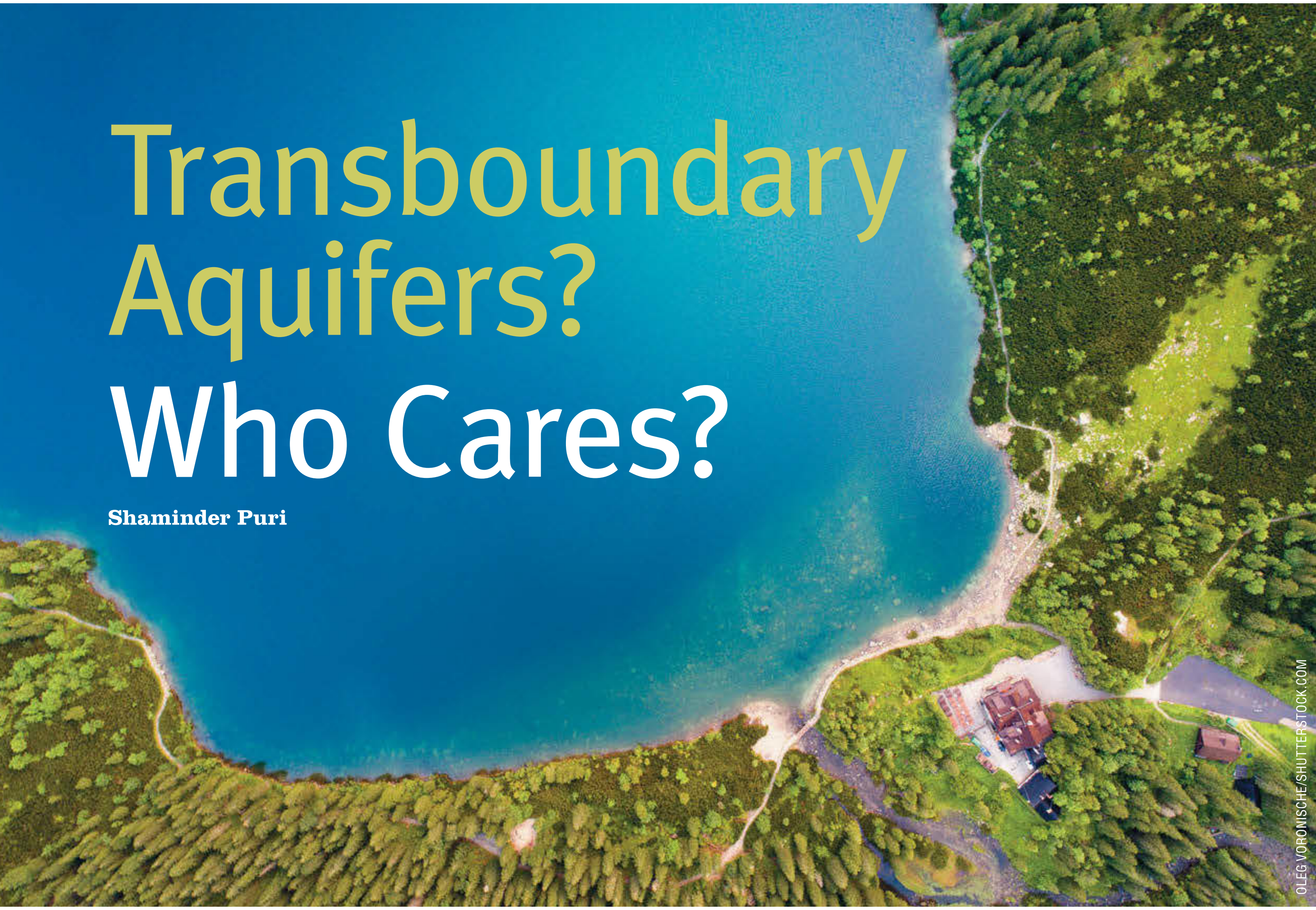

Transboundary Aquifers? Who Cares?

Shaminder Puri

It 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.

So, who cares?

Probably not the Bedouin family of the Bani Hasan tribe that I had befriended so long ago, in the village of Disi and their camps in Wadi Rum. They were fond of telling me about their water source, named after Lawrence of Arabia, who in the 1930s was spying against the Ottoman Empire from Wadi Rum. But as to transboundary aquifers, the Bedouin family had precious little interest, and why should they? Even though over the centuries, their tribe seasonally traversed the newly created borders of Jordan and Saudi Arabia, herding their sheep and camels, following traditional grazing grounds?

Borders and boundaries were irrelevancies in the ancient daily lives of nomadic peoples, be it the Bedouin of Arabia, or the Karamodjon agro-pastoralists of northeastern Africa, Guarani of Brazil, not to mention many other such people even in North America, so well described by Norman (2015). Her insight into nature's water courses in the lives of indigenous people, to whom modern day "transboundary" was "transparent," is a fascinating read.

Little wonder then, that some of the world's largest transboundary aquifers have been named after these indigenous nomadic people. Take the Guarani Aquifer System (stretching between Brazil, Argentina, Paraguay and Uruguay), or the Stampriet Aquifer System (between South Africa, Namibia and Botswana) or the Nubian Aquifer System (between Egypt, Libya, Chad and Sudan).

The descendants of the Guarani, Stampriet and Nubian tribes would probably have the same reaction as my Bedouin family when they were passing through Batn el Ghul, and I mentioned to them the aquifer, deep under our feet, stretching from far to the east of Saudi Arabia, to as far north as Amman in Jordan. Batn el Ghul is where we drilled well BH4 and found a legendary yield, an aquifer transmissivity and storage coefficient to bring tears of joy to the eyes of many a field hydrogeologist!

My Bedouin friend had come to watch the pump testing of this borehole—depth 800m (2625 feet) and pumping rate 80 L/s (almost 1300 gallons per minute)—and his reaction to my transboundary explanation was quite clear in his eyes and expression.

Oh yes, he knew about water deep in the ground from tales passed down by the Nabateans (the builders of Petra, immortalized by Steven Spielberg in "Indiana Jones") of secret places in the desert—caves and hidden ledges—where (discharging) waters of the Rum-Saq paleo-aquifer could be found (Photo 2). That mysterious 'hidden water source' skill which the Nabateans had honed around 330 BCE, enabled them to give the conquering Greek legionnaires the slip, and avoid being ransomed for taxes and other booty. Later, in the 1950s, the United Nations (UN) had drilled some exploration wells around Disi.

But back to my Bedouin family—what he wanted to know was, how could the sweet water from BH4 change his life? Unfortunately, analysis made it clear that the water from the transboundary aquifer was needed 350 km northwards of Batn el Ghul, in northern Jordan.

Thus, for all the tribes mention above, the water from a resource under their feet is required elsewhere; sometimes hundreds of kilometers away. The Nubian Sandstone Aquifer System's Great Man-Made River is another example.

So, who else might care?

Probably the hydrogeologists. Though not at first.

In the early 1950s, the term "transboundary aquifer" was the equivalent of a four-letter word! It was the post-war period. Mention of any resource freely crossing their highly valued expressions of nationhood—their international border—was bound to evoke a sense of gross interference.

The UN's Technical Cooperation programs that had fully swung into action, helping newly independent nations to build on their geological and hydrogeological capabilities, often produced maps and analysis that stopped at the national borders (Puri and Villholth 2018).

It was considered to be intrusive and highly undiplomatic to seek to extend a rock formation into the territory of another country. The so called East-West tensions were at their peak at the time. Hydrogeologists (among them some of my own peers, such as David Burdon and John Lloyd) who mapped aquifers were very conscious of this 'cross border' sensitivity. While the UN's diplomacy had to abide by the border constraint, scientists had to find a way to illustrate the cross border laws of nature, so they showed them as "regional aquifers" drawn without national boundaries.

But once those same hydrogeologists progressed on to the quantitative side of resource evaluation, there was little choice but to have to state that *'recharge occurred in country X, while the discharge occurred in country Y.'* Imagine the civil servant of the 1950s, facing his elected politician boss, and having to admit, or deny, that discharge from his country was going into or coming in from another one!

So, civil servants of the 1950s fudged it by calling on that oft repeated mantra (curiously still heard today)—"we have no data!"—thereby concluding that the findings were unreliable and enabling them to ignore it and press on with business as usual: "our aquifer is *ours*, and your aquifer is *yours*." And because continuous aquifers were out of sight, it was easy to leave them also out of mind.

Fast-forward to October 20, 2016, and the UN General Assembly Sixth Committee meeting in New York, where the following statement was made, "While Management of Transboundary Aquifers (is) Critical for 2030 Agenda Success, Draft Articles Must Be Tailored to Each State, Speakers Tell Sixth Committee" (https://www.un.org/press/en/2016/gal3528.doc.htm).

Today, the understanding and appreciation of transboundary aquifers has been transformed from the timidity of the 1950s, through the much-

Photo 1. Today, experts comfortably sit round a table, with maps of their territories, and mark out the transboundary extents of their aquifers. (Photo credit: Shaminder Puri)

applauded efforts of the community of ISARM (Internationally Shared Aquifer Resources Management) experts (Puri and Villholth, 2018, Photo 1). Every speaker in that UN meeting mentioned above recognized the existence of transboundary aquifers. While most also know that such resources have a common shared value, the diplomats of many countries still prefer to exercise deep caution in committing to specific actions with other countries.

So, what does constitute a transboundary aquifer?

