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MANAGING AQUIFERS FOR STORAGE

AQUIFERS AS EXTENSIONS OF SURFACE RESERVOIRS
IMPLEMENTING REAL CONJUNCTIVE WATER MANAGEMENT

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Introduction

Aquifers are geologic formations that store and transmit groundwater — often in quantities sufficient to permit economic development. The transmission and movement of groundwater is a specialized and complicated field employing scientific concepts involving hydrology, hydraulogy, geology, and other associated avenues of inquiry. The authors have generalized these concepts to be applicable to many aquifers in the western United States and internationally.

The fact that the bulk of the fluid freshwater in the world is groundwater creates the imperative to conjunctively manage groundwater and surface water supplies. The use of aquifers as extensions of surface reservoir systems to whatever extent possible will become increasingly more important. When implemented by design, joint aquifer/reservoir storage becomes an essential part of any unified overarching water management strategy.

This article identifies private incentives which can serve to enhance the use and sustainability of aquifer storage processes via the utilization of property rights to water stored in aquifers. It expands upon the concept of Incentivized Managed Aquifer Recharge (IMAR) introduced to readers of The Water Report last month (*see* Tuthill et al., *TWR* #176). IMAR is currently being beneficially implemented in the Eastern Snake Plain Aquifer. Here, your authors explore treating a local aquifer as an additional reservoir to be fully integrated with the surface reservoirs in a basin.

The question remains, how can long-term ongoing water management by IMAR be prioritized and implemented? An even more fundamental question is: what must be done to change the current state paradigm — with water calls, injury determinations, and administrative curtailment orders all occurring under the banner of "conjunctive administration" — to enable productive, sustainable, and efficient (i.e., "real") conjunctive water management. Finding answers to these questions is another purpose of this article.

Background

INCENTIVES, ACCOMPLISHMENTS, LOST OPPORTUNITIES

An appreciation of the importance of private incentives in the water sphere can be gained by looking back at the early principles guiding surface water supply development in the American West. It is readily apparent that water development was never driven by government. Rather, it was accomplished through private initiative that later became reflected in law and water policy.

The settlers of the western United States had ample incentive to collectively manage and amass available surface water supplies. For many of them water management was a matter of a community's life or death.

Aquifers as Reservoirs

"Sub-Irrigation"

Reservoir Impact on Aquifer

Reclamation Act

Storage Development

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Vital interests can spark admirable organization. Take, for example, the Egin Bench area of eastern Idaho where aquifer recharge directly interfaced with the surface water systems. There, the community implemented a management process they called "sub-irrigation." Sub-irrigation was a community irrigation process wherein every member of the community had to participate or no one could successfully raise a crop. It involved a united and coordinated effort to recharge and manage groundwater levels in a manner that filled the root zone of growing crops when irrigation was needed. This irrigation process is one example of the benefit of designing systems to enhance aquifer storage. It also confirms that incentivizing the management of aquifers is both possible amd rewarding. Incentives can be again applied to the use of aquifers as water storage reservoirs through IMAR.

During the 1970s, while sub-irrigation on the Egin Bench was still being practiced, it was becoming clear that new surface storage projects were becoming increasingly difficult to accomplish. Construction of the Teton Dam on the Teton River, a tributary of the Henrys Fork of the Snake River in eastern Idaho, was delayed and the work on the project interrupted many times by environmental litigation. The Teton project relied upon aquifer storage as an essential part of the project water supply, in addition to the surface reservoir. While there was no conjunctive storage and recovery element associated with the water rights for this project, such a relationship might have been possible if the processes and the necessary level of public understanding had been in place. During the initial filling of the Teton Dam in 1976 the United States Geological Survey (USGS) reported dramatic upward changes in the local water table. Surface water was indeed being diverted to storage in the aquifer while the reservoir was filling. Because the recharged volume could not be measured there is only anecdotal evidence that the recharge event associated with the Teton Dam provided a significant enhancement of water supplies in 1977, the single driest year of record in the Upper Snake River Basin.

The 1902 Reclamation Act made possible the opportunity for settlers to borrow money from the United States for the purpose of constructing dams and water delivery projects. The earliest water storage projects involved the employment of natural lakes as water storage reservoirs. These pioneering efforts exploited the opportunity to raise the elevation of the outflow from a lake and thereby increased the amount of water that could be retained. In some cases, these early efforts started with quickly constructed log-crib dam structures. The storage volume gained was computed and claimed by those who provided the motivation for the dam construction needed to elevate the outlet of the lake.

Jackson Lake, which now is located in Teton National Park, provides up to 847,000 acre-feet of stored water to supplement the "natural flow" water rights of Idaho water users (*see* Figure 1). The natural flow is defined as the water that would be in the river in the absence of any reservoirs. The rights to divert this flow are termed natural flow water rights. This continuing entitlement was gained through private efforts to establish storage space that could be created and owned. The development of storage space on the natural Henry's Lake in Idaho is an Idaho example of an early storage project that was constructed without federal funding and as a result had no lingering federal obligations for the long-term operation and maintenance of the structures.

Figure 1. Jackson Lake

Aquifers as Reservoirs

Having water stored in the basin — that could be added to a river when needed — enabled an important opportunity to enhance stream flows. Additional basin storage always creates new opportunities and tools for water management. During the past century many of the earliest lake-dams have been rebuilt or replaced at least once due to failure or deterioration, but the priority position in the sequence of water rights remains unaffected.

Surface Storage Development & Administration

Dam Upgrades

A dam replacement or upgrade usually resulted in an increase in the amount of storage space that could be claimed. Thus, the beneficiaries of these early reclamation projects established multiple storage rights with different priority dates. Over the decades stored water has become established as a supplemental source of water that can be called upon when needed.

Distribution processes develop from a number of different factors. In many Idaho basins the need for irrigation is driven by the lack of rain during critical periods when growing crops need water. State laws require that the diversion of water be for some identified beneficial use or purpose. Historically, the right to divert water was directly related to the fact that someone benefited financially from diverting the available streamflow. The right to appropriate water was often linked to the water needed by a crop.

Priority System

Under the priority system of water rights, those who were "first in time" could preferentially divert the water leaving others without a supply in times of shortage. Those users dependent upon "junior" water rights, which were subject to curtailment by the district watermaster because they were later in priority, faced the specter of crop loss. The solution was to store surplus water supplies that were available in the spring for later use.

Supplemental Right

The development of storage, largely because of the development history, has frequently been viewed as supplemental to natural flow water rights in the western United States. Due to its supplemental status, stored water has fewer state-imposed limitations than flow rights. Storage rights held by the United States identify the location of the dam as the point of diversion. Storage frequently has a generalized place of use (the place of use is described by county) with no defined point of re-diversion. Often there is no limitation on the rate of diversion. On the Snake River in Idaho, once stored water has been allocated to a space holder, the only loss assessed on this stored water is the measured reservoir evaporation.

Storage Space

The first step in developing an entitlement to storage space is to gain access to a defined volume of space. In the creation of storage projects the volume of space was defined for a specific project. The right to fill that space requires making application to the state for the right to divert available natural streamflow. The location of the created space remains the point at which the state, acting through a watermaster elected by the water users of the water district, determines and allocates storage accrued under the established storage water right(s). Storage deliveries are simply an accounting for a diversion of water taken in excess of the in-priority natural flow rights on any given day. Storage water is accounted as any water diverted by canals, ditches, or pumps that is not authorized by an in-priority natural flow water right.

Distribution

The second step is to identify the distribution process. Because river systems generally have many tributaries, the majority of which have no reservoirs to store and release water, seamless exchanges of natural flow and storage could become complicated processes. The accounting logic in the Upper Snake River Water District addresses many potentially complicated exchanges in a relatively simple way. If water is being diverted and there is no in-priority water right, the water diverted is — by definition — stored water. The diversion of storage mathematically causes the computed natural stream flow to increase in that reach and gain is credited to the next appropriator in line.

Storage Allocations

In the Snake River basin all of the earliest water rights were developed upstream of the Snake River at the Blackfoot river gaging station. The canal companies and irrigation districts located downstream from Blackfoot have organized under the name "Surface Water Coalition." Because of the late priorities of their natural flow water rights, these water user groups are dependent upon stored water. Because storage is delivered without loss these users know what their water supplies will be each year based upon their annual storage allocations. Water user demands can, in many reaches, only be filled because of flows being augmented by storage. Storage makes the surface distribution system work, and is the missing element in solving groundwater distribution issues.

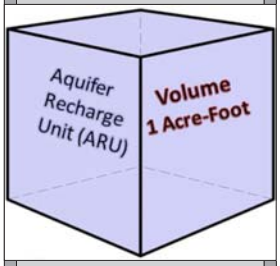
Accounting

The third step in developing an entitlement to storage space is regulation and accounting. This step is initially the job of the district watermaster who delivers water to the head of each canal. From there the actual distribution of water to the end user is the job of private entities like canal companies, or quasi-municipal entities like irrigation districts. Storage entitlements are generally held in the name of the canal company or irrigation district for the benefit of the stockholders or patrons.

Aquifers as Reservoirs

Recharge

ARU = Storage Space



Virtual Reservoir

Groundwater Storage Benefits

Exchanges

Reservoir Capacity

Adding Aquifers as Reservoirs

As a general rule, the bulk of basin water storage is found in aquifers. On the Eastern Snake Plain, available aquifer storage greatly exceeds available surface storage. Generally, this aquifer storage occurs because of gravity and surface infiltration rates. Water that infiltrates the groundwater from rivers, streams, lakes and reservoirs is often classified as "natural recharge."

The necessary elements to claim credit for recoverable storage in aquifers arise from established processes for gaining rights in surface reservoirs. Conceptually, aquifers can be viewed as comparable to the lakes that were used early in our history as storage reservoirs. Storage was created by damming the lakes' outlets. However, damming the outlet of an aquifer is not typically a process that is available for those wishing to increase basin storage — instead, water is actively recharged to a basin.

Last month's IMAR article in The Water Report discussed the definition of an Aquifer Recharge Unit (ARU) — defined as an acre-foot of storage space in the aquifer. Through the use of IMAR, ARUs become the equivalent of surface storage space. All of the elements of the surface storage and allocation processes can be virtually replicated through the measurement and accounting processes developed by the Recharge Development Corporation (RDC). The processes replicate the accounting, allocation, and distribution steps employed by the local water manager (for example, the Snake River Watermaster in Idaho).

IMAR's application of processes directly analogous to those used in surface water accounting represents a crucial step in the conjunctive management of surface water and groundwater.

With IMAR, storage is credited to a virtual reservoir comprised of individual one acre-foot ARUs, instead of the "space" defined as a percentage of the storage volume in a surface storage reservoir. Technologies to make aquifer storage space available for use and development were not available when the Teton Dam was being built in the early 1970s. Now, however, it is possible to virtually reproduce, through ARUs, the in-aquifer equivalent to surface reservoirs to which additional water was added through the construction of dams. Through ARUs a virtual reservoir can incentivize IMAR and encourage the retention of water in the basin that could otherwise be lost during reservoir-lowering flood control operations.

Within the Upper Snake surface reservoir system each reservoir water right is allocated storage each day based upon the priority. However, water stored can reside in any available space in any reservoir in the system. For example, storage allocated to the American Falls reservoir water rights can physically reside in Palisades, Ririe, or Island Park reservoirs. Under this management structure there would be great benefits gained by moving water to groundwater storage under one or more of the reservoir storage rights as an alternative to losing stored water through flood control operations. The total decreed entitlement of the Upper Snake surface reservoir system is 4,135,494 acre-feet. As an example, on June 11, 2011, 9054 **c**ubic **f**eet per **s**econd (cfs) was being released past Milner Dam at the outflow of the basin, but no water was being credited to the virtual reservoir through IMAR. All available water was being lost from the basin.

Water held in the aquifer can be delivered as easily in the surface system as American Falls storage is delivered to space holders who divert their American Falls storage entitlement above American Falls. This is made possible through comparable seamless exchanges of surface water for storage credited to ARUs.

The US Bureau of Reclamation storage right for American Falls is 1,700,000 AF. However, in 1977 the reservoir was empty while the dam was being rebuilt. The opportunity was taken to compute the water storage capacity of the American Falls Reservoir. It was found to be 1,662,786 AF. As a result, the annual allocation to the American Falls storage right was reduced by 37,214 AF. By filling ARUs through IMAR under the reservoir storage rights, the capacity of the American Falls reservoir would be restored to the full 1,700,000 AF it was originally licensed to store.

The combined decreed capacity of all the reservoirs in the system is 4,172,708 AF. If the surface storage plus storage under ARUs exceeds this amount, then the difference will be considered to have been stored under recharge water rights. This difference in storage will be credited to other owned ARUs under their associated recharge water rights.

ASRs: Statutory Adaptation

The State of Washington was the first state to make aquifer storage and recovery (ASR) possible by making it part of the original groundwater code enacted in 1945. Authorization to recover what the state recognized as "managed recharge groundwater" was defined as water present from uncontrolled leakage from irrigation canals located within groundwater management sub-areas. Only a few sub-areas were established, likely because the process for creating sub-areas was quite cumbersome and not well suited to individual ASR projects. A new process to permit ASR began in 2000, when state legislation modified the definition of "reservoir" to include "any naturally occurring underground geological formation where water is collected and stored for the subsequent use as part of an underground artificial storage and recovery project." 2000 Wash. Laws Ch. 98, Sec. 1. The state defines ASR as projects that add water to underground geologic formations for subsequent beneficial use. Managed aquifer recharge methods under the reservoir permitting structure include "surface spreading and infiltration, the use of injection wells, or any state-approved method."