After many years devoted to this subject across the world, I can offer the following: there are two classes of transboundary aquifers—those that can be adjudicated within the constitution of a country (i.e., domestic aquifers crossed by intra-national boundaries, e.g., the Murray-Darling basin of Australia) and those that cannot, because they cross sovereign borders.

Further, an aquifer is transboundary (intra-national or international), if a particle of water moving within the "aquifer system" crosses a border from one jurisdiction to another. These terms have been fully defined in the Draft Articles on the Law of Transboundary Aquifers, developed by the UN ILC (International Law Commission), though with profound input from the ISARM community. This nonbinding international instrument remains the most advanced and authoritative tool for sound management of transboundary aquifers, despite criticism from some sources.

Some words of caution!

While there is every reason to be enthusiastic about them, I fear there is a contest going on to find ever more numbers of transboundary aquifers. Global inventories now number them at more than 600, which beats the number of transboundary river basins handsomely!

In my view, a very careful application of the definition of the flow of a particle of water moving across jurisdictions, in a hydrogeologically well-defined aquifer system, may well reduce that huge number to something more modest, and thus make the issue more amenable to serious attention.

Today, academics are busy thinking up possibly peculiar reasons to pursue the topic—I have seen "worrisomeness" and the "transboundariness" as the means to prioritize them. Some are even applying 'game theory' where it has dubious value. I am not looking forward to an academic study of the "wateriness" of transboundary aquifers! I also fear the recent global trend of increase in nationalism, isolationism and construction of walls and barriers between countries put the benefits of past collaboration at risk.

Back to the future

Spielberg's use of Petra in his film has also immortalized the Rum Formation and its geoengineering properties, allowing every budding geologist to fully

Photo 2. Petra, Jordan—rock carvings attributed to the Nabatean civilization. (Photo credit: Shaminder Puri)

grasp the lithology and petrology of the part of the sandstone sequence that is a huge groundwater reservoir, which enables Jordan to face up to its chronic water scarcity.

The Rum-Saq transboundary aquifer system (see photos 3 and 4) was replenished in the last pluvial and receives minimal contemporary recharge. Jordan and Saudi Arabia have made a treaty agreement to collaborate over these shared resources. There is full recognition that in due course all exploitable water may be exhausted from the aquifer. Jordan has commenced an investment program to desalinate water from the Red Sea, transfer the brine to the Dead Sea, and then use the treated water to replace exhausted aquifers. Israel and the Palestine Authority are also collaborating on this endeavour.

Today, the Rum-Saq aquifer delivers 100 MCM/y (~ 81,000 acre-feet per year) of potable water to northern Jordan. In Saudi Arabia, the same aquifer delivers nearly seven times that volume for Saudi needs. The forecast is that resources in this transboundary aquifer system will be available for 200 years.

It is my good fortune continue work on this aquifer, helping put more science into the strategic management of the valuable Rum-Saq transboundary aquifer, a true hidden treasure! ■

Photo 3. Pump testing in the new well field in the Rum-Saq aquifer of southern Jordan. (Photo credit: A. Andruszkiewicz)

Shaminder Puri has been the chair of the IAH Commission on Transboundary Aquifers since 1997 and co-coordinator of the IAH-UNESCO ISARM Programme since its launch in 2000. He has worked on most of the major transboundary aquifers of the world, and has in-depth descriptive, well drilling, modeling and strategic development knowledge of the Rum-Saq Aquifer System. Puri was awarded the 2015 Presidents' Award from the IAH in recognition of his global work on transboundary aquifers. Contact: ShammyPuri@aol.com.

Photo 4. Deep well drilling is a complex operation—55 wells to 600m (almost 2000 feet) depth and nine piezometers, have been drilled into the Rum-Saq aquifer wellfield in Jordan. (Photo credit: Shaminder Puri)

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

Sharon B. Megdal

Membership 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

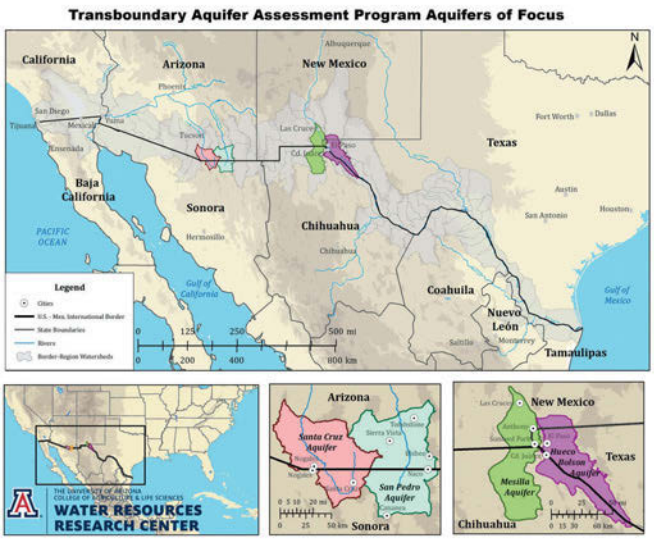


Figure 1. TAAP focus aquifers.

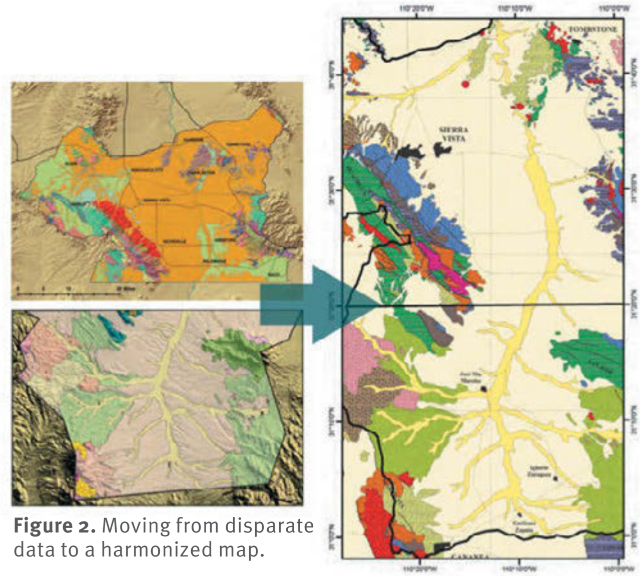


Figure 2. Moving from disparate data to a harmonized map.

own studies when such are limited to one side of the border.

The Six Principles of Agreement follow:

1. Activities described under this agreement should be beneficial to both countries.
2. Aquifers to be jointly studied, as well as the scope of the studies or activities to be done on each aquifer, should be agreed upon with the framework of the IBWC.
3. The activities should respect the legal framework and jurisdictional requirements of each country.
4. No provisions set forth in this agreement will limit what either country can do independently in its own territory.
5. Nothing in this agreement may contravene what has been stipulated in the Boundary and Water Treaties between the two countries.
6. The information generated from these projects is solely for the purpose of expanding knowledge of the aquifers and should not be used by one country to require that the other country modify its water management and use.

Importantly, the last principle states that this program is about transboundary aquifer assessment, not management. There is much global interest in governance and management of transboundary groundwater. The international legal community and others have for some time been advocating for UN adoption of the 2008 Draft Articles on the Law of Transboundary Aquifers (Draft Articles). The Cooperative Framework is consistent with two important provisions of the Draft Articles. Both "Article 7, §2: General Obligation to Cooperate" and "Article 8, §2: Regular exchange of data and information" speak to the desirability of cooperative study.

The TAAP is, by definition and design, about assessment, not management. Developing a common understanding of aquifer conditions can be seen as a first step to efforts to explore binational governance and management. Disagreement about groundwater conditions is likely to lead to different perspectives on approaches to groundwater management. Because it is beyond the scope of TAAP responsibility, the expert team has been silent on the prospects for binational groundwater management along the U.S.-Mexico border. Instead, the TAAP team has focused on expanding shared knowledge and understanding.

Since 2009, the Cooperative Framework has facilitated successful completion of the San Pedro Study, with completion of a similar study for the transboundary Santa Cruz aquifer in progress. The San Pedro Study includes harmonized maps and chapters on: physical geography; hydrography and hydrometeorology; conceptual geologic model; piezometry and hydraulic parameters; hydrogeology; hydrogeochemistry; and a conceptual model for hydrodynamic behavior. Conclusions and recommendations complete the report. Figure 2 provides an example of how the team moved from disparate data to a harmonized map. All text and all maps appear in English and Spanish. A six-page informational bulletin has also been prepared in English and Spanish.

Researchers and government officials have worked under uncertain funding conditions. The scientific results and the strong working relationship of the team members reflect respect for the Cooperative Framework – and for each other. Binational efforts are continuing for the other TAAP aquifers of focus. Carrying out technical assessments across differing languages, cultures, physical conditions, and units of measure is never easy. The approach of the TAAP Cooperative Framework will continue to guide our work and can serve as a model framework for other transborder studies.