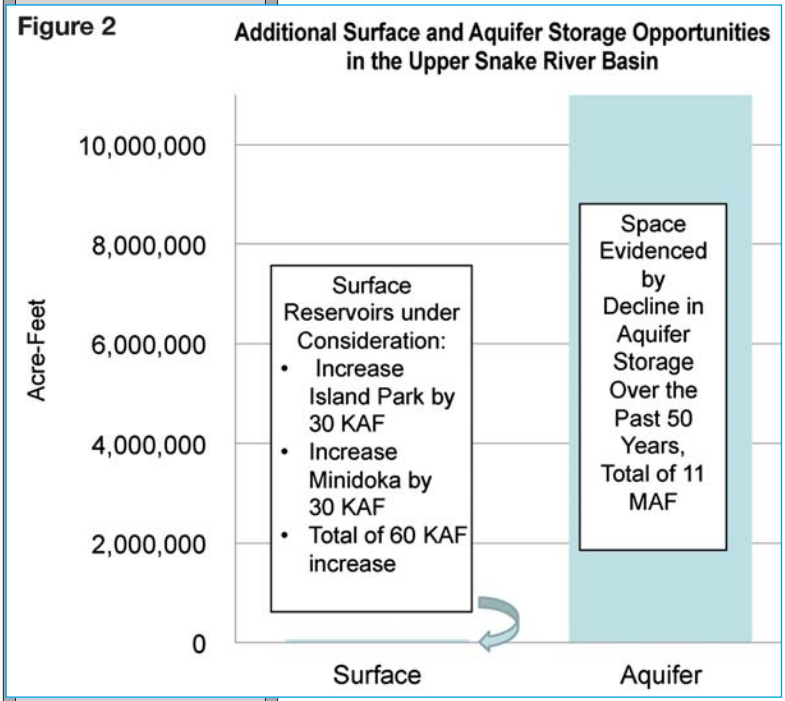
Aquifers as Reservoirs

Space in Aquifers

The opportunity to conduct IMAR is contingent on the following three criteria.

- First, there must be water available to incentivize MAR development.
- Second, the aquifer must exist and have space to accept and retain recharge. This criterion is met in most of the basins where groundwater is being regulated due to declining groundwater levels. Using aquifers as reservoirs must be compared with the only other possibility, additional surface storage.
- The third criterion for conducting MAR is access to sites where water can be moved from land surface to an aquifer from which water can be pumped.

Figure 2



Following the Upper Snake River Basin example, one can compare the opportunity for the development of additional surface reservoir storage to the opportunity for aquifer storage. Figure 2 depicts the comparison between the 60,000 acre-feet of surface water storage presently being investigated with the volume of 11,000,000 acre-feet that has been depleted from the aquifer over the past 50 years. This comparison emphasizes the need to seriously consider the use of aquifers as reservoirs. On one hand, not every aquifer has this much open space. On the other hand, the literature is replete with maps showing the extensive depletions of aquifers within the western United States and internationally where drought and diversions for agriculture and other purposes have depleted available supplies. The space in depleted aquifers presents an incredible opportunity for storage.

Delivery Organization

Creation of a Non-Profit Corporation for Delivery

As part of the RDC design, ARU owners in a basin form a non-profit organization which is the equivalent of a canal company for the purpose of accounting for sales of ARUs, maintaining ownership records, certifying MAR volumes, recording water use volumes and allocating ARU storage. In the Eastern Snake River Basin an operating corporation was created under the name of the Eastern Snake Plain Aquifer Recharge, Inc., or ESPAR. It is the responsibility of ESPAR to manage and deliver ARUs within the basin.

ARU Classes

Classes of Aquifer Recharge Units (ARUs)

One purpose of the RDC design is to intentionally make groundwater storage as directly analogous to surface storage space as possible. Because ARUs are filled from IMAR sites supplied by diverse water sources, the initial "fill" process is by necessity different from the process used when filling a surface reservoir. However, the fact that water can be temporarily retained in any available space in the system creates a similar multi-step process that must be resolved before surface storage can be allocated. By using four classes of ARUs, the RDC processes establish the internal protocols for properly allocating IMAR to the correct ARUs. Each of these classes is described below and illustrated in Table 1.

Class S: Rights + Recharge

Class S ARUs

Class S ARUs are those that are filled by suppliers who have water rights and groundwater recharge works. For example, the City of Blackfoot has access to recharge water via its own water rights and those held by the Snake River Valley Irrigation District (SRVID) of which it is a patron. The City of Blackfoot also has a recharge site, the Jensen Grove pond. The City owns Class S ARUs and the IMAR site needed to fill them.

Marketing

Water in Class S ARUs must be allocated to Class G ARUs for diversion and use. Such transfers have historically been fee-based allocation transactions. Fees likely will continue because they provide needed funding for the non-profit management corporation. In the past RDC has rented Class S ARUs to allow entities to capture their recharge and market it. This was a necessary yet interim step in the accounting process. The licensing to ESPAR will allow the development and establishment of MAR allocation policies. The exceptions to this are cities that have acquired Class S ARUs for capturing their own IMAR and have the potential to distribute ARU storage to Class G ARUs. The accounting processes for Class S ARUs are maintained by the local non-profit (like ESPAR in the Eastern Snake River Basin).

Aquifers as Reservoirs

All Class S ARUs, with the exception of those owned by municipal providers, will likely be licensed to the local non-profit as the representative of all ARU owners. As an example the ESPAR board will likely have discretion in delivering water directly from its Class S ARUs.

Class R ARUs

Class R: Reclamation Holds

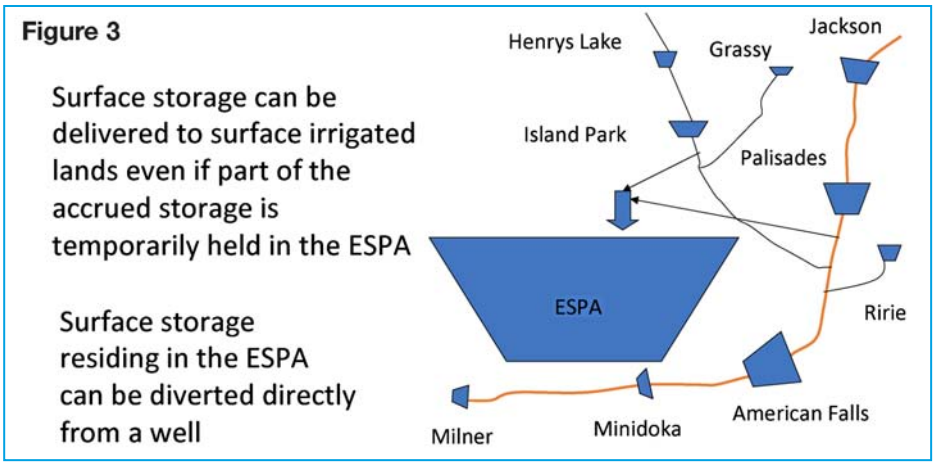
Class R ARUs have not yet been allocated. They are intended to be held by the US Bureau of Reclamation (Reclamation). During the reservoir fill and flood control periods, water is diverted to IMAR sites across the Eastern Snake Plain. By not treating diversions to IMAR as diversions from storage supplies, the district watermaster easily facilitates the extension of the surface reservoir system. All diversions to IMAR must be measured. The credited IMAR is tracked in the RDC accounting system. Recharge data are provided to the district watermaster which allows the accrued storage volumes to be properly credited to the surface reservoir system. While it is not necessary, the watermaster could compute and report on the amount of water that was beneficially stored under the water rights of the individual reservoirs. This process continues until the day of maximum reservoir fill. This extension of the reservoir system through IMAR allows those water users who chose to pump groundwater on project lands to take direct storage deliveries through their groundwater pumps.

Crediting System

Figure 3 illustrates the virtual reservoir made available to Reclamation through the acquisition of Class R ARUs.

Figure 3. The Surface Reservoir System with the Addition of a Virtual Reservoir

Virtual Reservoir



Storage Diversion (Accounting)

The question might be asked: what if the surface system is physically full and there is also storage accounted for as Class R ARU storage? The answer is that ARU storage is retained in the ARU storage accounting system until it is evacuated by a beneficial diversion of storage. A surplus of water allocated to Class R ARUs is considered to "cascade" into the Class S ARUs of the non-profit company such as ESPAR. From there the storage is allocated pursuant to the priority protocols established by the company. Storage credited to these Class S ARUs is analogous to the unallocated storage that has been credited via storage rights for storage in the surface reservoir system.

The proposal for extending the surface reservoir system has been discussed at several management levels within Reclamation. If implemented, the Class R ARU process has the ability to take conjunctive water management to unprecedented levels in many areas of the West.

Class T ARUs

Class T: Tribal ARUs

Only Indian Tribes can own Class T ARUs. The earliest agreements RDC entered into for IMAR were with the Shoshone-Bannock Tribes. Initially 100,000 ARUs have been reserved for licensing to the tribes in the Eastern Snake Plain. These Class T ARUs are similar to the Class S ARUs owned by ESPAR or its counterpart. Water from Class T ARUs can either be rented or purchased by ESPAR or its counterpart for redistribution to Class G ARU owners. RDC will continue to work with the tribes in expanding their IMAR opportunities.

Class G ARUs

Class G: Groundwater Users ARUs

Class G ARUs are expected to become the property of groundwater users and are designed to replicate surface storage space in basin reservoirs. By designating Class G ARUs as the ARUs that are designated for storage deliveries to the beneficial user, it is possible to expand surface water delivery protocols as rules for storage made available through IMAR. There are limitations for the Class G ARU owner. They cannot sell and transfer the allocated storage from their Class G ARU to other ARU owners. However, they can sell or rent their filled ARUs. This is because water from space owned in the surface storage system cannot be moved between and among surface space holders.

Aquifers as Reservoirs

ARU Attributes

Table 1 summarizes the types and attributes of the four classes of ARUs.

Table 1. ARU Classes, Purposes & Characteristics

Class	Application	Accounting Distinctions
Class S ARUs	These ARUs generally represent the catchment for IMAR activities. They are necessary to prevent the virtual escape of any water being accounted for at the many different site locations and agreement conditions that will likely determine how this aquifer storage ultimately gets allocated.	It is anticipated that all S ARUs will be owned by cities, and ESPAR or its counterpart. These are catchment ARUs that provide the substitute for priority in the surface system and assure that IMAR is accounted for in the ARU accounting system.
Class R ARUs	This class of ARUs has been designed to provide containment for IMAR designated to be an extension of the surface storage system and accomplished under the Bureau of Reclamation's reservoir storage rights. No additional storage space is made available through R ARUs. These ARUs simply act as an extension of the available surface storage space and are primarily designed to allow temporary storage to reduce the amount of storage that is evacuated from the basin during flood control operations.	MAR measured during the time the reservoir rights are being filled and supplied by the reservoir water rights is simply added to the volume credited to the surface storage system up to a combined total acre-feet. If a space holder entity wishes to distribute surface storage to a stockholder's pump, that pumper as a stockholder of the company or district can be delivered surface storage via the water district accounting process. G ARUs are not a factor in such a delivery.
Class T ARUs	T ARUs are made available to Tribes to aid in better managing and marketing of the surface storage acquired in their water rights. These ARUs have most of the attributes of S ARUs in that they represent the initial catchment for IMAR activities in the basin. The only difference is the water supply involved is storage owned by the tribes.	Water from T ARUs can be sold to any other ARU owner. The processes involved require an allocations step to convey Tribal storage to the proper G ARU owner.
Class G ARUs	This class of ARUs was created specifically to accommodate the end user of water stored through IMAR. These ARUs are the equivalent of owned space in a surface reservoir. While any water allocated to G ARUs cannot be moved to other G ARUs, the owner of Class G ARUs can sell or lease their ARUs and any water they might contain. G ARUs will largely be owned by pumpers.	G ARUs are filled by transferring, through established protocols, IMAR from S and T ARUs. When R ARUs hold IMAR which would result in more water than reservoir surface storage water rights provide, the excess storage "cascades" to the S ARUs of ESPAR for allocation to G ARU owners.

Allocation & Use

It is helpful in understanding the allocation process if one keeps in mind that water is always allocated to Class G ARUs and used from Class G ARUs. IMAR can be credited to Class S, Class R or Class T ARUs.

ARU Differences

The classes of ARUs are defined by three things:

1) Access to water that can be diverted and credited to the ARUs through IMAR
2) Access to recharge sites and facilities
3) Access to Class R, Class S or Class T ARUs

In identifying the differences that make the different classes of ARUs necessary, any entity with a recharge water supply and an IMAR site can own Class S ARUs. Class R ARUs were designed and designated for use by the US Bureau of Reclamation. Only Indian Tribes can own Class T ARUs.

Fill Crediting

ARU Storage Accounting

When the Snake River reservoir system is being filled, all of the computed natural stream flow entering the river each day is credited to one or more reservoir rights whether storage takes place or not. The reservoir rights are not allowed to reject available water. The computed natural flow is credited to the in-priority reservoir right(s) whether it is stored or not.

Aquifers as Reservoirs

Allocation Steps

If water is being diverted by a pump or a canal, the volume diverted is typically charged against the storage allocation of the space holder entity making the diversion. During this fill period no allocation to space holders takes place. Replicating this initial surface storage process through a virtual process requires classes of ARUs. Table 1 describes the classes of ARUs that are available as an aid in understanding the requisite steps in the accounting process. Like the surface reservoir system, every IMAR event results in an initial fill of owned or rented ARUs. While each surface reservoir has a defined space that is available to contain water, ARUs have a virtual space that is filled through IMAR activities.

Like the surface reservoir system, the initial step in IMAR storage is to contain the storage at the point where it occurs. From there the accrued storage is allocated to owned ARUs based upon an established set of protocols. This is more site dependent than the surface storage system because water right priorities have little significance in the IMAR processes. In fact, it was well established during the IMAR efforts of the 1990s that IMAR is fundamentally the movement of surface storage to aquifer storage. Also, unlike the surface system, the number of ARUs needed to accomplish proper accounting has not been established even though the annual allocable ARU storage was initially capped at one million acre-feet. The resolution may require more than one million ARUs being defined for the Snake River system to accommodate the necessary tracking and accounting without going outside the virtual ARU containment vehicle. Figure 4 depicts the process of first filling Class S, T or R ARUs and then filling the appropriate Class G ARUs.