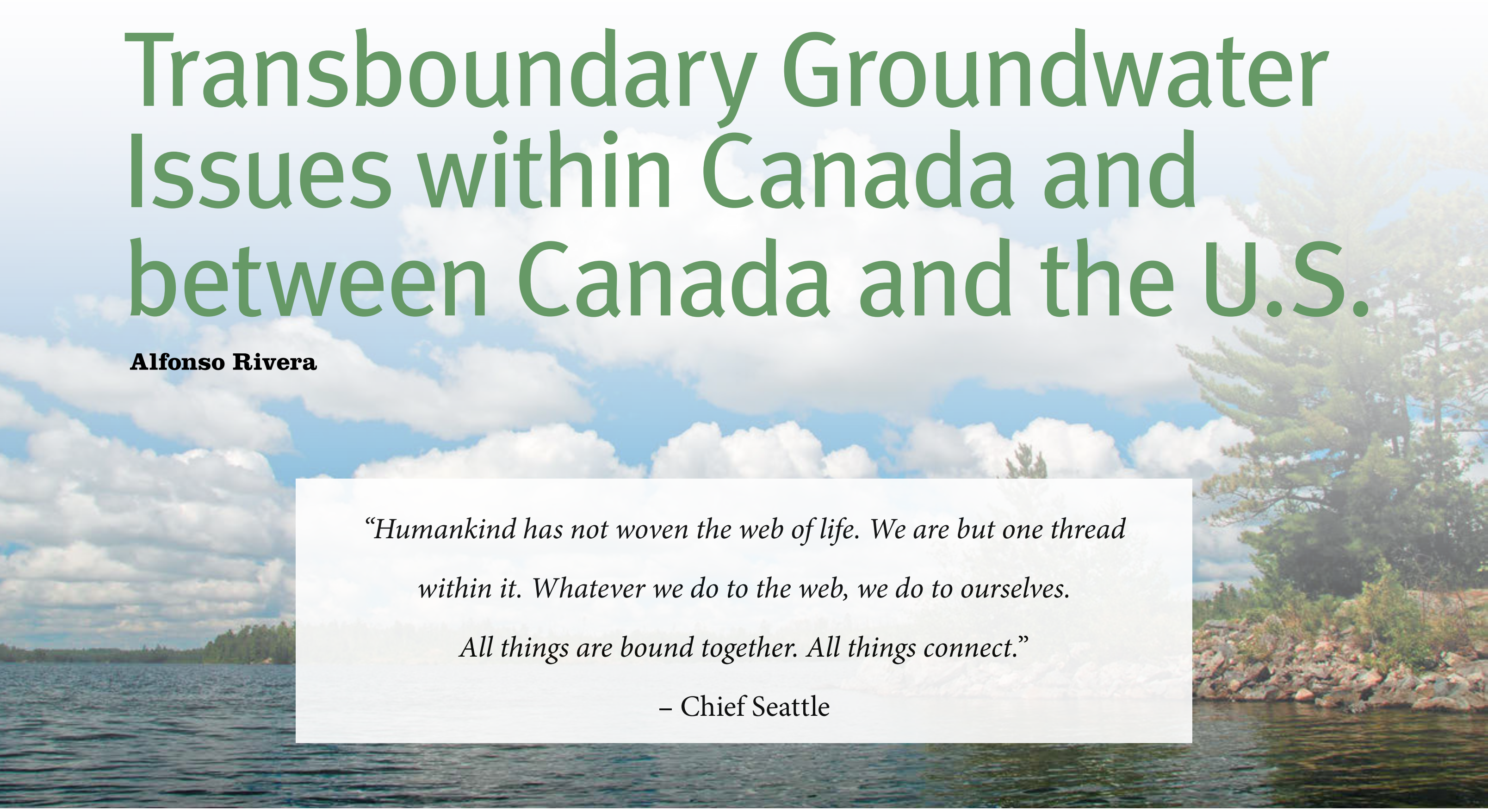
The Cooperative Framework, a link to the San Pedro Report, and other information on TAAP history and activities, particularly for the Arizona-Sonora transboundary aquifers, can be found at http://wrrc.arizona.edu/TAAP. ■

Sharon B. Megdal is professor and specialist, Department Soil, Water and Environmental Science, C.W. & Modene Neely endowed professor, and distinguished outreach professor. Her public service includes serving on the AWRA Board and the boards of the Central Arizona Project, the Universities Council on Water Resources, and the International Arid Lands Consortium. Contact: smegdal@email.arizona.edu.

FEATURE

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

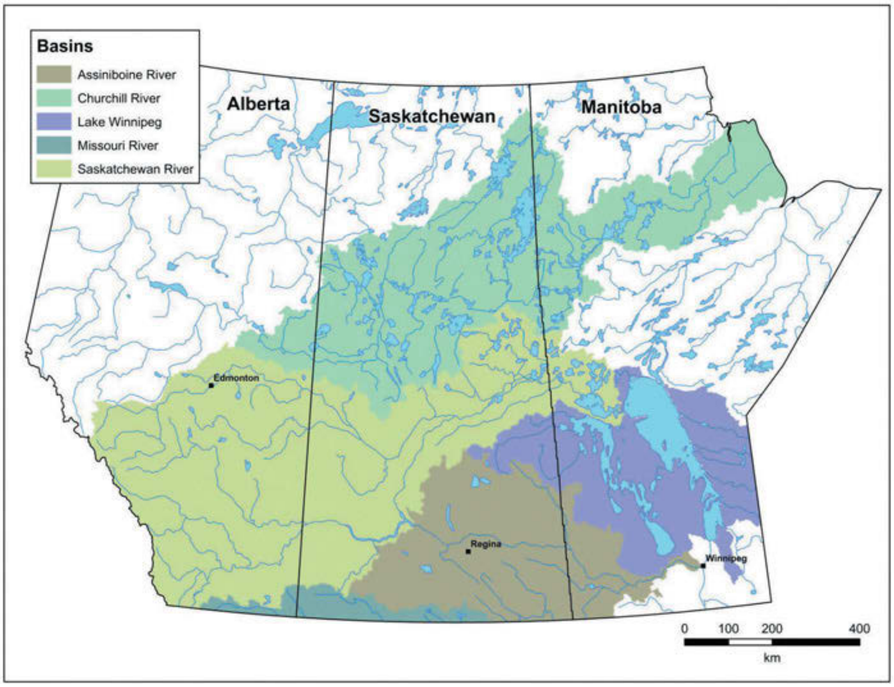


Figure 1: The Prairie Province river basins and monitoring stations: three provinces.

that the Milk River project involved up to eight jurisdictions: First Nations on both sides of the international border, counties and municipal districts, one province and one state and the two federal governments.

Interprovincial issues

Some provinces in Canada are now moving toward co-governance of watersheds, for instance, this is the case for British Columbia. In 2015 and 2016, the Centre for Indigenous Environmental Resources (CIER) collaborated with the First Nations Fisheries Council of BC (FNFC) to undertake a systematic review (see https://tinyurl.com/y9smk5r8) of Indigenous-led freshwater planning initiatives and co-governance arrangements in BC. The purpose of the research was threefold: to identify capacity gaps, to shape the future of freshwater planning in BC, and to contribute to a new watershed governance regime in the province.

The federal government, through its research agencies, is now being proactive developing mechanisms to help resolve First Nations' natural resources issues. The Geological Survey of Canada (GSC) for instance, is developing consulting mechanisms with First Nations across Canada and schemes for identifying aquifers and characterizing their hydrogeological properties, assessing their sustainability, and protecting groundwater-dependent ecosystems.

The prairie provinces

In central Canada, three provinces (Alberta, Saskatchewan and Manitoba) share four basins and nine transboundary aquifers (Figures 1 and 2). Five of these cross provincial boundaries and four the international boundary.

The Prairie Provinces Water Board (PPWB) is the body that oversees the sharing of water between the three provinces under the "Master Agreement on Apportionment," which was adopted and signed by all parties in 1969. The Agreement (PPWB, 2018) was signed by the governments of the three provinces and Canada in 1969 to ensure the equitable apportionment and protection of eastward flowing interprovincial streams. The agreement defines the apportionment of these streams and provides water quality objectives at the provincial boundaries; it also provides for the cooperation of the parties in interprovincial water management.

The respective provincial agencies are responsible for managing groundwater resources within their provinces. The PPWB deals with interprovincial groundwater concerns through its permanent Committee on Groundwater (COG). Thus, the COG's main area of responsibility is to advise and make recommendations on the management of interprovincial groundwater.

Over the years, the agreement has been revised and amended to respond to new challenges; it was not until April 1999 that the Master Agreement added groundwater as a sub-heading of water quality. Groundwater issues can be referred and reviewed by the Board,

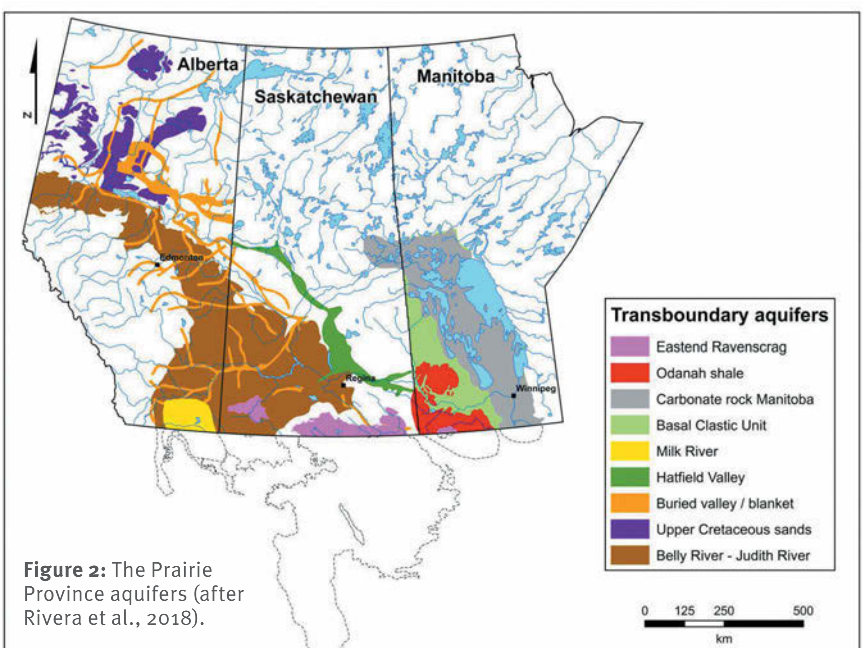


Figure 2: The Prairie Province aquifers (after Rivera et al., 2018).

which can then make recommendations on how to address transboundary issues.