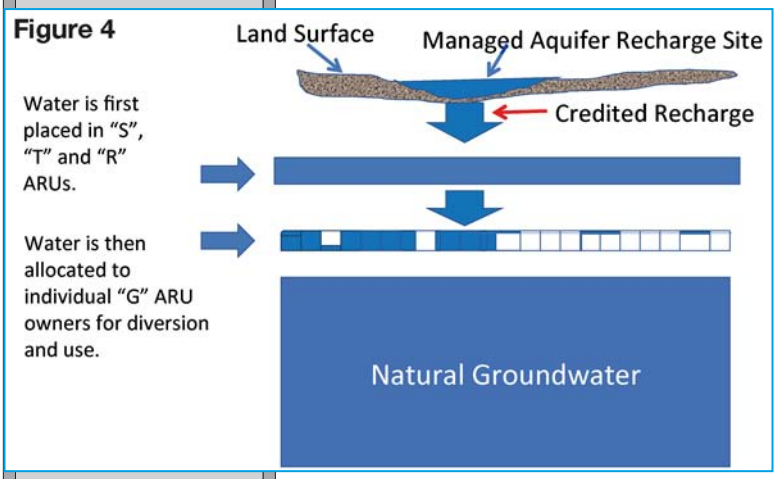


Figure 4
Transition from Class S, Class T and Class R ARUs to Class G ARUs

Municipal Applications

Municipal Providers are facing unique water supply issues. Many cities have undeveloped opportunities to expand their water supplies through aquifer storage and recovery. The example shown in Figure 5 is a group of abandoned sewage lagoons that reside 80 feet above the local water table. This provides a unique opportunity to supplement water supplies through ARUs and IMAR.

Municipal Recharge Opportunity

Figure 5. Recharge from Snake River into ponds that are not hydraulically connected to the river

Aquifers as Reservoirs

Local Management

Adaptive Accounting

Conclusion

BASINS IN IDAHO, OTHER STATES AND INTERNATIONALLY

The needs and opportunities to manage aquifers as reservoirs are extensive. RDC concepts have thus far been applied only in the Upper Snake River Basin in Idaho. However, implementation is presently being explored in other basins in Idaho and in neighboring states.

The essential steps in licensing the RDC IMAR concepts in basins throughout the western United States and internationally are described above. In every case there needs to be a local non-profit managing company to which the processes can be licensed. Not surprisingly, in other basins where RDC is investigating implementation of the IMAR protocols the aquifers are not as large as the Eastern Snake Plain Aquifer. In some cases fewer classes of ARUs will be required. Surface water deliveries may not be possible without pumping (which increases costs and limits IMAR volumes). The basin design in every case is determined by the available water supply that can be dedicated to IMAR and the cost of recharging. The accounting processes are essential and it is anticipated that the current system can be modified as needed to accommodate any basin. The key always is the availability of IMAR sites and a motivated local management entity. Motivation comes from the incentives built into the RDC design. RDC stands ready to assist implementation of these concepts in other basins upon request.

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Ronald Carlson started his work in the field of water resources as a farmer and surface water irrigator. It was from this vantage point that he commenced a 45-year career in the field of water resource administration and water management. He earned a B.S. and M.S. in Agricultural Engineering from the University of Idaho. He was licensed in the State of Idaho as a professional engineer and land surveyor in 1975. He served as the Watermaster of the Snake River in Idaho for 29 years and while in that capacity implemented automated data gathering and computerized accounting for the water district he was elected to serve. While Watermaster he managed basinwide recharge programs as proof of concept efforts and was successful in establishing the Water Bank and Rental Pool structures in Snake River Water District 1. He also was instrumental in getting the aquifer recognized as a reservoir when the Teton Dam failed in 1976. He is a founding member and Treasurer of Recharge Development Corporation.

PFAS Testimony

Persistent Pollutants

PFAS: CONGRESSIONAL HEARINGS

EXCERPTS FROM US HOUSE AND SENATE TESTIMONY

Compiled by David Light, Editor

Editor's Introduction

On September 6, 2018, the US House of Representatives Energy & Commerce Committee, Subcommittee on Environment held a hearing on PFAS chemicals — a class of environmentally persistent pollutants that are engendering growing health concerns both nationally and internationally. On September 26, 2018, the US Senate Committee on Homeland Security and Governmental Affairs, Subcommittee on Federal Spending Oversight and Emergency Management also held a PFAS-related hearing.

What follows are brief, minimally-edited, excerpts gleaned from the over 130 pages of submitted written testimony. Weblinks to the testimony and supplementary materials are provided below.

The House Subcommittee heard from:

Peter Grevatt, Director, Office of Ground Water and Drinking Water, US Environmental Protection Agency (EPA); **Maureen Sullivan,** Deputy Assistant Secretary of Defense for Environment, US Department of Defense (DoD); **Sandeep Burman,** Manager, Site Remediation and Redevelopment, Minnesota Pollution Control Agency, on behalf of Association of State and Territorial Solid Waste Management Officials (ASTSWMO); **Lisa Daniels,** Director, Bureau of Safe Drinking Water, Pennsylvania Department of Environmental Protection, on behalf of Association of State Drinking Water Administrators (ASDWA); **Emily Donovan,** Co-Founder, Clean Cape Fear; **Carol Isaacs,** Director, Michigan PFAS Action Response Team; **Erik D. Olson,** Senior Director, Health and Food, Healthy People and Thriving Communities Program, Natural Resources Defense Council (NRDC).

PFAS Testimony

The Senate Subcommittee heard from:
Peter Grevatt, (EPA); **Maureen Sullivan,** (DoD); **Linda Birnbaum,** Director, National Institute of Environmental Health Sciences and National Toxicology Program (NIEHS-NTP), National Institutes of Health, US Department of Health and Human Services; **Brian Lepore,** Director, Defense Capabilities and Management, US Government Accountability Office (GAO); A**ndrea Amico,** Co-Founder, Testing for Pease; **Arnold Leriche,** Community Co-Chair, Wurtsmith Restoration Advisory Board; **Timothy Putnam,** Vice President, Tidewater Federal Firefighters Local F-25, International Association of Fire Fighters

PFAS

Widespread Use

There are many PFAS chemicals, including the chemicals perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and GenX (HFPO dimer acid).

Because of their widespread use, most people have been exposed to PFAS.
Peter Grevatt, EPA, House Testimony

Class of Substances

Uses

Perfluoroalkyl substances (PFAS) refers to the entire class of poly- and per-fluoronated alkyl substances, of which perfluorooctane sulfonate (PFOS) and perfluorooctanic acid (PFOA) are the most well-studied substances. These substances are ubiquitous in many industrial and consumer products because they increase a product's resistance to heat, stains, water, and grease. …The Interstate Technology and Regulatory Council (ITRC) determined three to six percent of the perfluorooctanyl chemicals produced were used as firefighting foam. Of this percentage, DoD is only one of many users of Aqueous Film Forming Foam (AFFF), which also includes commercial airports, the oil and gas industry, and local fire departments. The remaining perfluorooctanyl chemicals produced were used in the following industrial and consumer applications: approximately 41 percent for paper and packaging protectors; 36 percent for textiles, leather and carpet treatment, and fabric protection; and 19 percent for industrial surfactants, additives, and coatings. Perfluorooctanyl chemicals are used in electroplating and etching, household additives, insecticides, and other applications.
Maureen Sullivan, DoD, House Testimony

Carbon-Fluorine Bond

First created in the 1930s and 1940s, PFAS are among some 4,700 man- made chemicals that contain fluorine atoms bonded to a carbon chain. The carbon-fluorine bond is one of the strongest ever created by man and is rarely seen in nature.
Linda Birnbaum, NIEHS-NTP, Senate Testimony

"Forever" Chemicals

These "forever chemicals" are extremely long-lived in the environment, and concentrate and last a long time in our bodies and in those of animals. Scientists are finding that certain PFAS likely have adverse effects on our health at vanishingly low levels of exposure — *at parts per trillion* levels.
Erik Olsen, NRDC, House Testimony

Health Effect Exposure Levels

One part per trillion is comparable to one drop in a swimming pool covering the area of a football field 43 feet deep.
Brian Lepore, GAO, Senate Testimony

Health Effects

While we have studies that indicate adverse health effects due to PFOA and PFOS exposure, we do not have strong data on which to base conclusions for the great majority of thousands of PFAS and we have only limited findings that support the following adverse health effects. More research is needed to form definitive links between exposure to PFAS chemicals and adverse health effects in humans.

Decreased Immune System Function

Immune System Threat

As early as 1978, scientists observed immunotoxicity in non-human primates exposed to PFAS. In 2016, NTP concluded that PFOA and PFOS are presumed to be a hazard to healthy immune system function in humans, based on a systematic literature review. This conclusion is based on a high level of evidence that PFOA and PFOS suppressed the antibody response in animal studies, and a moderate level of evidence that these chemicals affect multiple aspects of the immune system in humans. Adult PFAS exposure has also been associated with decreases in antibody production.

NTP is in its earliest stages of conducting another systematic review on PFAS immunotoxicity; this one will focus on six related chemicals: PFDA, PFNA, PFHxA, PFBA, PFBS and PFHxS.

Cancer

The epidemiological data on associations between PFAS and cancer risk are limited. Those published studies were recently summarized by the Agency for Toxic Substances and Disease Registry (ATSDR) in

PFAS Testimony

Cancer

their Draft Toxicological Profile for Perfluoroalkyls. According to the Toxicological Profile, "Occupational and community exposure studies have found increases in the risk of testicular and kidney cancer associated with PFOA. No consistent epidemiologic evidence for other cancer types were found for PFOA. For PFOS, one occupational exposure study reported an increase in bladder cancer, but this was not supported by subsequent occupational studies. General population studies have not consistently reported increases in malignant tumors for PFOS. Epidemiologic studies examining other perfluoroalkyl compounds consisted of two case-control studies. No increases in breast cancer risk were observed for PFHxS or PFNA; an increased breast cancer risk was observed for PFOSA. Another case- control study did not find increases in prostate cancer for PFOA, PFOS, PFHxS, PFNA, PFDeA, or PFUA. However, among men with a first-degree relative with prostate cancer, associations were found for PFOA, PFOS, PFHxS, PFDeA, and PFUA, but not for PFNA." Animal studies are consistent with the human epidemiologic studies of cancer endpoints.

Prenatal Exposure

Child Development

PFOA and PFOS cause developmental toxicity in animals. Human epidemiology studies also show associations between some PFAS and developmental effects. One human study found that PFAS exposure during pregnancy was associated with decreased birth weight and head circumference only in males. Similar decreases in birth weight have been reported in rodents for over a decade. Recent findings from NIH-supported epidemiological studies of a cohort of mothers and babies showed that prenatal exposure to PFOS is associated with cognitive effects and decreased ability to regulate behavior in school-age children. However, no similar association was observed in this study for PFOA exposure.

A review of the epidemiological literature by an NIEHS-funded scientist summarized findings from several prospective cohorts on the relationship between prenatal exposure to certain PFAS and neurodevelopmental and neurobehavioral outcomes — for example, cognitive abilities, psychomotor development, attention-deficit hyperactivity disorder, and cerebral palsy. So far, the available body of evidence is inconsistent with respect to these associations, both with respect to which compounds may have adverse effects and timing of potential windows of vulnerability. Additional studies are needed to resolve these questions.

Hormonal Functions

Endocrine Disruption

Studies suggest that some PFAS may interfere with healthy hormonal function in the body. Our endocrine system controls our basic physiology, including metabolism, growth, fertility, and development. Studies suggest that early-life exposure to some PFAS may contribute to the development of metabolic diseases, including obesity and type 2 diabetes, which are major public health problems. Although further confirmation is required, the findings from one study suggest that exposures to some PFAS during pregnancy may influence lipid metabolism and glucose tolerance. A study of pregnant women in Cincinnati found that those with higher prenatal PFAS levels had children with higher body fat levels at age eight — a finding reinforced by other epidemiological studies and similar effects on excessive body weight gain reported for experimental animals. It appears that some PFAS may also affect body weight later in life. Scientists at the Harvard School of Public Health have found that adults with higher blood levels of some PFAS have lower resting metabolic rates, meaning they burn fewer calories while resting, which makes it difficult for them to maintain weight loss. Effects on weight gain have been seen in numerous animal studies, supporting this association in humans. It is particularly concerning that some PFAS alter thyroid hormone homeostasis that regulates metabolism and growth.

Pregnancy Effects

Fertility

Fertility is another outcome related to endocrine effects. A literature review of recent human epidemiologic evidence on the association between exposure to some PFAS and measures of human fertility show the potential for effects on female fecundability (i.e., the probability of conception). In addition, several recent studies have shown an association between women with higher PFAS exposure and the length of time they are able to nurse their child after birth, although not at all levels of exposure. This is similar to 2006 findings in animals reporting impaired breast development and breastfeeding during and after pregnancy in mice.

Linda Birnbaum, NIEHS-NTP, Senate Testimony

Other Risks

Scientists have found certain PFAS may increase the risk of: thyroid and liver disease; asthma; lower fertility in women; high blood pressure or pre-eclampsia in pregnant women; increased cholesterol levels; decreased ability to respond to vaccines; and lower infant birth weights. Studies of people exposed in West Virginia also found that PFOA exposure is probably linked to kidney cancer and testicular cancer. Additional evidence has shown links between early life exposures to PFOA and altered mammary gland development. Animal studies have found that PFOA and PFOS can cause damage to the liver and the immune system, birth defects, delayed development, and newborn deaths.

Erik Olsen, NRDC, House Testimony

PFAS Testimony

There is evidence suggesting that PFAS can cause tumors in lab animals exposed to very high doses, particularly in the liver, reproductive organs, and pancreas. Studies among highly exposed populations have shown a more than insignificant risk of testicular, kidney, bladder, and thyroid cancer related to PFOA and PFOS exposure. The International Agency for Research on Cancer (IARC) classifies PFOA as a Group 2B carcinogen, meaning it is "possibly carcinogenic to humans" based on limited evidence of carcinogenicity in humans and limited evidence in lab animals.

Toxic Foams

Studies on non-cancer health effects are also limited due to small study populations and inconsistent results. However, research suggests that high exposures to PFAS are associated with developmental effects during pregnancy or breastfeeding, thyroid damage, increases in blood cholesterol levels, and liver damage. PFAS are corrosive and can cause damage to the skin and eyes, including blindness. Unfortunately, I only learned of this through information provided by my union, the International Association of Fire Fighters, and not my employer. I am convinced all fire fighters should receive mandatory annual training on the hazards of toxic foams.

Timothy Putnam, Tidewater Federal Firefighters Local F-25, Senate Testimony

Human Exposure

Exposure Pathways

Humans are exposed to PFAS through a myriad of pathways, practices, and products. Ingestion, particularly through drinking water, is the predominant human exposure pathway for many individuals or communities, but recent studies suggest that other exposure pathways, including inhalation and dermal absorption, may have significance for human exposure. Some PFAS bioaccumulate, leading to concentrations in animals that are significantly higher than the surrounding environment, and they can enter the human food chain.

Widespread Exposure

Evidence suggests that human exposures to PFAS are extremely widespread. The Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics' 2011–2012 U.S. National Health and Nutrition Examination Survey (NHANES) reported detectable PFAS blood serum concentrations in virtually all individuals (97 percent). The most recent NHANES data indicate a reduction in serum concentrations of PFOS and PFOA since their removal from consumer products in the early 2000s, but replacement PFAS appear to be rising quickly and exposure is more difficult to assess accurately due to a lack of analytical standards.

Linda Birnbaum, NIEHS-NTP, Senate Testimony

US Contamination

Recent Detection

Although PFAS have been manufactured and used for several decades, they could not be detected in the environment until the mid-2000s. This was due to the absence of suitable laboratory analytical methods.

As sampling and analysis efforts have been developed, studies have now shown that PFAS are extremely widespread in the environment. They are detected in soils and sediments, surface and groundwater, wildlife, and human blood.

Sandeep Burman , ASTSWMO, House Testimony

Drinking Water

According to a recent study by Harvard researchers, PFAS are in the drinking water in at least 33 states, and they have been detected at levels exceeding EPA's weak Health Advisories for PFOA and PFOS (two such PFAS) in the drinking water of more than 6 million Americans. Tens of millions more U.S. residents likely are drinking water with PFAS levels higher than those considered safe by CDC [Center for Disease Control] and independent scientists. …there are hundreds, or more likely thousands, of PFAS contamination sites nationally, including over 400 military installations with known or suspected releases.

Military Sites

These blanket the landscape from potentially hundreds of sites in Michigan, to the former Chanute Air Force Base in Champaign County, Illinois, Hoosick Falls, NY, Parkersburg, WV, and the Cape Fear River in NC.

Erik Olsen, NRDC, House Testimony

Non-Regulatory Measures

Stewardship Program

The EPA has taken steps under its statutory authorities to understand and address these chemicals. For example, certain PFAS chemicals are no longer manufactured in the United States as a result of the EPA's PFOA Stewardship Program in which eight major chemical manufacturers agreed to phase out the use of PFOA and PFOA-related chemicals in their products and as emissions from their facilities. All companies met the PFOA Stewardship Program goals by 2015. In support of this effort, through the EPA's work under the Toxic Substances Control Act, the agency has issued various significant new use rules (SNURs) to guard against the unreviewed reintroduction and new use, through domestic production or import, of certain PFAS chemicals in the United States. However, the SNUR authority did not cover ongoing uses such as low-volume use of some PFAS in limited industrial applications.

PFAS Testimony

Lifetime Exposure

The EPA has also worked with the states and local communities to monitor for six PFAS under the Safe Drinking Water Act to understand the nationwide occurrence of these chemicals in our drinking water systems. In 2016, the EPA issued drinking water lifetime health advisories for PFOA and PFOS of 70 parts per trillion individually or combined. The health advisories are non-regulatory values that help to provide technical information to state agencies and other public health officials on the level of PFOA and PFOS that would provide Americans, including the most sensitive populations, with a margin of protection from a lifetime of exposure to PFOA and PFOS from drinking water. The EPA is also working to move research forward on other PFAS to better understand their health impacts, options for treatment, and how information on better-known PFAS (such as PFOA and PFOS) can be applied to inform our knowledge of other PFAS chemical classes.
Peter Grevatt, EPA, House Testimony

Groundwater Protection

State Actions

According to a July 16, 2018 internet posting by the Interstate Technology and Regulatory Council (ITRC), four states (Alaska, Michigan, North Carolina, and Texas) and the U.S. Environmental Protection Agency had soil screening levels of PFOA for groundwater protection and Alaska, Michigan, and Texas have a value for PFOS. Nine states (Alaska, Delaware, Michigan, Minnesota, Nevada, New Hampshire, North Carolina, Texas, and Iowa) and EPA all have human health soil screening levels for PFOA and PFOS or other PFAS.

Guidance Standards

ITRC also reports that 21 states (Alabama, Arizona, Alaska, Colorado, Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, Minnesota, Nevada, New Hampshire, New Jersey, North Carolina, Oregon, Pennsylvania, Rhode Island, Texas, Vermont, and West Virginia) and EPA have adopted guidance values or standards for PFOS, PFOA, or other PFAS — the State of Washington began a rulemaking for PFAS in drinking water in late 2017; New Jersey proposed a drinking water standard for one PFAS (PFNA) in 2017 and is evaluating PFOA and PFOS. That evaluation will take about two years to complete.
House Committee Memo, Sept. 4, 2018

"Associations" v. "Causality"

Increasing PFAS Numbers

The Science

The science is still evolving regarding PFAS exposure and risks to human health. Most studies have focused solely on PFOA and PFOS, which leaves a huge data gap for other PFAS. Many studies have shown liver, kidney, immunological, and reproductive effects in laboratory animals, but animal studies do not always translate well to adverse health effects in humans. And while some studies have been able to show "associations" with adverse health effects, they have not necessarily documented "causality." The increasing number of PFAS is creating a host of data collection, analytical and technological issues, as regulators and researchers struggle to obtain enough robust information on health effects, analytical methods, and treatment efficacy. Clearly, more research and data are needed to support consensus health-based toxicological values and risk determinations and inform regulatory decisions.
Lisa Daniels, ASDWA, House Testimony

Teflon & Scotchguard

"Short-Chain" Alternatives

Our scientific understanding of PFAS compounds stems almost entirely from studies on a select few. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) have been manufactured the longest, are the most widespread in the environment, and are the most well-studied. PFOA was used in the production of Teflon®, and PFOS in Scotchgard®. PFOA and PFOS are considered "long-chain" PFAS due to the length of their carbon chain backbones and have been studied for several decades. A wide range of "short-chain" PFAS have been introduced recently as alternatives to the linear, "long-chain" compounds.
Linda Birnbaum, NIEHS-NTP, Senate Testimony

Leadership Summit

EPA Further Action Commitments

EPA hosted a PFAS National Leadership Summit in May 2018 that brought together state, tribal, and federal partners, as well as key stakeholders including industry, utilities, Congressional staff, and nongovernmental organizations.

EPA Commitments

At the event, the EPA committed to work on four significant actions:
- Initiating the steps to evaluate the need for a Safe Drinking Water Act maximum contaminant level for PFOA and PFOS.
- Beginning the necessary steps to consider designating PFOA and PFOS as "hazardous substances" through one of the available statutory mechanisms, including potentially CERCLA Section 102.
- Considering groundwater cleanup recommendations for PFOA and PFOS at contaminated sites.
- Working in close collaboration with federal and state partners to develop draft toxicity values for GenX (HFPO dimer acid) and for perfluorobutane sulfonic acid (PFBS).

Peter Grevatt, EPA, House Testimony

PFAS Testimony

Drinking Water Priorities

Recommendations

ASDWA [Association of State Drinking Water Administrators] has identified three key areas for action:

ASDWA believes that PFAS must be addressed at the national level using a holistic approach and asks that Congress direct all appropriate federal agencies to develop a unified message regarding the PFAS risks, and as soon as possible, list PFAS compounds as hazardous substances under CERCLA, require PFAS reporting under the Toxic Release Inventory, and take other steps to control and limit PFAS contamination.

ASDWA asks that Congress provide additional funding to EPA and the states to address PFAS. At present, state primacy agencies are diverting resources from core drinking water programs (including inspections, technical assistance and training, permitting/plan approvals, and compliance/enforcement) to address PFAS. Without additional funding, both the core program and the additional work to address PFAS will suffer.

Expand Focus

ASDWA asks that Congress recommend that EPA expand the PFAS focus beyond drinking water to encompass PFAS reductions across all programs and media. Our efforts should be coordinated across all contributing media.

Lisa Daniels, Association of State Drinking Water Administrators (ASDWA), House Testimony

Public Health Focus

The federal government must take swift and protective action against all PFAS and not just a couple chemicals within this class. The government must stop giving PFAS the benefit of the doubt and instead give public health the benefit of the doubt. It is known that some of the chemicals in this class of PFAS cause harm to human health and therefore the government should not allow these chemicals to be in the products, environment, and drinking water of millions of Americans. Communities need a consistent and coordinated action plan from federal agencies to address PFAS contamination and we need action now. It is critical the federal government take a leadership role by lowering the standard for all PFAS to 1 ppt, prioritize health & toxicological studies on PFAS to advance the science, allocate resources for ongoing investigations & remediation efforts, and hold the polluters responsible for their actions.

Andrea Amico, Testing for Pease, Senate Testimony

Fire Fighters

We know PFAS presents a health risk to workers, such as fire fighters, who are exposed on a regular basis and thus we seek to ultimately discontinue the use of PFAS foams. In recent years, driven by the European and US reforms, fluorine-free foam technology has advanced to counter concerns raised with PFOS and PFOA fluorinated foams. Fluorine-free foams are now available in the international market.

Fluorine-free foams continue to gain wide acceptance in Europe and Australia where the use of Mil-Spec AFFF isn't required. Several European locations having transitioned to the new formulations have reported acceptable firefighting experiences with fluorine-free UL approved foams. In 2015 an engine fire occurred on a British Airways aircraft located at London's Heathrow International Airport. The fire was successfully extinguished using a fluorine-free foam. Following the incident, officials were not only pleased by the performance of the fluorine-free foam, but also recognized the fluorine-free foam came with the benefit of an absence of known health hazards, zero clean-up cost and no environmental damage.

Discontinuing Use

The IAFF [International Association of Fire Fighters] supports the use of non-toxic foam formulations. …To better protect fire fighter health, we support discontinuing the use of legacy foams and turnout gear containing PFOA.

Timothy Putnam, Tidewater Federal Firefighters Local F-25, Senate Testimony

Costs v. Risks

Approaching PFAS as a class for assessing exposure and biological impact is the best way to protect public health. Based upon their persistent nature, widespread exposure, and known toxicity, it begs the question: does the value of PFAS production and use for modern-day convenience outweigh the potential costs and risks to public and environmental health? Thus, science is moving in the direction of safer alternatives.

Linda Birnbaum, NIEHS-NTP, Senate Testimony

For Additional Information:

US House of Representatives Energy & Commerce Committee, Subcommittee on Environment
September 6, 2018 hearing website: https://energycommerce.house.gov/hearings (select Sept.6)
US Senate Committee on Homeland Security and Governmental Affairs, Subcommittee on Federal Spending Oversight and Emergency Management
September 26, 2018 hearing website: www.hsgac.senate.gov/hearings (*see* 09/26/18)

Groundwater & the CWA

Groundwater Conveyance

Citizen Suits

"Groundwater Conduit" Theory

"Point Source"

"Nonpoint" Source

Migrating Pollutants

Groundwater Distinction

GROUNDWATER & THE CLEAN WATER ACT

THE SIXTH CIRCUIT CREATES WIDER SPLIT ON WHETHER GROUNDWATER IS REGULATED UNDER THE CWA

by Kathy Robb, Sive Paget & Riesel, PC (New York, NY)

Introduction

The Clean Water Act requires a permit to discharge pollutants from a point source to navigable waters. Last month, stating that the "Clean Water Act does not extend liability to pollution that reaches surface waters via groundwater," a divided panel of the Sixth Circuit held in two separate cases that unpermitted discharges from unlined coal ash ponds through groundwater to surface water did not violate the Clean Water Act. *See Kentucky Waterways Alliance et al v. Kentucky Utilities Co*., No. 18-5115 (2018), *Slip Op*. at 2. The cases widen the split on the issue among the federal circuit courts, create further regulatory uncertainty, and raise broad questions about the Clean Water Act — the reach of jurisdiction, the meaning of Justice Scalia's plurality opinion in *Rapanos v. United States*, 547 U.S. 715 (2006), and the scope of "cooperative federalism" under environmental statues.

Groundwater Conduit and Other Theories

In both Sixth Circuit cases, *Kentucky Waterways Alliance et al v. Kentucky Utilities Co*., No. 18-5115, (*Kentucky Utilities*) and *Tennessee Clean Water Network v. Tennessee Valley Authority*, No. 17-6155 (*TVA*), environmental groups brought citizen suits under the Clean Water Act (CWA). These groups alleged that discharges of pollutants migrating through groundwater to surface water from coal ash ponds at power plants in Kentucky and in Tennessee required National Pollution Discharge Elimination Permits (NPDES) permits. The Sixth Circuit rejected their allegations.

The concept that indirect discharges of pollutants to navigable waters through groundwater are regulated under the CWA —sometimes known as the "indirect discharge" or "groundwater conduit" theory — is not new. But the Sixth Circuit decisions directly conflict with recent prior holdings by the Fourth Circuit in *Upstate Forever v. Kinder Morgan Energy Partners*, L.P., 887 F. 3d 637 (4th Cir. 2018) (*Kinder Morgan*) and the Ninth Circuit in *Hawai'i Wildlife Fund et al v. County of Maui*, 881 F.3d 754 (9th Cir. 2018) (*County of Maui*) and thus spark renewed controversy about the regulatory reach of the CWA when groundwater is part of the equation. The Fourth and Ninth Circuit decisions, now on petitions for review pending before the US Supreme Court, also are in conflict with older decisions from the Second, Fifth, and Seventh Circuits which limited CWA jurisdiction to discharges from point sources directly to navigable waters. [Editor's Note: *See* discussion of these cases in Robb, *TWR* #170, April 15, 2018 and Robb, *TWR* #171, May 15, 2018; *see also* Moon, *TWR* #176.

Generally, groundwater historically has not been regulated under the CWA. The CWA prohibits a discharge of a pollutant to "navigable waters" — defined under the Act as "the waters of the United States, including the territorial seas" — from a "point source" without an NPDES permit. A "discharge" is defined as "any addition of any pollutant into navigable waters from a point source." A "point source" is defined as "any discernable, confined and discrete conveyance including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container…from which pollutants are or may be discharged… ." CWA § 1362(7), (14). The CWA defines "nonpoint" sources by exclusion — anything that is not a "point source" under the CWA definition. The US Environmental Protection Agency (EPA) describes "nonpoint" sources as those caused by rain or snow runoff over or through the ground, including land runoff, precipitation, drainage, and seepage, coming from many diffuse sources. *See* www.epa.gov/nps/what-nonpoint-source and https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2788.