Agreement 6.1 specifically reads: "The parties mutually agree to consider groundwater matters that have implications affecting transboundary surface and groundwater, to refer such matters to the Board, and to consider recommendations of the Board thereon."

Until now, however, no issues have been raised and there are no specific publications on the identification and/or assessment of transboundary aquifers shared by the Prairie Provinces. Figure 2 is the first attempt to identify and delineate the transboundary aquifers based on current knowledge of hydrostratigraphy following Rivera *et al.* (2018); the map includes interprovincial as well as international transboundary aquifers.

The PPWB is currently in the process of adding a new schedule to its water sharing agreement specifically relating to the sharing and quality of groundwater in transboundary aquifers. This proposed agreement will be the first of its kind in Canada.

The Mackenzie Watershed

In northern Canada, three provinces and two territories (BC, Alberta, Saskatchewan, Yukon and the Northwest Territories) share the Mackenzie River Watershed and many tributaries, as well as three bedrock transboundary aquifers. There may be other unconsolidated aquifers, but these have not been mapped yet. Figure 3 shows the Mackenzie Watershed with the bedrock aquifers located within the watershed; these were extracted from the Canada map proposed by Rivera *et al.* (2018).

There are no agreements for transboundary aquifers located among the five jurisdictions sharing the Mackenzie Watershed. The only agreement in effect is the Mackenzie River Basin Transboundary Waters Master Agreement, issued in 1997.

The agreement commits all five governments (plus the government of Canada) to work together more closely to manage the water resources of the whole Mackenzie River Basin. The agreement is founded on four guiding principles for cooperative management: 1) equitable utilization; 2) prior consultation; 3) sustainable development; and 4) maintenance of ecological integrity.

The agreement makes provision for neighboring jurisdictions to negotiate bilateral water management agreements to address water issues at jurisdictional boundaries on transboundary streams and to provide parameters on the quality, quantity and flow of water. The agreement also includes a section on Aboriginal and Treaty Rights.

It is only until very recently that two of those jurisdictions became interested in aquifers that may cross the boundaries of their jurisdictions. British Columbia (BC) and the Northwest Territories (NWT) are now in the planning process to identify and map those aquifers.

To that end, the GSC is collaborating with the NWT and BC in gathering and sharing available information on aquifers in the region, in particular aquifer mapping in transboundary areas in the Liard Basin, the Hay River Basin and the Peel Basin.

The map of Figure 3 shows preliminary results of potential transboundary bedrock aquifers located in the region; there is also good potential for Quaternary unconsolidated aquifers in the area composed of sands, gravels, till, silts and clay. However, at this point no map of Quaternary sediments has been produced.

Transboundary groundwater is excluded in the MRB Agreement, except where the Parties to a Bilateral Water Management Agreement agree to its inclusion (Part B, Definitions).

As for the Prairie Provinces region, gathering baseline data and information, identifying, mapping and assessing transboundary aquifers is a first and important step in shared management and dispute resolution.

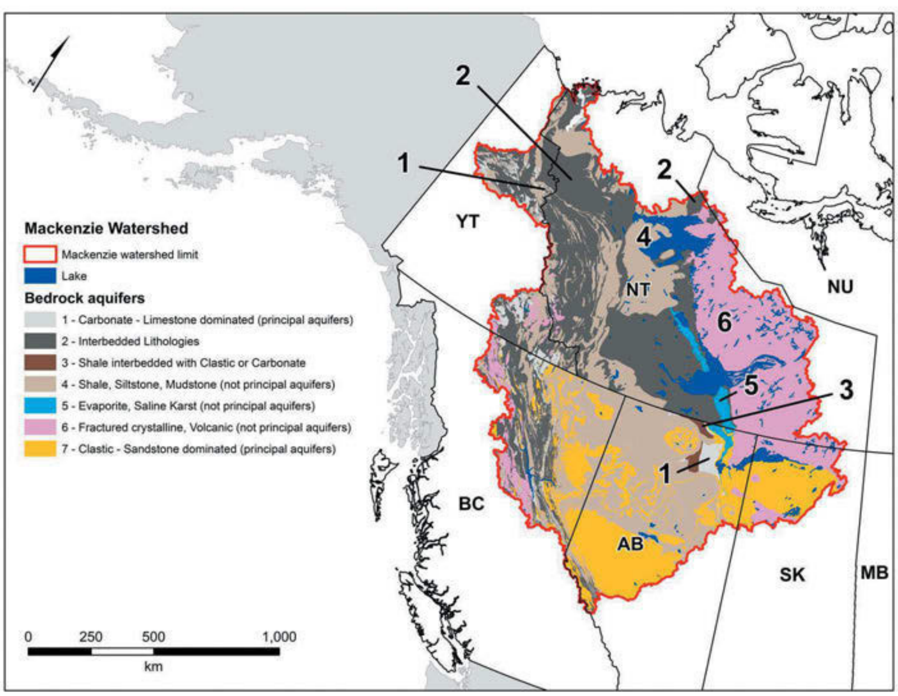


Figure 3: The Mackenzie watershed and potential aquifers (after Rivera et al., 2018).

Canada-U.S. transboundary aquifers

Canada and the United States share one of the largest international jurisdictions in the world with about

8,000 km (5,000 miles) of border, and more than 20 million Canadians living in watersheds and aquifers that cross that border (more than 17 million reside in the Great Lakes-St. Lawrence watershed).

Canada's interest in transboundary groundwater issues has sharply increased in recent years. Since 2005, Canada has followed international developments in transboundary groundwater issues in cooperation with its southern neighbor within the Internationally Shared Aquifer Resources Management (ISARM) Initiative of UNESCO. As a result, 10 Transboundary Aquifer Systems (TBAs) were identified along the border between Canada and the United States (Figure 4). Rivera (2015) provided an extensive review of the current state of the 10 TBAs, concluding among other things that documentation of scientifically-based knowledge on TBAs was an important step in identifying potential issues in policies that might be adopted to address shared water resource issues.

Since then, cooperation between the two countries and between provinces and states has increased as exemplified by the recently published assessment of the Milk River transboundary aquifer (see https://tinyurl.com/y9ezh5qu) traversing Alberta (Canada) and Montana (United States).

There are hundreds of wells that extract groundwater from shared aquifers located on both sides of the border, but there are no formal legally-binding agreements in any of the 10 TBAs identified. Only four of the 10 TBAs have been fully mapped and their hydrodynamics partially assessed; furthermore, it is likely that other TBAs are yet to be identified.

Disputes about water bodies that span or cross the Canada-United States border can challenge sustainable groundwater management. Recent disputes involving surface water illustrate the variety of issues that might arise, such as the introduction of alien species in the Garrison Diversion project and the Devils Lake disputes between Manitoba and North Dakota; the transboundary pollution in the Flathead River originating from a proposed coal mine in British Columbia and flowing into Montana; the mine and energy development proposals that threaten wilderness areas in the Taku and Iskut-Stikine watersheds in British Columbia and Alaska; and the continuing pollution and water-level problems in the Great Lakes.

To date, transboundary groundwater tensions have been more rare than surface water disputes in Canada-U.S. relations.

In issues regarding transboundary groundwater, clear communication, shared knowledge and common objectives in the management of TBAs will help prepare the provinces and the two neighboring countries for future negotiations and cooperative interprovincial and binational programs. ■

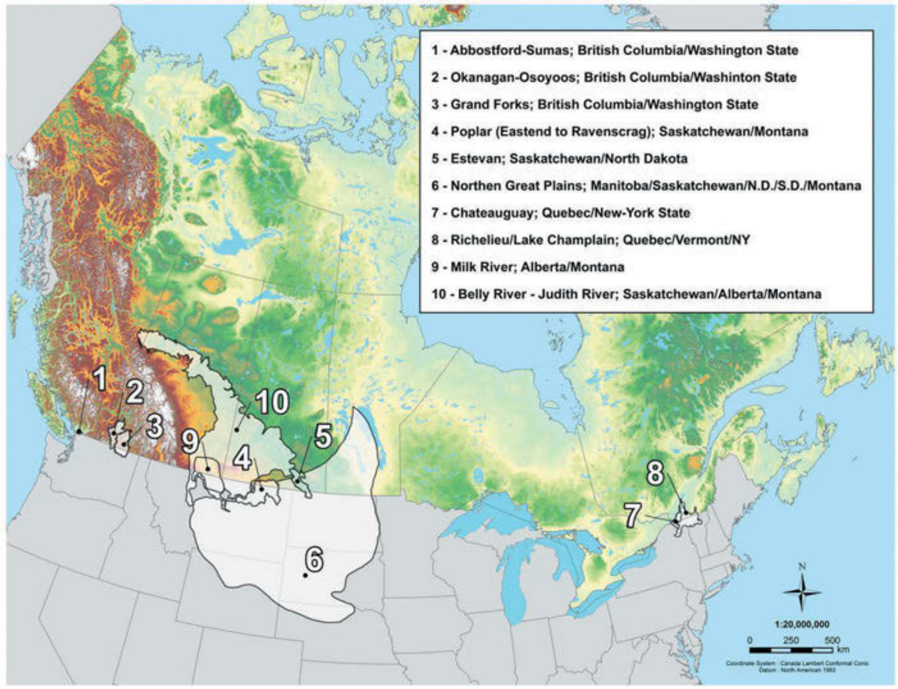


Figure 4: Transboundary aquifers located along the Canada/USA international border (Rivera, 2015).