In *Kentucky Utilities* and *TVA*, citizen groups argued that the utilities violated the CWA because coal ash pond pollutants were migrating through groundwater to surface water, constituting a discharge without a permit. The utility had a permit allowing regulated discharges from ash ponds through an external outfall. The plaintiffs argued that the ash ponds also discharged to a nearby surface water through naturally flowing groundwater that was infiltrating the settling ponds and flowing through springs to the surface water. The utility argued that these indirect discharges were not regulated under the CWA, and the Sixth Circuit agreed, first highlighting the point source requirement of the CWA: "[A]s noted, the CWA regulates parties that pollute navigable waters where that pollution comes from a 'point source.' 33 U.S.C. §§ 1311(a), 1362(12). A point source, in turn, is a 'discernible, confined and discrete conveyance.' § 1362(14). Thus, for pollution to be governed by the CWA, it must have traveled through a conveyance, and that conveyance must have been discernable, confined, and discrete." *Kentucky Utilities, Slip Op*. at 10. The Sixth Circuit then discussed how groundwater differs from a point source in its view. "[B]y its very nature, groundwater

Groundwater & the CWA

"Diffuse" Medium

Coal Ash

"Into" Equals "Directly"

"Designed to Store"

Measurable Discharge

Indirect Seepage

Responsibility Avoidance

is a 'diffuse medium' that seeps in all directions, guided only by the general pull of gravity…Thus it is neither confined nor discrete." *Slip Op.* at 10-11 (citation omitted). "One cannot look at groundwater and discern its precise contours as can be done with traditional point sources like pipes, ditches, or tunnels. 33 U.S.C. § 1362(14). For that reason, the CWA's text forecloses an argument that groundwater is a point source." *Slip Op*. at 11. The court applied a similar analysis and reached the same result in the *TVA* case.

Coal-burning power plants produce "fly ash" that is discharged up smokestacks into air, and "bottom ash" that remains at the base of the smokestacks. The bottom ash is combined with water in a sluice system that pipes the waste to man-made ponds. Ash sinks to the bottom of the ponds and is intended to remain there. In *Kentucky Utilities* and in *TVA*, the ash ponds sit on top of karst terrain — eroded, highly-soluble subsurface limestone. The citizen groups asserted in each case that groundwater flows cause a release of pollutants from the ash ponds to nearby surface waters, due to the caverns and tunnels in the karst terrain, constituting a "point source" under the CWA. Alternatively, they argued that the groundwater was "hydrologically connected," acting as a "conduit" through which pollutants passed to reach surface waters, with the coal ash ponds as "point sources." The *Kentucky Utilities* Plaintiffs also argued that groundwater itself is a point source under the CWA.

The Sixth Circuit rejected all these theories. The panel held in a 2-to-1 decision in each case that "neither groundwater nor the karst" is a "point source" because neither are discernable, confined, or discrete (*see Kentucky Utilities*, *Slip Op.* at 10). The Plaintiffs position was that the "...CWA allows for pollutants to travel from a point source *through* nonpoint sources en route to navigable waters." *Id*. at 11 (emphasis in original). Plaintiffs' argued that the CWA does not contain the word "directly" in the relevant CWA provision and therefore "only prohibits the discharge of pollutants 'to navigable waters from any point source'" without reference to how "direct" the discharge is. Referring to this "backbone" of the plaintiffs' argument, the Sixth Circuit rejected the hydrological connection theory, holding that the interpretation contradicts other text in the CWA. *Id*. "Thus, for a point source to discharge *into* navigable waters, it must dump *directly* into those navigable waters — the phrase 'into' leaves no room for intermediary mediums to carry the pollutants." *Id*. at 12 (emphasis in original). In reaching this conclusion, the Sixth Circuit noted expressly that "we disagree with the decisions from our sister circuits" in *Kinder Morgan* and *County of Maui*. *Id.* at 10.

Point Source - Direct Discharges

The Sixth Circuit also noted that "even if there were some legal basis for the hydrological connection theory, Plaintiffs would still be required to identify a point source." *Id*. at 12. The Sixth Circuit expressed doubt that a coal ash pond is a point source, as it is "designed to *store* coal ash in place." *Id.* at 12, fn 8 (emphasis in original). The Sixth Circuit pointed out that the Fourth Circuit had recently reached the same conclusion in *Sierra Club v. Va. Elec. & Power Co*., No. 17-1952,_ F.3d _, 2018WL 434513 (4th Cir. Sept. 12, 2018) (*VEPCO*). In *VEPCO*, the Fourth Circuit held that indirect discharges of arsenic through groundwater from closed coal ash landfills to a nearby river and creek are *not* regulated under the CWA and that the coal ash ponds are not point sources. The Fourth Circuit accepted without discussion in *VEPCO* that a direct hydrologic connection can establish liability under the CWA, based on the Fourth Circuit's *Kinder Morgan* decision. But the Fourth Circuit reversed the district court's finding of liability on the basis that even if the pollutants come from hydrologically connected groundwater, the CWA requires a discharge from a "point source," and a settling pond is not a point source. In addition, the Fourth Circuit said that the "Congress clearly intended to target the *measurable* discharge of pollutants" which is "impossible" with a diffuse discharge through soil to groundwater. *VEPCO*, *Slip. Op*. at 15-16.

After *VEPCO*, *Kentucky Utilities*, and *TVA*, some commenters have suggested that distinctions might be made based on the original source of the discharge — characterizing the coal ash ponds in the three cases as diffuse, and attempting to distinguish them from the injection wells in *County of Maui* and the broken underground pipe in *Kinder Morgan*. But in all these groundwater conduit cases, including *County of Maui* and *Kinder Morgan*, pollutants were alleged to have moved eventually through soil and groundwater to surface waters — an indirect, diffuse seepage through groundwater of the kind that the Sixth Circuit held did not establish liability under the CWA. The Sixth Circuit stated that when pollutants are discharged from the ponds to navigable waters, '"they are coming from groundwater, which is a nonpoint source conveyance. The CWA has no say over that conduct." *Kentucky Utilities*, *Slip Op*. at 12.

RCRA Regulation

Proponents of the groundwater conduit theory argue that without liability for indirect discharges, operating facilities can just set up a settling pond close to a river or stream but not discharging directly into it and thus avoid responsibility for pollution making its way to the surface water through groundwater.

Groundwater & the CWA

RCRA Regulation (Storage)

One factor considered in the *Kentucky Utilities* case is that EPA regulates coal ash under the Resource Conservation Recovery Act (RCRA) and the Coal Combustion Residuals Rule or "CCR rule." In contrast to the CWA, which regulates discharges of pollutants to waters of the United States, RCRA regulates solid and hazardous waste and disposal while it is stored in a pond or landfill. The CWA and RCRA do not overlap. In *Kentucky Utilities*, the Sixth Circuit reversed the district court and found that the Plaintiffs could pursue their RCRA claims (no RCRA claims were filed in the *TVA* case). (On August 21, 2018, the US Court of Appeals for the DC Circuit vacated and remanded significant portions of the CCR rule, raising questions about the status of coal ash disposal and EPA's next steps.)

Scalia Plurality

***Rapanos* Support?**

Noting that proponents of the hydrological connection theory have relied on *Rapanos* in support, the Sixth Circuit stated that its holding "does not stand in conflict with the *Rapanos* plurality." *Kentucky Utilities, Slip Op.* at 14. In *Rapanos*, the US Supreme Court considered the question of whether wetlands adjacent to point source "ditches or man-made drains" intermittently flowing into navigable waters constitute "waters of the United States" under the CWA and concluded that the wetlands were jurisdictional waters. *Rapanos* was a 4-1-4 split decision. Justice Scalia stated in the plurality opinion that "[t]he Act does not forbid the 'addition of any pollutant *directly* to navigable waters from any point source,' but rather the 'addition of any pollutant *to* navigable waters.'" *Rapanos*, 547 U.S. at 715, 743 (2006) (*Plurality Op*., emphasis in original). Plaintiffs have relied on the quote to support arguments that pollutants need not be discharged directly from a point source into navigable waters in order to come within the permitting requirements of the CWA. In its decisions, the Sixth Circuit stated that "the quote has been taken out of context in an effort to expand the scope of the CWA well beyond what the *Rapanos* Court envisioned," *Kentucky Utilities*, *Slip Op*. at 14. The Sixth Circuit distinguished Justice Scalia's opinion as "not binding here" because it is a "plurality opinion answering an entirely different legal question" and because Scalia's opinion addressed a situation where "pollutants which travel through multiple *point sources* before discharging into navigable waters are still covered by the CWA." *Id*. (emphasis in original), citing *Rapanos* at 743.

Connection Evidence

Hydrologic Connection

While *County of Maui* involved a dye tracer test, the Fourth and Sixth Circuit cases rely on indirect evidence and extensive expert testimony to establish a hydrologic connection. In *Kentucky Utilities* and *TVA*, the district courts considered comparisons of samples taken from groundwater and surface water, expert reports discussing hydrologic principles, and factual statements in the defendants' reports to find a hydrologic connection between the landfills and surface waters. Even the more direct dye tracer test in *County of Maui*, however, raises issues of how much time can it take for contaminants to reach surface waters through groundwater, and how far away can the point source be from the navigable water, for indirect discharges through groundwater to come within CWA regulation? In *Kentucky Utilities*, the Sixth Circuit noted that the Plaintiffs' expert explained "that when he injected dyes into three different locations" from an ash pond, "only one was recovered." *Kentucky Utilities*, *Slip Op*. at 11.

State Impacts

In addition, if the federal government regulates hydrologically connected groundwater, it is not clear how that will impact the rights of the States. Many argue that the cooperative federalism under the CWA could be affected, and the power of States to regulate water limited, if indirect discharges to groundwater come within the CWA permitting program. A similar concern regarding limiting states has been voiced in the ongoing multi-court litigation surrounding the "Waters of the United States" rules. *See* Glick, *TWR* #175; Water Briefs, *TWR* # 161 and #168; Taylor, *TWR* #157; and Glick & Atencio, *TWR* #149.

State Regulation

Cooperative Federalism

In its opinions, the Sixth Circuit points out that in addition to protecting the nation's waters, one of the express purposes of the CWA is to foster cooperative federalism, to "recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, [and] to plan the development and use…of land and water resources. " *Kentucky Utilities*, *Slip Op*. at 15, quoting 33 U.S.C. § 1251(b). In *TVA*, the Sixth Circuit notes that the CWA achieves this goal by allowing qualifying States to administer the NPDES program; by restricting the CWA jurisdiction to discharges of pollution into navigable waters, leaving the States to regulate non-navigable waters, and "most notably" by distinguishing point source and nonpoint source pollution, leaving nonpoint source pollution "within the states' regulatory domain." *TVA*, *Slip Op*. at 4.

Groundwater & the CWA

Scope?

Regulatory Certainty

Conclusion

The Supreme Court is likely to address these inconsistent decisions. Depending on the outcome, there is the possibility for increased federal permit requirements for those discharging wastewater that moves through groundwater and ultimately reaches navigable waters. Superfund site cleanups, municipalities, golf courses, recreation areas, agriculture, recreation areas, agriculture, businesses that contain stormwater onsite in unlined ponds, cesspools, septic systems, underground storage tanks, surface impoundments, landfills, and pipelines — all potentially may fall under the CWA if groundwater carries a discharge from them to navigable waters. Fines under the statute could run as high as about $53,000 a day for violations.

With petitions for review already filed in the US Supreme Court in the *Kinder Morgan* and *County of Maui* cases, the Sixth Circuit decisions only strengthen the split among the Circuits, a factor in whether the Supreme Court chooses to take up a case for review. A decision by the Supreme Court would provide regulatory certainty and limit costly, time-consuming court challenges case-by-case which can result in inconsistent decisions.

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Interstate Litigation

Water Litigation

Groundwater Development

Groundwater Depletion

Legal Reforms

Alternative Mechanisms

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Special Masters

INTERSTATE WATER LITIGATION

INTERSTATE WATER LITIGATION IN THE WEST: A FIFTY-YEAR RETROSPECTIVE

by Burke W. Griggs, Washburn University School of Law (Topeka, KS)

Editor's Note: This article is excerpted from a more comprehensive law review article published by the Water Law Review of the University of Denver Sturm College of Law. The Water Report wishes to acknowledge the Water Law Review and thank it for allowing the republication of portions of the article. The article has been edited to fit *The Water Report's* format and includes a portion of the original introduction, while presenting Parts V and VI only (Parts I through IV not included). The original article also contains extensive footnoting that is not included in these excerpts (limited footnoting is incorporated into the text here). The full article is highly recommended to our readers for the sections not included here and for the additional references in the footnotes. The citation for the original article is Burke W. Griggs, *Interstate Water Litigation in the West: A Fifty-Year Retrospective*, University of Denver Water Law Review (Spring, 2017), 20 U. Denv. Water L. Rev. 153.

Introduction

Woody Allen comically summarized War and Peace as a novel that "is about Russia." The enduring conflicts between states over western rivers can be similarly summarized as something that "is about water." Readers looking for a comprehensive legal survey of the subject should look elsewhere. What, then, to do here? Interstate water litigation in the West is the recurring consequence of the longstanding structural relationships of western water, and of the irreconcilable conflicts among hydrological and geological facts, arbitrary and flawed political decisions, and constitutional and legal fictions. The original sins of interstate water allocation have repeatedly required litigation brought under the original jurisdiction of the Supreme Court. A brief history of this litigation cannot do these structures justice; it is better to stress the role of contingency. If these structures and structural conflicts do not change over time (and for the most part, they have not), then it is something beyond them that has forced litigation. Something, presumably, that is about water.

Over the past fifty years, that water has been groundwater. Across most of the western states, water law developed into a state of reliable maturity and general doctrinal consistency roughly between 1890 and 1950, when the West's available water supplies were predominantly surface water supplies. Because groundwater was relatively unimportant by comparison during that period, western groundwater law and its attendant doctrines remained marginal and balkanized. *See* Samuel C. Wiel, *Water Rights in the Western States* (1905), at §§ 72-80 (describing contemporary legal categories of groundwater and their attendant doctrines). No less an authority than Elwood Mead confidently predicted that the "millions and millions of acres" of fertile and gently sloping farmland outside the reach of surface-water irrigation projects across the West "will never be farmed, however, because water is lacking." Elwood Mead, *Irrigation Institutions: A Discussion of the Economic and Legal Questions Created by the Growth of Irrigated Agriculture in the West* (1903), at 6. The industrial groundwater revolution proved Mead wrong, and turned the world of western water upside down during the postwar period. Groundwater irrigation soon dwarfed surface water irrigation across much of the West, and especially across the Great Plains. As pumping depleted the surface flows of interstate rivers, groundwater raised new boundary issues — jurisdictional, legal, and technical — that groundwater depletion made impossible to ignore, disturbing interstate water relations established by compact or decree.

Part V explores two of the most important and revealing consequences of interstate groundwater litigation. Litigation has served the salutary purpose of forcing necessary legal reforms within states' water codes, reforms that have enabled more effective regulation of groundwater pumping. Yet litigation has also forced the development of alternative mechanisms to comply with interstate compacts and the Court's decrees, such as water right retirement programs and stream augmentation projects.

Part VI concludes with several observations about interstate water litigation. It has forced states to integrate groundwater within the federalist structures of interstate water governance, but it has not yet forced the states to meet their interstate obligations by confronting the problem of groundwater depletion. Interstate water litigation has also revealed problematic political and jurisdictional asymmetries across interstate basins, while exposing troubling inconsistencies on the part of the United States. And the means by which states have chosen to comply with their interstate obligations have raised basic questions about western water law doctrine. Throughout, this article relies heavily upon the reports issued by Special Masters in these cases. While they lack the power of the Court's decisions, they provide a level of historical detail, context, and analysis which the Court's decisions rarely do.

Interstate Litigation

State Water Codes

Compact Compliance

Surface Water & Groundwater Integration

Reducing Consumption

Water Rights Retirements

Federal Subsidy

V. The Evolution of Interstate Compact Compliance in Groundwater-Dependent Basins

A. Interstate Litigation as a Forcing Tool for State Law Reform in Groundwater

Interstate litigation has proven to be a powerful forcing tool for state law reform in groundwater. Kansas fundamentally rewrote its water code in 1945, largely in response to its failure to secure an equitable allocation of the Arkansas River, and in the hope of securing a defensible compact allocation on the Republican River. More recently, Special Master Kayatta's belief that Nebraska's post-2007 legislative response to the problem of its noncompliance constituted a new era in Nebraska water law and policy kept him from imposing a higher amount of disgorgement. *Kansas v. Nebraska & Colorado*, 2013 Report, at 112. That belief raises an important point. Across the West, interstate compact litigation has served the salutary and politically difficult purpose of achieving important legal reforms in the regulation of groundwater pumping. Colorado struggled to regulate postcompact alluvial wells in the Arkansas River Basin during the 1950s, 1960s, and even the 1970s. *Kansas v. Colorado*, however, provided the necessary impetus that allowed Colorado's State Engineer to reduce groundwater pumping significantly through rulemaking. Colorado's 1995 rules for wells in the Arkansas River Basin ordered the pumping of all post-compact wells discontinued, unless their depletions to usable stateline flows could be replaced in accordance with a plan approved by the State Engineer. The same rules similarly limited the aggregate pumping from all pre-compact wells to 15,000 acre-feet annually. The need for Colorado to comply with its interstate compacts has also promoted compact-specific rulemaking in the Republican River and Rio Grande Basins. Groundwater models developed in response to interstate litigation have also enabled downstream states such as Kansas to effect important reforms in groundwater management. Northwest Kansas Groundwater Management District No. 4, for example, adapted the RRCA Model to create the "Northwest Kansas Groundwater Model," which estimates impacts of groundwater pumping on both streamflows in the South Fork Republican River and upon Ogallala groundwater levels. The latter model enabled the Kansas Chief Engineer to establish a local enhanced management area pursuant to Kan. Stat. Ann. § 82a-1041, reducing groundwater pumping bytwenty percent.

The two rounds of litigation in *Kansas v. Nebraska & Colorado* have similarly motivated Nebraska to make changes to its water code. In the wake of the 1998-2003 litigation, the Nebraska legislature required Nebraska's NRDs [Natural Resources Districts] to adopt and implement "Integrated Management Plans" (IMPs), to promote better cooperation between the NRDs, which exercise local control over groundwater, and Nebraska DNR [Department of Natural Resources], which exercises centralized control over surface water — largely to ensure compliance with the Republican River Compact. Nebraska has also enacted statutes defining both "overappropriated" and "fully appropriated" river basins, with corresponding regulatory requirements. Special Master Kayatta stressed the importance of these statutory changes, as well as changes in its Republican River IMPs, in convincing him that Nebraska had significantly restructured its regulation of groundwater pumping. *Kansas v. Nebraska & Colorado*, 2013 Report, at 112-19. It is probably too early to evaluate the effects of these changes. So far, they have survived constitutional scrutiny. *Hill v. State*, 894 N.W.2d 208 (Neb. 2017); *Garey v. Nebraska Dep't of Nat. Res*., 759 N.W.2d 919 (2009); and *Kiplinger v. Nebraska Dep't of Nat. Res*., 803 N.W.2d 28 (2011).

B. Alternative Compliance Mechanisms

Sadly for states upstream, the efficient breach of an interstate compact is not a legally available strategy. Happily, however, there is a compliance strategy that exchanges money for water while avoiding the political pitfalls of reducing groundwater pumping: the state leases or purchases irrigation rights, and then temporarily or permanently retires them, thereby reducing its water consumption. New Mexico has shouldered a heavy financial burden to comply with the demands of paying off the water debt to Texas imposed by the Court in the Pecos River litigation. By 2000, New Mexico had spent more than $40 million for its Water Rights Acquisition Program (WRAP), purchasing over 25,000 acre-feet of water rights appurtenant to nearly 9,000 acres in the lower Pecos River Basin. By 2009, it had spent approximately $100 million in total for water rights retirements. In Colorado's portion of the Republican River Basin, the Republican River Water Conservation District (RRWCD) has also pursued an aggressive retirement policy. Financed by its own substantial irrigated land and water right assessments and assisted by a low-interest loan from the State of Colorado, the RRWCD spent around $51 million by 2011 to purchase and retire water rights.

To protect their sovereign rights under these various compacts, the states naturally seek federal subsidies. In this regard, western water managers have followed the western stockmen's creed concerning

Interstate Litigation

Federal Programs

the federal government: "Get out and give us more money." Wallace Stegner, *The Uneasy Chair: A Biography of Bernard Devoto* 302 (1988) (quoting DeVoto). The most common federal programs are the Conservation Reserve and Enhancement Program (CREP), the Environmental Quality Incentives Program, and the (recently repealed) Agricultural Water Enhancement Program. These programs pay landowners to retire their lands from irrigation, typically on a temporary basis. Surface rights and groundwater rights close to the river bring the highest prices, because their retirement brings the highest returns in stream flow. By taxing themselves, and by obtaining state and federal funds to purchase and retire irrigation rights, irrigators can better maintain their current pumping levels on lands not enrolled in such programs.

"Augmentation Plan"

A second alternative to reducing groundwater pumping is the "augmentation plan" — the "euphemism of choice" for relocating water supplies into depleted river basins. Marc Reisner, *Cadillac Desert: The American West and Its Disappearing Water* 47 (rev.ed. 1993); at 264. By the time interstate groundwater cases came to be litigated in the 1980s and 1990s, augmentation plans had been in use in both Colorado and New Mexico. An augmentation plan enables junior groundwater rights (such as the post-compact wells in Colorado's portion of the Arkansas River Basin) to continue to pump during water shortages as long as they have a state-approved and legally binding plan to "augment" the water supply, by providing substitute water to senior rights that would otherwise be affected by such out-of-priority pumping. Colo. Rev. Stat. § 37-92-103(9) (2014); *see also Cache LaPoudre Water Users Ass'n v. Glacier View Meadows*, 550 P.2d 288, 293-94 (Colo. 1976). Colorado has applied this concept at the interstate level to zero its shortfalls under the Rio Grande Compact, by diverting San Luis Valley groundwater into the Rio Grande before it crosses into New Mexico; in the immediate wake of *Texas v. New Mexico*, New Mexico considered a similar but more ambitious plan, but shelved it in favor of WRAP [Water Rights Acquisition Program]. In 2003, state and federal stakeholders within New Mexico entered into the 2003 Pecos Settlement Agreement, under which New Mexico's Interstate Stream Commission operates two augmentation well fields and pipelines to supply water to the Pecos River under specified water-short conditions, to ensure compliance with the Pecos River Compact. (*See* www.ose.state.nm.us/Compacts/Pecos/PDF/settlement_03-25-2003.pdf). Colorado has also relied upon replacement water from the western slope to offset stream depletions due to groundwater pumping in the Arkansas River Basin. *Kansas v. Colorado*, Fourth Report, 2003, at 10-24.

Replacement Water

Interstate Strategies

The Republican River litigation has brought augmentation plans to the front and center of interstate compliance strategies in that basin. Colorado introduced the concept during the FSS [Final Settlement Stipulation of 2002] negotiations, and the states agreed to allow such plans, subject to the unanimous approval of the states in each instance. *Kansas v. Nebraska & Colorado*, FSS, 2002, § III.B.1.k, at 15. Aside from rain, they have become the most important compliance tools for both Colorado and Nebraska. Their augmentation projects pump groundwater from supplies that are hydrologically more distant from the Republican River, such as the High Plains-Ogallala Aquifer, pumping that creates a smaller effect on the compact accounting than pumping from wells closer to the river, such as alluvial wells. The projects then pipe that groundwater to tributaries of the river and dump it there, where it augments streamflows. This artificial transportation of more distant groundwater compensates for depletions to streamflow caused by groundwater pumping closer to the streams, tributaries, and mainstem of the river, which accordingly has a greater effect on the compact accounting. These plans do not augment the water supply of the basin; rather, they use low-impact groundwater pumping (as determined by the compact accounting procedures and the RRCA Model) to offset the effects of high-impact groundwater pumping (also as determined by the same procedures and model). *See* www.republicanrivercompact.org.

Augmenting Streamflows

Compact Compliance Pumping

In Colorado, the RRWCD has spent approximately $50 million to construct its Compact Compliance Pipeline (CCP), which can pump 25,000 acre-feet of Ogallala water annually. The CCP then pipes it to a point just upstream of the gage at the Nebraska border, dumping it into the North Fork of the Republican River to ensure Colorado's compliance on the North Fork.

Nebraska has built two similar augmentation projects. One pumps as much as 15,000 to 20,000 acre-feet of groundwater annually and pours it into Rock Creek, a distant tributary of the Republican River. The other, the Nebraska Cooperative Republican Platte Enhancement Project (N-CORPE), can pump up to 65,000 acre-feet of deep groundwater from beneath Lincoln County, Nebraska, and pour it into Medicine Creek, a tributary of the Republican River, and into the Platte River system as well. In 2014, Nebraska's Rock Creek and N-CORPE augmentation projects together pumped 65,000 acre-feet of groundwater into the Republican River system. While these projects are expensive — NCORPE alone cost approximately $130 million — they are less expensive than reducing groundwater pumping to comply with the Republican River Compact. Absent the Rock Creek and N-CORPE plans, compact requirements would force the retirement from irrigation of approximately 330,000 acres in Nebraska's portion of the Republican River Basin, causing a commensurate decline in assessed land values of between $500 and $900 million. Overview, N-CORPE, http://www.ncorpe.org/overview (last accessed Mar. 5, 2017).

Interstate Litigation

Streamflow Impacts

Artificial Delivery

Cautions

Equitable Apportionment (Allocation)

Reclamation Projects' Impacts

Groundwater Revolution

Compacts Protection

Hydrological Imbalance

The impact of these augmentation plans has been substantial. With a combined annual capacity of 110,000 acre-feet, these three augmentation plans can compensate for significant groundwater over-pumping in Colorado and Nebraska under the Republican River Compact. Hydrologically, they rely upon and deplete largely non-renewable groundwater; ironically, they cause their own, additional depletions to streamflows, which in turn must also be offset under the compact accounting. *Kansas v. Nebraska & Colorado*, FSS, 2002, §IV.H, at 25. These hydrological facts aside, augmentation plans have already made a significant impact on the way in which states manage their compact allocations. Unlike delivery compacts such as the Colorado River Compact or the Rio Grande Compact, the Republican River Compact effectively adopted something like the precautionary principle: it allocates the water supplies of the basin across its various sub-basins and requires retrospective accounting. (Republican River Compact, art IV, ch. 104, 57 Stat. 86, 88-89 (1943)). These features encouraged a certain amount of conservatism in how the states planned their water consumption — a conservatism that the groundwater revolution sorely tested, a test that the states mostly failed. By contrast, augmentation not only enables augmenting states to replace surface water supplies with increased groundwater pumping; it also enables them to retime the rivers flows across the basin. Augmentation has thus changed the dynamics of compliance from one dependent upon the basin's natural hydrology to one built upon an artificial water delivery system.

VI. Conclusion

OBSERVATIONS ABOUT INTERSTATE WATER LITIGATION

This article began with an assertion of the underlying structures of interstate water relations. It has surveyed how the groundwater revolution forced litigation, which in turn has produced decisions and settlements that have transformed those relations over the past half-century. With these historical developments in mind, let it end with some observations about that transformation. Readers should receive them with two cautions, however. First, be mindful of the tangled coexistence of the Court's federal common-law jurisprudence concerning interstate water relations with the unique features of each interstate basin, compact, and decree. Second, beware of "the old familiar story of heroic efforts to subdue a desert and at the same time maintain an action in court over a contested water right." Mead at 307 (quoting Professor S. Fortier, of Bozeman, Montana).

The first observation concerns balance. The first half-century of interstate water disputes was tumultuous, but it eventually achieved a workable détente between two recurring rivalries: those between states, and those between the states and the United States. The year 1902 witnessed both the filing of *Kansas v. Colorado* and the enactment of the Reclamation Act; five decades later, most of the West's important interstate river basins had been allocated pursuant to interstate compacts or decrees, according to the doctrine of equitable apportionment. The compacts called for joint action by the states and the United States, including the protection of federal investments and interests in interstate basins — typically, reservoirs and irrigation projects upon which the compacting states predominantly depended for their water supply. The Court protected the compact mechanism against rival state law claims, ensuring the security and durability of the states' equitable apportionments. *Hinderlider v. La Plata River & Cherry Creek Ditch Co*., 304 U.S. 92 (1938). Congress and the Executive, through Reclamation and the Corps, built most of the West's interstate water infrastructure accordingly, in general (but not complete) deference to state law. With the titanic exception of *Arizona v. California* (1952-1963), the 1950s and 1960s produced relatively little interstate water litigation in the West. Federal reservoir and irrigation projects regulated and stabilized interstate surface water supplies, which were, for a time, their principal and even exclusive water supplies.