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

Noah D. Hall

BY TINNAPORN SATHAPORNNANONT/SHUTTERSTOCK.COM

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.

But Mississippi instead claims that Memphis' pumping for municipal supply has "wrongfully converted" groundwater within Mississippi's territory that it claims to own with absolute right, title and exclusive possession. In deciding this case, the U.S. Supreme Court will likely shape the future law of transboundary groundwater.

The Sparta-Memphis Aquifer sits in northwest Mississippi and southwest Tennessee and is part of the Mississippi Embayment aquifer system, a sedimentary basin that reaches across nine states in the south-central United States. The city of Memphis and its utility MLGW are located in Shelby County, Tennessee, along the border of Mississippi and Arkansas. Memphis began withdrawing groundwater from the aquifer for municipal use in 1886, and the aquifer has thus supplied drinking water throughout the region for more than a century. MLGW provides drinking water to over 257,000 customers, relying solely on groundwater (the Sparta-Memphis Aquifer) as its source of drinking water. Among United States municipalities, Memphis is the largest city to rely solely on groundwater for its municipal supply. San Antonio, Texas, formerly held that distinction but now derives some of its supply from surface water.

Groundwater withdrawals from the Sparta-Memphis Aquifer in Shelby County have grown dramatically over time, in line with population growth in the region. Between 1886 and 1975, groundwater withdrawals increased from fewer than about 10 million gallons (38,000 cubic meters, or 30 acre-feet) to over 179 million gallons (681,000 cubic meters, or 550 acre-feet) per day. Over the next 20 years, from 1975 to 1995, withdrawals plateaued, averaging almost 166 million gallons (628,000 cubic meters, or 510 acre-feet) per day. By 2005, however, withdrawals increased again to over 187 million gallons (710,000 cubic meters, or 575 acre-feet) per day.

Mississippi alleges that Memphis has for decades pumped water at rates much higher than that of the aquifer's "natural seepage rate," and thus made permanent, harmful changes to a vital source of groundwater to the state. Mississippi maintains that the extensive pumping to supply water to Memphis has allegedly diverted water from "Mississippi's portion" of the Sparta-Memphis Aquifer.

In June of 2014, Mississippi took its case to the Supreme Court—and not for the first time, but after numerous rejections, Mississippi's persistence apparently paid off. Mississippi argued that it has sovereign ownership of the water being drawn from the Sparta-Memphis Aquifer. Based on this claim of sovereign ownership, Mississippi argued that the pumping of groundwater by (and allowed by) the state of Tennessee, the city of Memphis, and MLGW is tantamount to conversion (the wrongful taking of one's property). Mississippi claims that when it was admitted to the Union in 1817, it "became vested with ownership, control and dominion over the land and waters within its territorial boundaries." Mississippi thus contends that Tennessee's pumping of groundwater that in its natural state would remain in Mississippi violates Mississippi's "retained sovereign rights under the United States Constitution" and "constitute[s] . . . trespass upon, and conversion, taking and misappropriation of, [Mississippi's] property." As relief, Mississippi requests "a declaratory judgment establishing Mississippi's sovereign right, title and exclusive interest in the groundwater stored naturally in the Sparta Sand formation underlying Mississippi," along with $615 million in damages for water already taken.

The United States, through its Solicitor General, has sided with Tennessee in urging the U.S. Supreme Court to simply apply equitable apportionment as it would for any other shared transboundary resource, from a river to migratory salmon. After taking the case, the Supreme Court appointed a Special Master (a common procedure in interstate water disputes)—the Honorable Eugene E. Siler, Jr., who served on the Sixth Circuit Court of Appeals and was formerly a district court judge in Kentucky. Judge Siler, as an initial matter, has taken evidence on whether the aquifer is an "interstate resource." This may help frame the more fundamental legal question, whether the aquifer should be treated as a shared resource or the property of a state.

As important as this case (and the aquifer itself) are for the parties and especially the residents of Memphis, the impact and implications could be far more significant. If the U.S. Supreme Court sides with Tennessee and applies equitable apportionment to the aquifer, it will harmonize interstate groundwater law with a century of established interstate surface water law. Having the same rules for groundwater and surface water (which are often connected) makes practical and legal sense. Further, equitable apportionment and the general rule of sharing help encourage and frame cooperative interstate water management. Once states are faced with the legal reality of compromise, they often find better ways to use shared resources for all interests.

Conversely, Mississippi's argument of absolute ownership would undermine efforts to manage groundwater in conjunction with connected surface water, setting the law way behind current science. Mississippi would bring back the legal fallacy that groundwater is isolated, mysterious and too unknown to manage. But most troubling, Mississippi would reduce a shared flowing transboundary resource to the fiction of owned property. With states claiming absolute ownership of groundwater, there would be little incentive to cooperate in the management of these shared water resources.

These issues are all before the U.S. Supreme Court as it weighs the future of interstate groundwater law. The decision could also have international implications as well, since U.S. Supreme Court rulings often carry weight beyond U.S. borders. ■

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FEATURE

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

Rosario Sanchez

Defining 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 most important finding of the transboundariness approach: aquifers located across political boundaries are addressed, evaluated and treated in a unique matter. Methodologies and criteria do not necessarily follow national or state standards, but rather those agreed upon at a negotiation table where usually more than just water is considered.

Recently, this approach was applied to the identified hydrogeological units between Mexico and Texas (Sanchez *et al.* 2018b) and a prioritization scheme was proposed (see Figure 1). Results from this research offer interesting insight into the characterization of aquifers located on national frontiers.

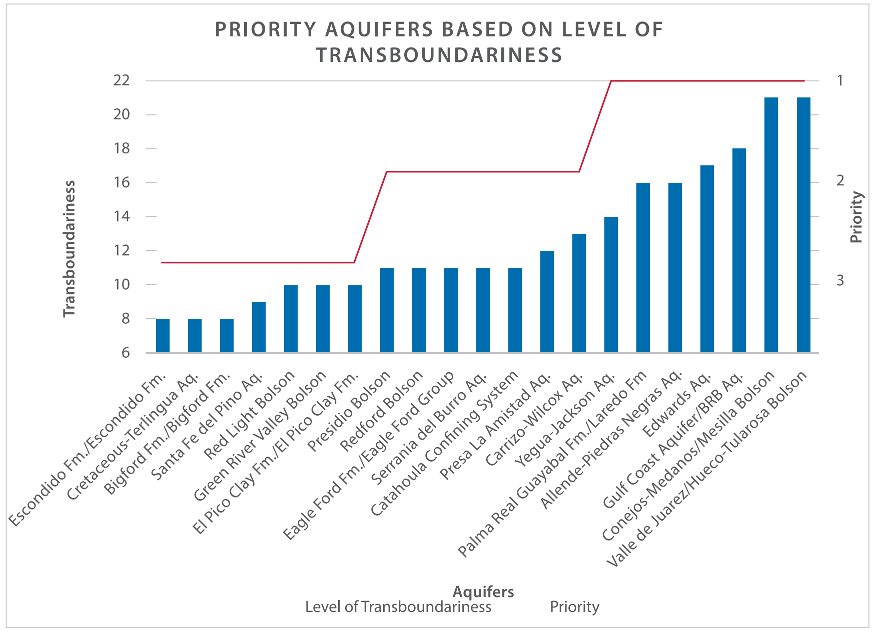

Figure 1. Transboundariness and Priority of Transboundary Aquifers (Sanchez et al. 2018b) Left vertical axis indicates level of transboundariness according to seven proposed criteria measured on a scale from 1 to 3, with 1 being the lowest and 3 the highest. Maximum level of transboundariness is 21 and minimum 7.

First, the level of transboundariness correlates with the current level of attention given to those priority aquifers identified by the Transboundary Aquifer Assessment Program (TAAP—see article by S. Megdal in this issue), which is not surprising. However, that same level of first priority was also given to the Allende-Piedras Negras aquifer, Laredo Formation, the Yegua-Jackson aquifer and the Carrizo-Wilcox aquifer. While none of these aquifers has been recognized as transboundary by Mexico or the United States, their level of transboundariness can foresee changes in the binational agenda.

The second level of prioritization was given to those aquifers with significant level of transboundariness, but not as high as the first priority level. Aquifers with particular and unique geostrategic elements were identified in this second level: Presidio Bolson, Redford Bolson, Eagle Ford Formation, Serrania del Burro aquifer, Catahoula Confining System and Presa la Amistad aquifer. The importance of this ranking relies on its capability to highlight the socio-economic local dimensions that determine significant groundwater resources—the local dimensions of the aquifers' groundwater productivity. The Presidio and Redford bolsons are the only source of water for local communities and the Eagle Ford has additional value as a shale gas producer. The same logic applies to the Serrania del Burro aquifer, which feeds springs in a region highly dependent on groundwater.

The Presa La Amistad aquifer has an additional security element due to its connection with surface water committed to fulfill Mexico's obligations under the 1944 Water Treaty. The Catahoula Confining System has water quality and groundwater productivity challenges.

None of the above aquifers is recognized as a transboundary aquifer by Mexico or the United States, and yet there is evidence indicating hydrogeological connectivity on both sides of the border. What evidence and information do we need to consider an aquifer that underlies a border region to be transboundary? Answers vary, and it is precisely that variation that transboundariness is able to identify and measure.