Yet the groundwater revolution destabilized these supplies, eventually overwhelming surface water diversions across the West. That loss of stability eventually caused a collision between federal surface-water infrastructure and nonfederal groundwater development. By the 1970s the ever-lowering water levels of Reclamation reservoirs had become sources of interstate conflict — and indicators of the growing hydrological imbalance inflicted by excessive groundwater pumping. Yet the Court, as well as the litigant states, largely addressed that imbalance — largely because the most prominent interstate groundwater cases were compact cases. Compacts provide a fundamental protection to their member states: the Court can interpret and enforce compacts, but it cannot rewrite them. *Texas v. New Mexico*, 462 U.S. 554, 564 (1983). Compacts achieve equitable allocations of basin water supplies, and once the states (and Congress) have fixed those allocations, the Court will not order relief inconsistent with their terms, "no matter what the equities of the circumstances might otherwise invite." *Id*. Accordingly, the Court required the integration of the effects of groundwater pumping on compacted river basin water supplies, mitigating — for a time — the seriousness of the hydrological imbalance wrought by the groundwater revolution. Despite these decisions, however, groundwater's dominance has continued, exacerbating the already profound hydrological imbalance in western water. To comply with compacts in groundwater-dependent basins, states are making unprecedented investments in groundwater augmentation projects. Across the West's groundwater-dependent interstate river basins, the solution to an upstream state's overpumping of groundwater is to pump groundwater — but then to deliver it to the stream.

Interstate Litigation

Jurisdictional Asymmetry

The second observation also concerns balance: specifically, the difficult balancing problems within jurisdiction and water-based federalism. The dominance of groundwater development has revealed problems of jurisdictional asymmetry. Between rival states, the Court's jurisdiction is both original and exclusive. U.S. Const. art. III, § 2, cl. 2; 28 U.S.C. § 1251(a). Furthermore, there must be no alternative forum to resolve the conflict. *Mississippi v. Louisiana*, 506 U.S. 73, 77 (1992). Between a state and the United States, however, jurisdiction is original but not exclusive, and the appropriate forum is federal court, as in the major cases involving Reclamation or the Corps. Unless the United States waives its sovereign immunity, the Court lacks jurisdiction to decide the case — to determine the appropriate rights, duties, and roles for these federal entities, which have become the pivotal and dominant actors in interstate river basins — even if the United States is a necessary party. *Idaho v. Oregon & Washington*, 444 U.S. 380, 386-91 (1980). This asymmetry has not traditionally been a problem in interstate compact litigation, largely because federal interests receive explicit protections in most compacts, even if the United States is not a signatory party to them, and water rights for federal projects within compacted basins are obtained under state law.

Cooperative Federalism Risks

Nonetheless, there are troubling signs that the established structures of cooperative federalism in western water are falling out of balance, largely because the states' continued over-dependence on groundwater pumping has placed that balance under unprecedented stress. The federal role in compact litigation has become inconsistent and unpredictable, producing the legal equivalent of asymmetrical warfare. Consider the contrast between recent litigation over the Republican River Compact and the current litigation concerning the Rio Grande Compact. In the former, the Department of the Interior (Interior) played a minimal role. While it recommended that the Court accept Kansas's motion for leave, it did not intervene on behalf of its Reclamation projects in the Republican River Basin, which service irrigators in both Nebraska and Kansas from a common reservoir, Harlan County Lake. Far too late, Interior issued a comprehensive critique of Nebraska's excessive groundwater pumping and its deliberate hostility to surface water irrigation, in a demand letter that appears in retrospect to be more of a gesture than a commitment to defend Reclamation's own projects. By contrast, in the Rio Grande litigation, the United States has intervened and, in what appears to be an unprecedented decision, gone so far as to assert a cause of action against a state under an interstate compact to which it is not a signatory party, seeking injunctive relief against New Mexico to protect surface water irrigators in New Mexico and Texas who share a common dependence upon Elephant Butte Reservoir. (Exception of the United States and Brief for the United States in Support of Exception, at 32-48, *Texas v. New Mexico & Colorado*, No. 141 Orig. (June 2017)). In short, the United States of *Kansas v. Nebraska & Colorado* is unrecognizable to the United States of *Texas v. New Mexico & Colorado*.

Federal Intervention

US Claims to Groundwater

Outside of these different litigation arenas, the United States continues to make jurisdictional claims to western groundwater, provoking predictably reactionary responses from western legislators. In 2014, the United States Forest Service proposed a groundwater rule that would increase federal supervision of groundwater withdrawals from national forest lands, potentially at the expense of state jurisdiction. The Service withdrew the directive after a year of intensive criticism from western governors, congressmen, and state interests. United States Department of Agriculture, Forest Service, Notice of Withdrawal of Proposed Directive, 80 Fed. Reg. 35299 (*withdrawn* June 19, 2015). Western senators responded with "The Water Rights Protection Act of 2017," which would prohibit the federal government from conditioning federal land use permits on the transfer of water rights to the United States, on the acquisition of water rights on behalf of the United States, or upon the limitation and modification of existing rights, including groundwater rights. S. 1230, 115th Cong. § 3 (2017). Notably, the bill would prohibit the Secretary of the Interior and the Secretary of Agriculture from asserting "any connection between surface and groundwater that is inconsistent with such a connection recognized by state law." *Id*. at § 4(2)(B). There are even troubling signs from the Court itself: one Special Master has gone so far as to hold that the Court's power to interpret compacts "is so robust as to be almost indistinguishable from the act of rewriting." *Kansas v. Nebraska & Colorado*, 2013 Report at 40.

States' Reaction

Rewriting Compacts?

In response to the unpredictability and inconsistency of federal actions and positions, there are similarly troubling signs of the states' withdrawal from these long-established structures. In the Republican River Basin, the RRCA (Republican River Compact Administration) has rediscovered interstate comity by way of a shared hostility to Reclamation. Kansas has faced hydrological-political reality and grudgingly accepted Colorado's and Nebraska's augmentation plans; it has become clear that neither state will substantially reduce groundwater pumping to comply with the Republican River Compact. Frustrated by Reclamation's understandable concerns about augmentation, the RRCA has passed a series of resolutions that embrace augmentation and define compact compliance downwards, in apparent defiance of the compact, which requires the safeguarding of federal infrastructure. *See* Republican River Compact, ch. 104, 57 Stat. 86 (1943) at art. X (protecting the property of the United States). In the Republican River Basin at least, anti-federalism has replaced cooperative federalism. The United States remains reluctant to protect its own interests, as well as the irrigators who depend upon surface water stored in Reclamation reservoirs. In deference to groundwater irrigators, the RRCA may have engineered an efficient breach of its own.

Anti-Federalism

Interstate Litigation

Source of Supply Prevails

Eastern Conflicts & Lack of Compacts

Prior Appropriation Doctrine

Scarcity

Beneficial Use v. Priority

Litigation Pressure on Priority

What then, of the surface water irrigators within Reclamation projects whom their parent states have effectively abandoned? Here, the boundaries between compacting states may be yielding to the boundaries between surface and groundwater. In *Kansas v. Nebraska & Colorado*, surface water irrigators in Nebraska assisted Kansas, because they shared a common interest in seeking reductions in Nebraska's groundwater pumping. When the Court refused to consider, much less order, such reductions, they sought remedies within Nebraska with a similar lack of success. *Hill v. State*, 894 N.W.2d 208 (Neb. 2017). And in *Texas v. New Mexico & Colorado*, surface water irrigators in New Mexico who depend upon Reclamation's Rio Grande Project have aligned with Texas and the United States, in defiance of their own State Engineer, who asserts the sovereign right to allow continued groundwater pumping at their expense. In both basins, irrigators' dependence upon the source of water supply — whether surface or groundwater — is trumping allegiance to their parent states. [*See* Part IV, original article].

By contrast, eastern states have generally not entered into interstate compacts — and that has raised its own set of structural problems, even as upstream states have condoned levels of groundwater development that have clearly injured downstream states. [See Part IV, D. original article]. Without a compact or decree in place, states claiming that they have been deprived of water supplies managed or regulated by federal entities have been forced to pursue separate and arguably redundant litigation avenues to obtain relief. At this writing, *Florida v. Georgia* provides a cautionary tale reminiscent of the Republican River litigation: without the active involvement of the relevant basin-wide federal agency — Reclamation for the Republican River Basin, the Corps for the ACF Basin — interstate litigation does not provide a satisfactory result. Conversely, *Mississippi v. Tennessee* reveals what is perhaps the limit case of that frustration: an attempt to avoid the doctrine (and the inevitable structures) of equitable apportionment altogether. The Court should probably not have accepted either case. *Florida v. Georgia* is premature before the Corps decides how to manage the ACF Basin, and in such a way that it can be bound by that decision. In *Mississippi v. Tennessee*, Mississippi has requested the Court to reject or just ignore over a century of its own consistent equitable apportionment jurisprudence.

These problems of balance in hydrology, jurisdiction, and federalism lead to a third observation, one concerning doctrine. Western water law was founded upon the original condition of permanent aridity. That condition justified the prior appropriation doctrine, which was intended to protect, clearly and quickly, those with the oldest and thus best water rights. MEAD, at 65-66. Without priority administration in times of drought, shared beneficial use would be insufficient for all rights, diluting them all into waste. Likewise, the principal purpose of interstate water compacts is to fix the equitable allocation of scarce water supplies among states that would rather not share them. (*See* Norris Hundley, Jr., *Water and the West: The Colorado River Compact and the Politics of Water in the American West* (2d ed., 2009), at 53.) These compacts matter most in times of drought, when water is most valuable, and so the temptation to overuse is greatest. The Court's application of the prior appropriation doctrine at the interstate level motivated the first interstate water compact, the Colorado River Compact, and most interstate compacts stress the importance of maximizing beneficial uses of the allocated water.

As long as most of the usable waters of the West ran above ground, western water law and interstate water compacts operated in a workable tandem. Before the groundwater revolution, prior appropriation and beneficial use were united indivisibly. *See, e.g.*, *Washington v. Oregon*, 297 U.S. 517, 545 (1936) ("The essence of the doctrine of prior appropriation is beneficial use ... ." (internal citations omitted)). In practice, however, the groundwater revolution led states to decouple them, to place the principle of beneficial use over that of priority, and to regulate groundwater less stringently than surface water. For a time, the delayed impact of groundwater pumping on streamflows, and the imperfect understanding of the relationship between groundwater pumping and streamflow depletions, enabled these policy decisions. But as depletions became more obvious and their causes better understood, these decisions destabilized the administration of interstate compacts and eventually made their violation inevitable. Over the past fifty years, litigation to enforce these compacts has clarified their meaning, their scope, their measure, and their power.

Yet in making the states' obligations clear, litigation has produced an unintended consequence. The states have been reluctant to reduce groundwater pumping, and the Court has been reluctant to order such reductions or otherwise to intrude upon state law. This shared reluctance has created a divergence between the means of compliance and some of the founding principles of western water law, most prominently the prior appropriation doctrine. The pressure of interstate litigation on the doctrine has largely gone unrecognized by legal scholars. Scholarly literature on the death, life, or irrelevance of the prior appropriation doctrine has generally been limited to discussing federal environmental law and innovations in state water law, such as the accommodation of instream flow rights. But it has long been an open secret among those who must comply with a decree from the Court. As an engineer candidly declared in the wake of *Texas v. New Mexico*, "[a]dministration of priorities in the Pecos River Basin...is the only option currently available for meeting the delivery obligation under the Amended Decree. That option should be avoided at all costs." G. Emlen Hall, *High and Dry: The Texas-New Mexico Struggle for the Pecos River* 119-21, at 205 (quoting John Whipple, engineer for the New Mexico Interstate Stream Commission).

Interstate Litigation

Groundwater v. Surface Water Regulation

The Nebraska Supreme Court has recently reached a similar conclusion, albeit one resting on different jurisdictional and doctrinal foundations. *See Hill v. State*, 894 N.W.2d 208 (Neb. 2017). In a decision denying surface irrigators' inverse condemnation claims, the court essentially held that prior appropriation rights to the surface waters of the Republican River in Nebraska — rights which date back to the nineteenth century and upon which Nebraska's Reclamation projects substantially depend — are essentially defenseless against junior groundwater permits, because Nebraska has made a political bargain with its groundwater irrigators. Nebraska has decided to delegate groundwater pumping to NRD's, which Nebraska DNR does not control; but in meeting its compact obligations, it has chosen to administer surface water rights — which it does control — before entertaining the politically suicidal option of reducing groundwater pumping. Thus, claiming as universal the protections established in *Hinderlider*, Nebraska has pursued, so far successfully, a peculiar but effective compliance strategy. Nebraska DNR has exercised its regulatory power over surface water in water-short years by shutting off all prior appropriation surface rights in the Republican River Basin; but because it has no authority to curtail groundwater pumping, it is thus excused from curtailing groundwater pumping during those same years. *In re Cent. Neb. Pub. Power & Irrigation Dist.*, 699 N.W.2d 372, 378 (Neb. 2005). Despite their senior priorities, surface water users in the basin "are being singled out to bear the burden of water shortages for the benefit of the groundwater using majority." Anthony Schutz, *Takings Litigation against Nebraska Department of Natural Resources*, Rocky Mtn. Mineral L. Found. Water Law Newsletter, vol. L, No. 2, 1-3 (2017) at 3. In both New Mexico and Nebraska, then, the means by which upstream states are fulfilling their compact obligations have raised fundamental questions about the efficacy of the prior appropriation doctrine in practice.