The concept of transboundariness has the potential to offer an alternative approach for assessing aquifers in the region where two or more international political jurisdictions meet and where the variable conditions of the overlying communities and its linkages with groundwater can actually be measured. This effort, by itself, relieves pressure from the technical aspects and opens the discussion for a more integrative perspective where the physical boundaries of the aquifer become more a societal extension of local and national priorities. Whether or not this reality adds complication to the water negotiation process, water borders (surface water or groundwater) have never been more flexible and powerful as determining factors of national priorities as they are today. ■

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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 pracademics because it moves beyond the tired and overused cliché of agreeing to disagree.

What are the best approaches to negotiations regarding groundwater

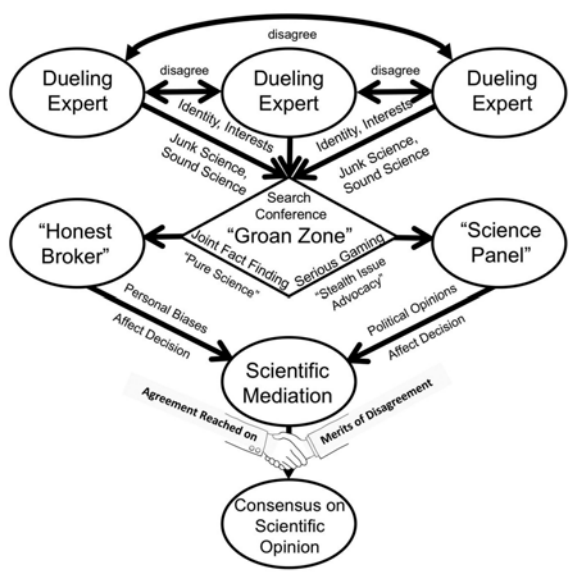

Figure 1. Scientific Mediation Framework. Modified after Moore et al. (2015).

Game	Situation	Year	Developed By
Water on the West Bank Role Play	Water well siting, aquifer depletion	1988	Harvard Program on Negotiation
Managing Groundwater beneath the Pablo-Burford Border Role Play	Agriculture water quantity and quality across borders	1996	Harvard Program on Negotiation
Santiago Board Game	Diversion of spring water to canals for plantations	2003	AMIGO Spiel
International Groundwater Negotiation Role Play	Hydraulic connection to a transboundary water resources	2007	FAO training manual for international water-courses/river basins including law, negotiation, conflict resolution and simulation training exercises
Tragedy of the Groundwater Commons Computer Assisted Role Play	Hydrogeologic capture analysis and economics of pumping wells between many well owners and a lake	2013	International Groundwater Resources Assessment Centre (IGRAC)
Groundwater Protection Dueling Expert Role Play	Wellhead protection and aquifer protection boundaries across the urban/rural divide	2014	Contesting Hidden Waters: Conflict Resolution for Groundwater and Aquifers
California Water Crisis Board Game	Groundwater use and depletion across three regions for agriculture, ecosystems, and urban growth	2014	Firstcultural Games
The Edwards Aquifer Case Role Play	Groundwater, common law rule of capture, Endangered Species Act, and role of science	2016	The Program for the Advancement of Research on Conflict and Collaboration (PARCC), Maxwell School of Citizenship and Public Affairs, Syracuse University
Save the Water Board Game	Agriculturists struggle with profitable cropping and groundwater depletion	2017	Zurich University of the Arts (ZHdK) with ETH Zurich

Table 1: List of Serious Groundwater Games

and related aquifers? In addition to the use of "search conferences" and "joint fact finding" described by Moore *et al.* (2015), serious games are a useful approach to addressing the "groan zone" that groundwater conflicts and negotiations enter regardless of the scale of the conflict (see Figure 1). Serious games in one form or another are incorporated into nearly all international water negotiation frameworks and trainings described in the literature (Hockaday *et al.*, 2017). The games can be an interactive, realistic virtual environment in which players attempt to simultaneously "juggle" growing food, growing cities, sustain the environment and make a profit. They come in many forms, ranging from role plays, board games, computer-assisted board games and online games. And there are games that are exclusively about gaming groundwater situations developed over the past 20 years (see Table 1).

Serious games provide an opportunity to make friends out of enemies through casual conversation and to learn about negotiating over water. Hockaday *et al.* (2017) suggest the social learning in gaming brings common ground between diverse players and stakeholders, who may otherwise be unable to cooperate with each other. Groundwater practitioners can begin to find the fun around water that inspired them to pursue studies and careers in groundwater once again through serious gaming. ■

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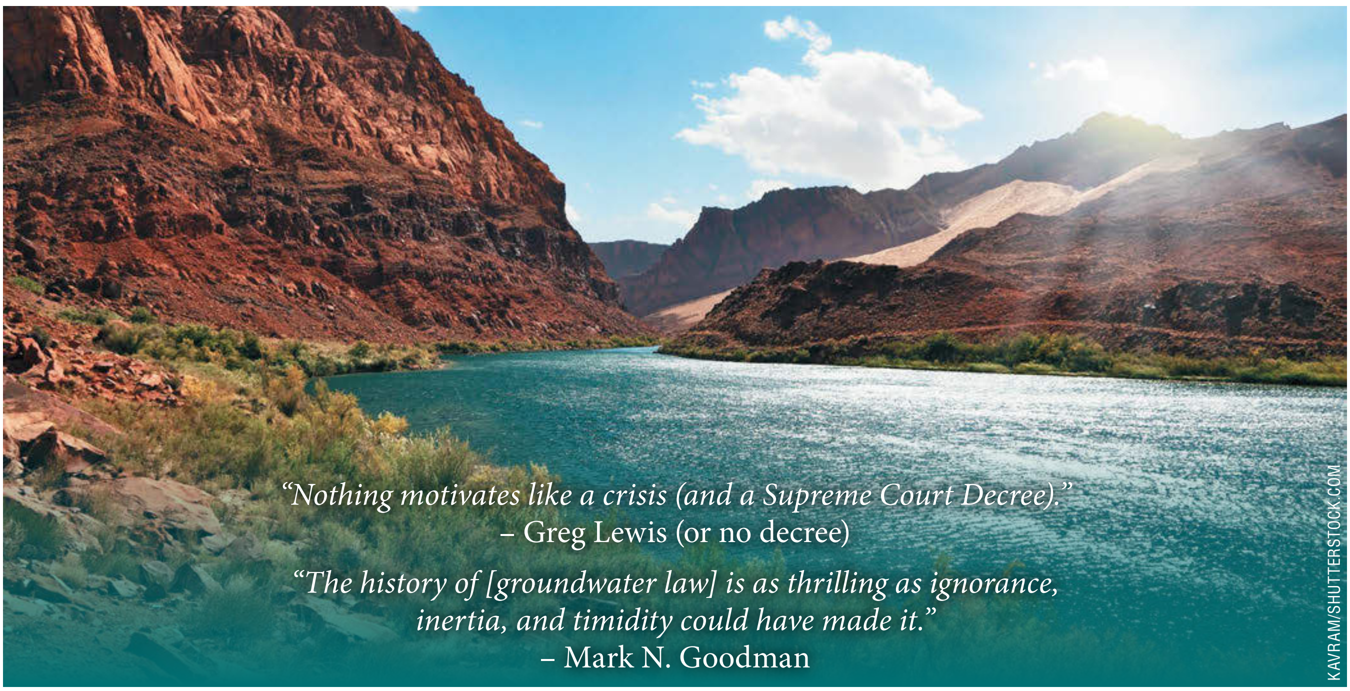
The *Winters* Doctrine Goes Underground

Michael E. Campana



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.

Supreme Court declined to hear the case, so the Ninth Circuit Court's decision stands. At this juncture the decision applies only to the states covered by the Ninth Circuit: Alaska, Hawaii, Washington, Idaho, Oregon, California, Nevada, Arizona and Montana.

Why is this decision important? Ten states—Nevada, Arizona, Idaho, Nebraska, Arkansas, Wyoming, North Dakota, South Dakota, Texas and Wisconsin—filed an *amici curiae* brief supporting the water agencies' position. This action indicates the concern the states have about the ramifications of this decision vis-a-vis their primacy when it comes to water law and allocation of water within their borders. Groundwater underlying tribal reservations could be treated as a transboundary resource subject to water law different from the state's water law.

Furthermore, two aspects of the case are still being litigated—the tribe's claim to ownership of its aquifer's pore space (storage) and degradation of its groundwater quality by the water agencies' use of inferior Colorado River water to recharge an aquifer they share with the tribe.

The pore space issue is particularly important, since, should the tribe prevail, ownership of pore space might interfere with states' or water agencies' efforts to implement managed aquifer recharge (MAR) projects, since the water might enter pores owned by tribes and possibly pollute the tribes' groundwater. It should be noted that the Coachella Valley Water District implements MAR. Its Thomas E. Levy Groundwater Replenishment Facility graced the cover of the September 2017 *Water Resources IMPACT*. I suspect that its use of Colorado River water might be a reason for the tribe's water quality complaint.

Pore rental or purchase might be available in future water banks.

The aforementioned case is most decidedly a transboundary groundwater case—tribal v. water agencies, or districts, or states or...

For further information and the sources I used for this article, check out these two brief Congressional Research Service publications: *Federal Reserved Water Rights and Groundwater: Quantity, Quality, and Pore Space* by Peter Folger (https://tinyurl.com/ya2rvgs5) and *Supreme Court Declines to Review Ninth Circuit Decision Applying Federal Reserved Water Rights Doctrine to Groundwater* by Alexandra M. Wyatt (https://tinyurl.com/yd9vmxzq). Both contain far more information than that presented here. Each is only a few pages.

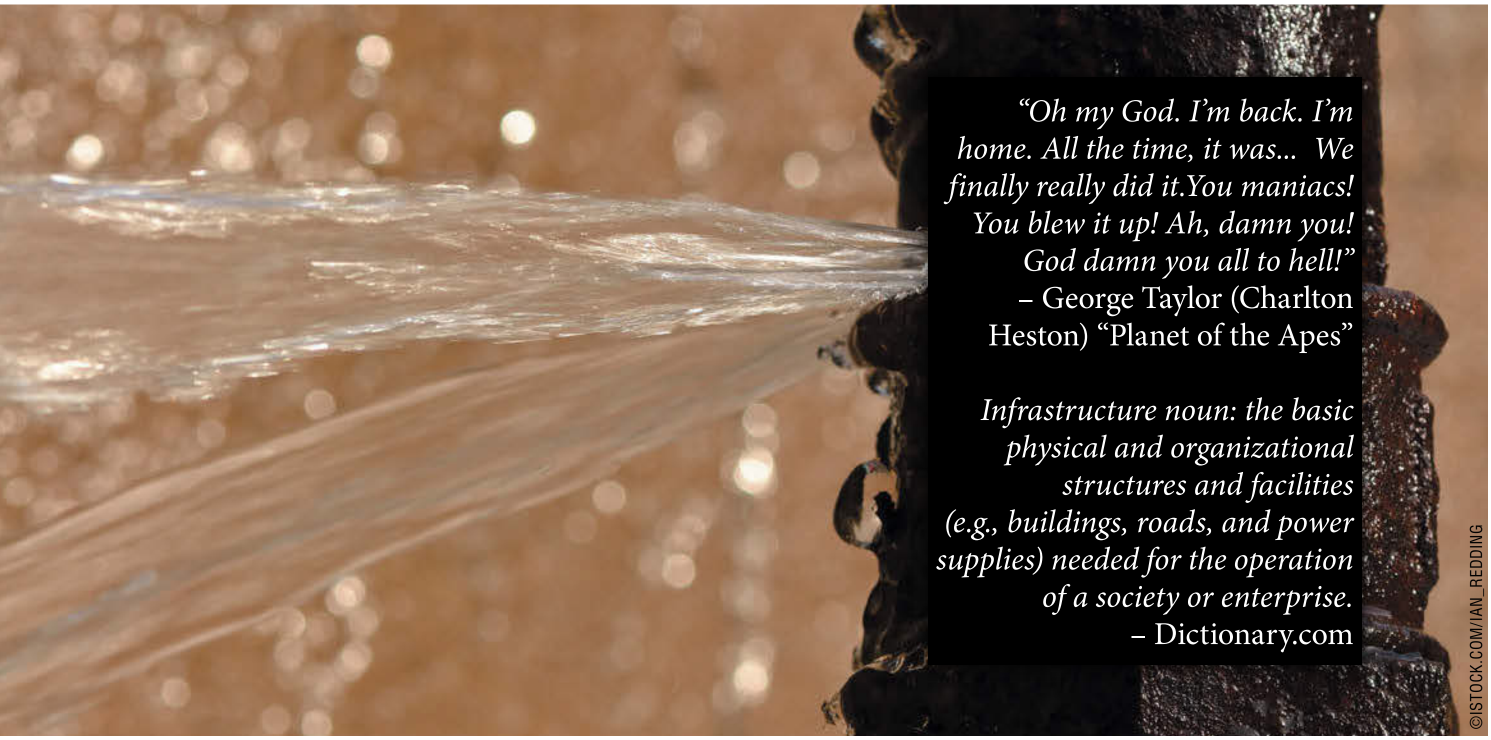
"May you live in interesting times."
– Many sources

One thing is certain: when it comes to groundwater, we are living in interesting times. I look forward to the future. ■

Michael E. Campana is a professor of hydrogeology and water resources at Oregon State University and Technical Director of AWRA. He has 45 years of domestic and international experience in water resources. Campana serves on the Steering Committee of the Global Water Partnership. He tweets @WaterWired and blogs at www.waterwired.org about all things freshwater. Contact: aquadoc@oregonstate.edu.

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 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.

Is the diagnosis for American infrastructure that bad? In the most recent (2017) Infrastructure Report Card produced by the American Society of Civil Engineers (ASCE), necessary investment for all types of infrastructure from 2016 through 2025 is projected to require $4.59 trillion dollars, with a projected shortfall in dedicated funding of $2.064 trillion. These funding projections are with regard to dedicated funding from federal, state and local governments and private institutions. These estimates are based on the premises that: (1) infrastructure be restored/improved to a high enough level of functionality that it meets society's need into the near-term future (next couple of decades); and (2) the system has resilience to respond to impacts of climate change, sea level rise, population increase and increasing demand.

The numbers are no better when water supply and treatment-related infrastructure are considered: wastewater infrastructure earned a D+ and drinking water infrastructure a D. A D/D+ means that the infrastructure nationally is in poor to fair condition and mostly below standard. The system as a whole has significant deterioration and there are ongoing risks of failure both in condition and capacity, and it is far from ready to deal with future needs and challenges. Total funds needed to bring the nation's potable water, stormwater and wastewater systems up to grade over the decade would be $150 billion with a projected shortfall of $105 billion.

From Flint, MI, to Charleston, WV, and across the nation, failures in the systems providing potable water and treating wastewater are dramatically increasing, with more and more Americans left bereft of these essential services. A fact that is representative of how bad the drinking water infrastructure has become is that every day across America, 6 billion gallons of treated water are lost per day before they reach consumers. Things are so bad in parts of Appalachia that there have even been occasions where it has been at least suggested that requests for foreign aid be sent to members of the European Union to gain the funds for essential infrastructure improvements.

Finally, water impoundment, flood control, and navigation infrastructure are in similar dire straits. The ASCE estimates the decadal funding needs for inland waterway and marine ports at $37 billion, with a projected shortfall of $15 billion; dams with a projected need of $45 billion and a shortfall of $39.4 billion and levees with a projected need of $80 billion and a whopping shortfall of $70 billion!

The Trump Administration recently unveiled an infrastructure "plan" which was both wholly inadequate and lacking in sufficient analysis to address the enormity of the problem. Previous administrations have also failed at these tasks. The reality is that the United States, led by the federal government, must soon initiate a New Deal or a Marshall Plan to address these needs. We need to fix our damaged, failing infrastructure. If we don't, then in the not-too-distant future, those in a poorer, weaker, less-great nation may well echo George Taylor's (Charlton Hesston's) anguished cry at the end of the original "Planet of the Apes"—"You maniacs! You blew it up! God damn you! God damn you all to hell!" ■

Eric J. Fitch can be reached at fitche@marietta.edu.

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 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

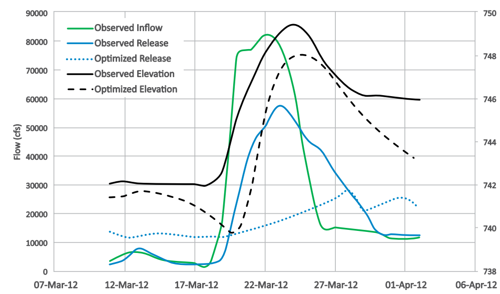
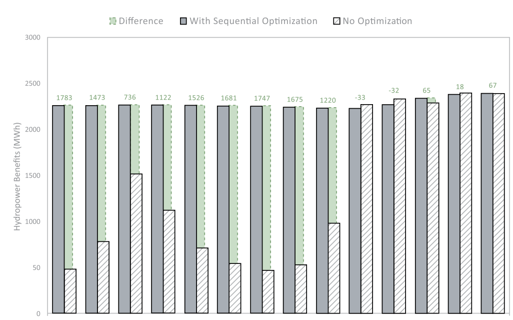


Figure 1. (a) Optimized releases and elevations for Pensacola dam along with the respective observed values using real-time sequential run, updating forecasts every alternate day from 11 March to 17 March (b) Daily comparison of hydropower benefits (MWh) obtained using observed operations (without optimization)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



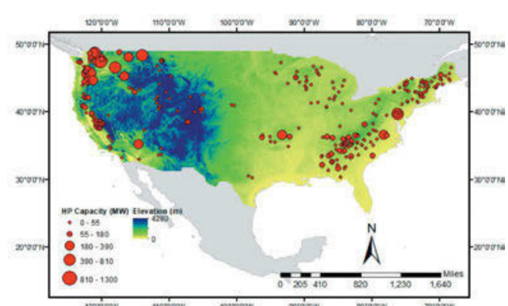
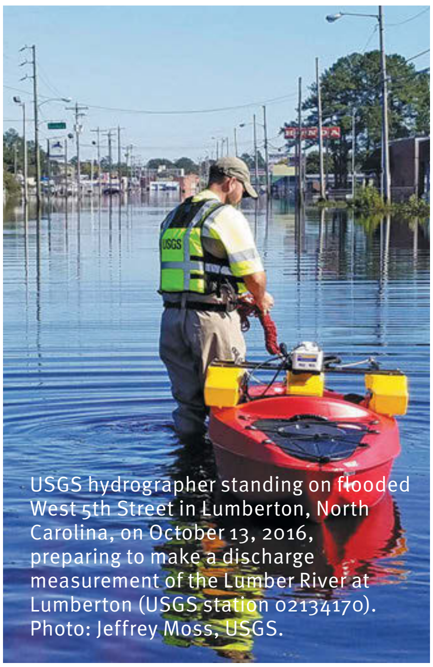


Figure 2. Distribution of small to medium hydropower dams in the US that receive unregulated inflow at upper catchments of river basins. The circle size represents turbine capacity.

GUEST COLUMN

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

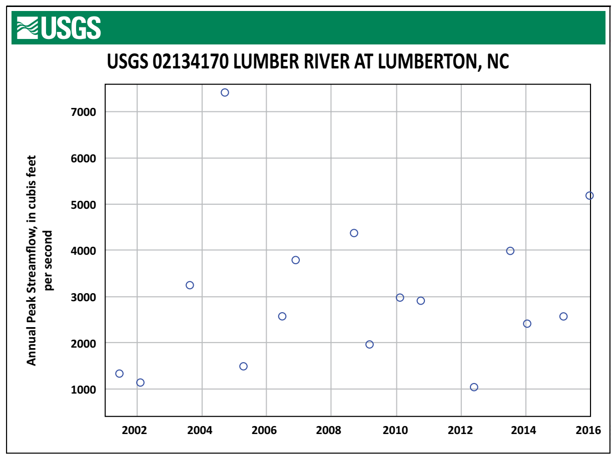


USGS hydrographer standing on flooded West 5th Street in Lumberton, North Carolina, on October 13, 2016, preparing to make a discharge measurement of the Lumber River at Lumberton (USGS station 02134170). Photo: Jeffrey Moss, USGS.

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



Associated peak flow record.

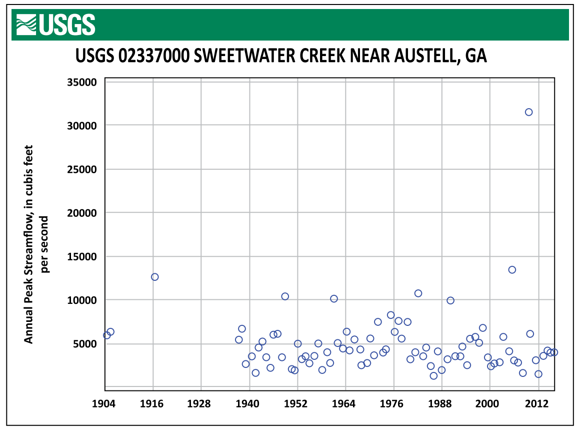
Hydrologists employ flood frequency analysis to generate these estimates of the likelihood of various events, such as the 1% annual exceedance probability flood, often called the 100-year flood. It is imperative that different agencies and engineering organizations generate consistent, reproducible estimates 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:

USGS hydrographers Mark Reynolds and Mark Truhiar measuring flow over 6 lanes of Interstate 20 during a flood event on Sweetwater Creek near Austell, GA (USGS station 02337000, operated in cooperation with Cobb County Water System). (Photo: Alan Cressler, September 22, 2009).



Associated peak flow record.

- Adoption of a generalized representation of flood data that allows for interval and censored data types that can describe historical and paleoflood information;
- The new Expected Moments Algorithm (EMA) that extends the method-of-moments approach for fitting the log-Pearson Type III (LP3) distribution to allow interval and censored data, and simultaneously incorporate regional skew information;
- A generalized approach for identifying multiple potentially influential low floods (PILFs) in a flood record, using the new Multiple Grubbs-Becks test (MGBT);
- A method for correctly computing confidence limits for estimated quantiles with gaged data supplemented by regional skew information, as well as records including zeros, historical information, or below-threshold records; and,
- Improved procedure for estimating regional skew and its uncertainty.

By implementing these new guidelines, agencies will be able to obtain more robust estimates of flood frequency. The most significant implications will be the ability for engineers and scientists to augment traditional streamflow records with diverse sources of flood data, such as: data from paleoflood investigations including those gleaned from sediment deposits and tree scars, as well as observations inferred from nontechnical sources including historical news accounts or diaries. The new methodology also makes better use of regional skew information, one of the descriptors of the LP3 statistical distribution. If there are no historical data, potentially low floods, or interval flood values, the results of flood frequency computations performed following the guidelines set forth in Bulletin 17C are essentially the same as those computed following the guidelines in Bulletin 17B.

Information on USGS regional skew reports, flood frequency examples and software for performing Bulletin 17C analyses is available at https://acwi.gov/hydrology/Frequency/b17c/.

As Robert Hirsch noted in his article in Eos (Hirsch, 2017), many of the statistical advances used in the new federal guidelines would not have been possible without the contributions of Timothy Cohn, one of the key authors of Bulletin 17C and its new methods, who passed away last year. ■

Andrea G. Veilleux is a hydrologist with the U.S. Geological Survey (USGS). As a member of the Analysis and Prediction Branch, she is in engaged in the study of statistical hydrology with an emphasis on flood-frequency analysis. Andrea received her PhD in civil and environmental engineering from Cornell University. Contact: aveilleux@usgs.gov

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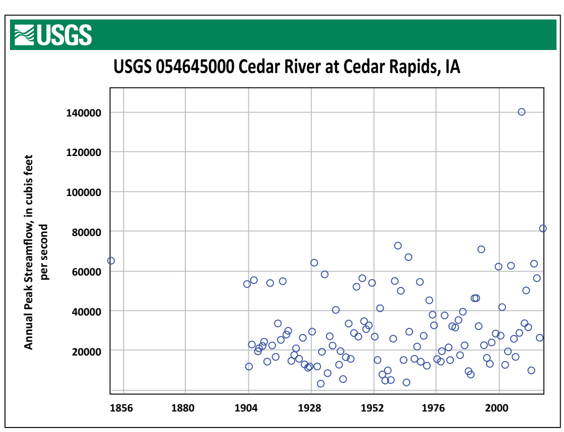
England, J.F. Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas Jr., W.O., Veilleux, A.G., Kiang, J.E., and Mason, Jr. R.R., 2017, Guidelines for Determining Flood Flow Frequency—Bulletin 17C: U.S. Geological Survey Techniques and Methods book 4, chap. B5, https://dx.doi.org/10.3133/tm4–B5/.

Hirsch, R. M., 2017, Timothy A. Cohn (1957–2017), Eos, 98, https://doi.org/10.1029/2017EO076523.

USGS hydrographers Jason McVay and Dillon Wilkins wading through floodwaters to reach the station for inspection during a flood event on the Cedar River at Cedar Rapids, IA (USGS station 05464500). (Photo: Scott Strader, June 12, 2008).



Associated peak flow record.

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, 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 ridgid 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-fact-sheet.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 with questions or concerns. The complete Bylaws of the American Water Resources Association may be found by visiting 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:

- o Quality and sustainability of solutions
- o Ability to build relationships and create consensus among diverse community members and stakeholders
- o 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. 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 with any questions concerning the submittal process.

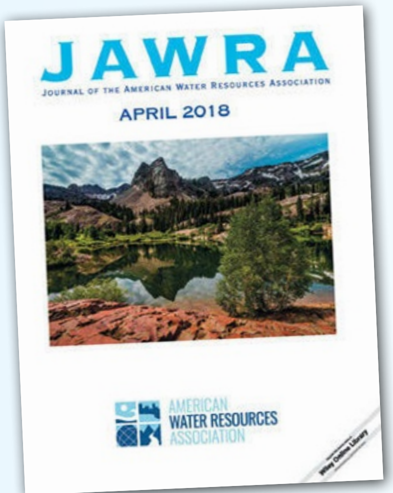
Material submitted must include:

- 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 Southerwestern 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. ■

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flood control, a maximum release of 1620 m^3/s was limited to just 850 m^3/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 ix 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

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References

Ahmad, S K. (2017) Investigating Weather Forecasts for Hydropower Maximization in Small and Medium Storage Dams, MS thesis, Graduate School, University of Washington.

Loucks, D. P., E. Van Beek, J.R. Stedinger, J.P. Dijkman, and M.T. Villars, M. T. (2005). Water resources systems planning and management: an introduction to methods, models and applications. Paris: Unesco.

Miao, Y., X. Chen and F. Hossain. (2016). Maximizing hydropower generation with observations and numerical modeling of the atmosphere. *Journal of Hydrologic Engineering*, 21(6), 02516002.

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

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

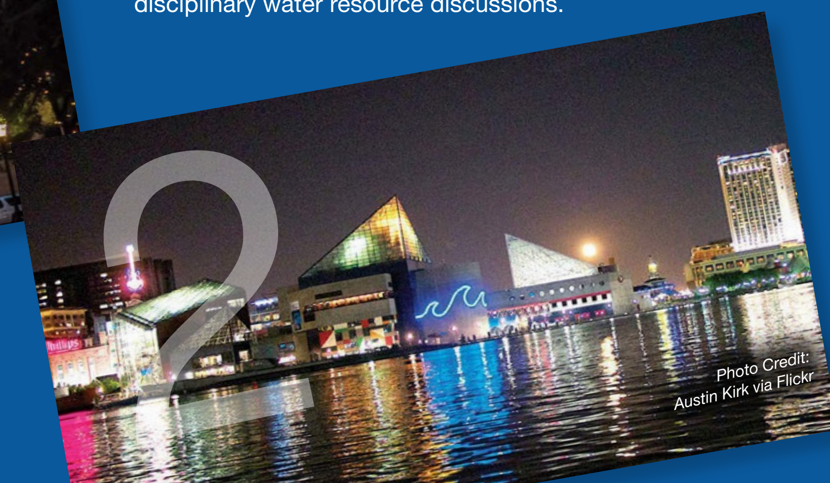
November 4-8, 2018

SuperSaver Discount Registration Deadline: September 4, 2018

www.awra.org

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.



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