Negotiation v. Litigation

A final observation concerns interstate litigation itself. With all of these problems in mind — political, jurisdictional, and doctrinal, but always hydrological — we are left with a recurring question asked by risk-averse downstream governors, thoughtful journalists, and the often-weary Court: are interstate water conflicts best resolved or even resolvable by litigation? The answer, to conclude with lawyerly equivocation, depends upon the basin. Commentators have recently pointed to the agreements reached on the Colorado River as proof that negotiation is always superior to litigation. The Colorado River is the most important river in the West, but it is exceptional. Its "law of the river" combines decades of binding federal law and federal and state agreements into a unique jurisprudence. Moreover, federal law confers upon the United States a central management role in the Colorado River Basin from which it cannot shrink — a role that convinced the Court to issue its sole decision on congressional apportionment in 1963, and one that continues to this day. *See Arizona v. California*, 373 U.S. 546, 560 (1963). The Colorado's importance to desert megalopolises such as Denver, Las Vegas, Phoenix, and Los Angeles, as well as its vast hydropower resources, make for considerably higher stakes compared to lesser and primarily agricultural theaters such as the Pecos, Arkansas, Republican, and Rio Grande Basins.

Colorado River Stakes

Depletion Compels Litigation

And most tellingly for this article, the parties to the Colorado River Compact have not confronted the problem of groundwater depletion — at least not yet. In other groundwater-dependent interstate river basins of the West, litigation has forced defendant states to own the consequences of their groundwater overuse, in the form of damages, remedies, legal reforms, and compliance strategies. Without the weapon of litigation — without the guns of downstream states fixed upon the upstream "frontiers of their kingdoms" — it is certain that they never would have done so. Litigation has also forced states to enter into negotiated settlements and interstate compact resolutions whose endurance will certainly be tested over the next fifty years — at both the interstate and intrastate levels. In sum, litigation is not so much the answer to conflicts over interstate groundwater as it is their inevitable consequence — but one both ultimately necessary and the most effective in making the requisite "interstate adjustments" that the groundwater revolution has demanded.

For Additional Information:
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Burke W. Griggs is an associate professor of law at Washburn University. He specializes in American water law, and has published articles on groundwater law, surface water-groundwater issues, interstate water litigation, and water policy. In his prior capacity as an assistant attorney general for the State of Kansas, Mr. Griggs represented the state in *Kansas v. Nebraska & Colorado* (2009-2015), an original action before the Supreme Court to enforce the Republican River Compact. Mr. Griggs also served as counsel of record in Kansas's first reserved tribal water rights settlement, with the Kickapoo Tribe of Kansas. As Senior Legal Counsel to the Chief Engineer of the Kansas Division of Water Resources, he defended DWR in court and drafted legislation enabling the formation of Local Enhanced Management Areas for high-stress regions of the High Plains-Ogallala Aquifer in Kansas. Mr. Griggs is a fellow at the Woods Institute for the Environment at Stanford University, where he contributes to its Water in the West Project. He holds a B.A. from Stanford, a Ph.D. from Yale, and a law degree from the University of Kansas.

WATER BRIEFS

SEPTEMBER CLIMATE ANOMALIES US

The National Oceanic & Atmospheric Administration's (NOAA's) National Centers for Environmental Information (NCEI) provides monthly summaries of weather in the United States. The complete US climate report for September 2018 became available on October 15 and noted a number of climate anomalies.

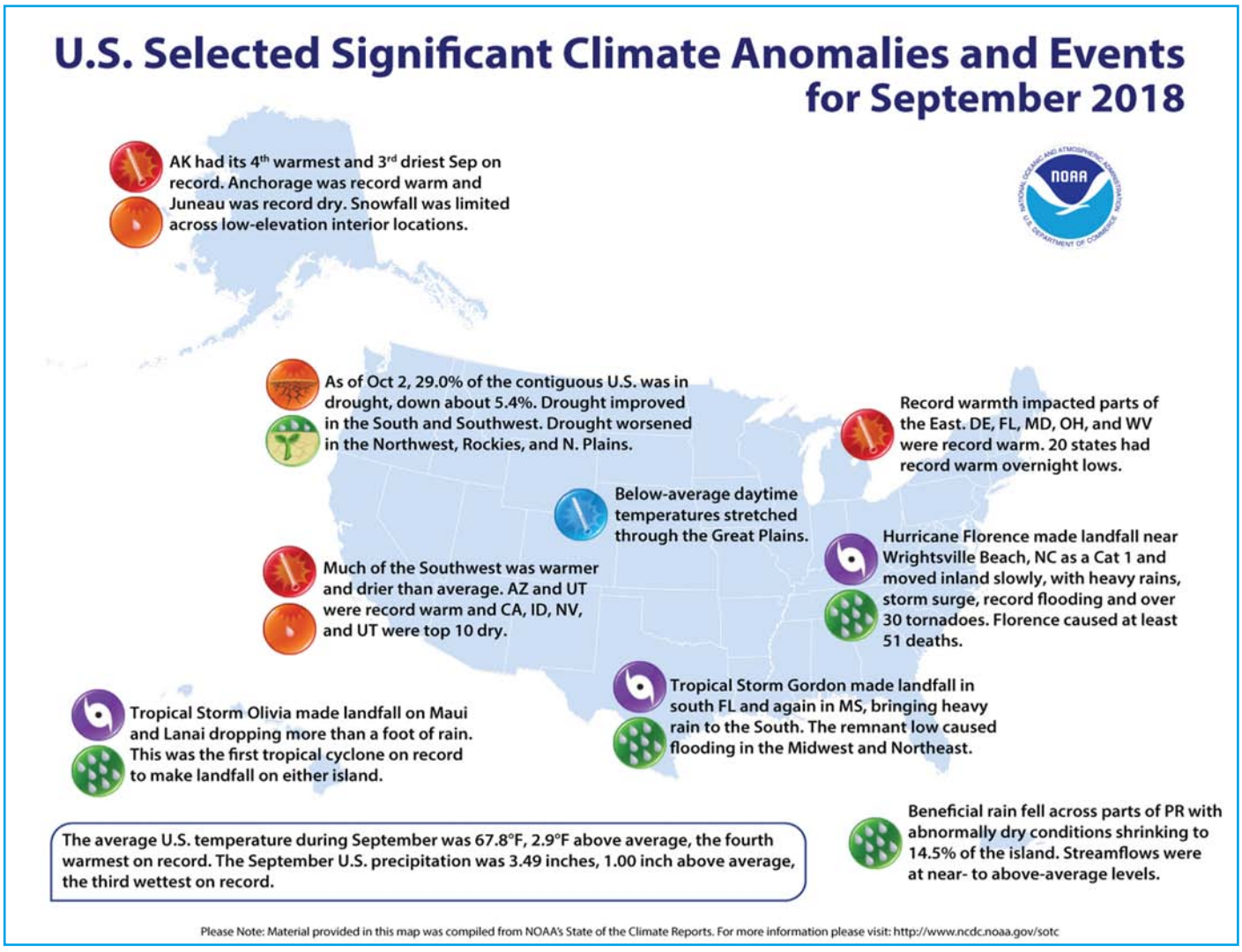
For September, the average contiguous US temperature was 67.8°F, 2.9°F above the 20th century average. Record warm conditions were observed for parts of the Southwest, Southeast, Midwest, and Mid-Atlantic with near- to below-average temperatures across parts of the Northwest and Great Plains. For the year-to-date, the contiguous US temperature was 57.0°F, 2.0°F above the 20th century average and the eighth warmest January-September on record.

The September precipitation total for the contiguous US was 3.49 inches, 1.00 inch above average, and marked the third wettest September in the 124-year period of record. Tropical systems fueled record-setting precipitation across parts of the eastern US. Hurricane Florence made landfall near Wrightsville Beach, North Carolina, bringing torrential rainfall, prolonged storm surge and record flooding to the Carolinas. For the year-to-date, the national precipitation total was 25.20 inches, 2.00 inches above average, the 13th wettest January-September on record.

NCEI has updated the "2018 billion-dollar weather and climate disaster list" to include five additional events: Hurricane Florence; the Western wildfires; the Southwest/Southern Plains drought; a mid-June Colorado hail storm; and a mid-April southern and eastern tornadoes and severe weather event. This brings the year-to-date total to 11 weather and climate disaster events with losses exceeding $1 billion each across the US.

Below average precipitation stretched from the west coast to the Rockies with record low precipitation totals for parts of California, Utah, and Wyoming. For only the fifth time since reliable records began in 1874, Salt Lake City received just a trace amount of rain in September. On the statewide level, California, Idaho, Nevada, and Utah each had a "top ten" dry month.

For info: John Leslie, NOAA, 301/ 713-0214 or john.leslie@noaa.gov
National Climate Report website: www.ncdc.noaa.gov/sotc/national/201809



WATER BRIEFS

STORMWATER CAPTURE CA
WATER REUSE / STORAGE

The Orange County Water District (OCWD) has made significant investments in researching and developing cutting-edge technology, such as water reuse, to help the region weather droughts. On the chance that a large rain event does occur, OCWD has found a way to capture more stormwater without having to spend tens of millions of dollars in new infrastructure. The solution is to collaborate with the Army Corps of Engineers (Corps) to conserve a larger pool of water behind Prado Dam in Riverside County.

Since 2006, OCWD and the Corps have had an agreement in place to capture stormwater behind the dam up to an elevation 498 feet above mean sea level (amsl) during the flood season, which is from October 1 to February 28, and up to elevation 505 amsl during the non-flood season. On October 4, the Corps approved a Major Deviation (MD) to the Prado Dam Water Control Manual that will now allow OCWD to conserve water up to 505 amsl *year-round* for the next five years. Previously, the Corps granted deviations intermittently during past flood-seasons.

This historic, long-term MD could result in an additional 10,000 acre-feet (AF) (32 billion gallons) of water, per storm event, that OCWD would put back into the Orange County Groundwater Basin where it would become part of Orange County's drinking water supply. Ten thousand AF is a year's supply of water for about 80,000 people. Without the deviation, the stormwater would simply run into the Pacific Ocean — the cost to purchase the equivalent amount in imported supplies from Northern California or the Colorado River would be more than $10 million.

OCWD and the Corps are also currently working on a long-term plan called the Prado Basin Feasibility Study that, if successful, will lead to permanently changing the conservation level to 505 amsl year-round. The plan would also include additional restoration of ecosystems behind the dam, which has led to OCWD's successful recovery of an endangered California songbird, the least Bell's vireo. OCWD is also working closely with the Corps and the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography to study atmospheric rivers, which cause large rainfall events in California (for more info on atmospheric rivers, *see* Morrison, *TWR* #164). This research will ultimately lead to Forecast Informed Reservoir Operations (FIRO), which is a proposed management strategy to use modern weather forecasting, runoff modeling, and watershed monitoring to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions. The ultimate goal of FIRO is to update dam water conservation and flood control guidelines to improve water management and environmental outcomes without diminishing flood risk management or dam safety.

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FLOOD RESTRICTIONS TX
SILT & DEBRIS

On October 22, the City of Austin, Texas issued emergency water use restrictions including a boil advisory and request to restrict water use. The restrictions were necessary due to a high level of silt and debris in Austin's water supply lakes from flooding in the area, resulting in an urgent need to reduce water demand to allow treatment plant operations to stabilize.

During the restrictive period, which lasted until October 28th, all outdoor water use was prohibited. Customers were prohibited from: using water for irrigation or testing of irrigation equipment; washing vehicles, including at commercial car wash facilities; washing pavement or other surfaces; adding water to a pool or spa; conducting foundation watering; or operating an ornamental fountain or pond, other than aeration necessary to support aquatic life. The City asked that violations of these restrictions be reported to Austin 3-1-1 and noted that the support in reducing water use was needed to help stabilize Austin's water treatment plants.

The emergency water use restrictions were necessary to ensure water was available for firefighting and basic needs. Historic flood waters flowing into the region's water supply lakes, the Highland Lakes, contained much higher levels of debris, silt, and mud. Austin water experienced reduced water treatment capacity.

Austin Water issued a city-wide boil water notice for all customers. To ensure that water is safe, customers were asked to boil water used for drinking, cooking, or ice for three minutes.

Other actions were taken by the City to ensure the health and safety of the community during this flood event. These included activating the Austin-Travis County Emergency Operations Center to closely monitor the evolving conditions, closing the City's waterway, closing Parks and Recreation facilities along City waterways, monitoring and managing low-water crossings, and working with neighbors to the west of Austin to respond to their own flood emergencies.

For info: Austin's website at: austintexas.gov/boilh2o

RESIDENTIAL SHUTOFFS US
WATER AFFORDABILITY

On October 22, Food & Water Watch published the results of is new survey in a report entitled, "America's Secret Water Crisis: National Shutoff Survey Reveals Water Affordability Emergency Affecting Millions." The first-ever nationwide assessment of water shutoffs for nonpayment has revealed that households across the US are facing an alarming and hidden water affordability crisis. Food & Water Watch contacted the two largest water systems in each state, receiving responses back from 73 utilities. The average responding water utility shut off 5% of households for non-payment in 2016. Among responding utilities, more than half a million households lost water service for nonpayment, affecting an estimated 1.4 million people in 2016. Based on this data, Food & Water Watch estimates that 15 million people in the United States experienced a water shutoff in 2016, or a shocking 1 out of every 20 households.

WATER BRIEFS

Top findings of the survey include the fact that fifteen utilities reported shutoff rates of more than 10%. The states with the highest shutoff rates are mostly concentrated in the South: Oklahoma, Arkansas, Louisiana and Florida. Jacksonville, Florida's high shutoff rate (16%) affected 41,311 households, or an estimated 107,409 people. Phoenix, Arizona's shutoff rate, 9%, affected over 33,000 households, or 94,000 people. Tucson, Arizona had the highest shutoff rate in the West, at 11%.

High rates of shutoffs occurred in midwestern states including South Dakota, Iowa, Michigan and Wisconsin. There is no data for four states including New Jersey and West Virginia, where private companies operate the two largest utilities. Only one private company responded to the survey, representing a 9% response rate. The response rate of public utilities was 93%.

The highest shutoff rates were disproportionately in cities with more people living in poverty, more unemployment and more people of color. While the average city with the most shutoffs is low-income, not all low-income cities engage in mass shutoffs. Jackson, Mississippi had high rates of poverty (31%) and a zero percent shutoff rate. Jackson has not had a water or sewer rate increase since voters approved an increase to the sales tax to help improve the city's infrastructure. Meanwhile, some cities surveyed, like Eau Claire, Wisconsin and Leominster, Massachusetts do not shut off water service for non-payment at all.

The report recommends the following policies:

- Local governments should set up affordability programs, and employ best practices to ensure that households have sufficient time and notice to pay their bills prior to disconnection.
- States should pass legislation requiring utilities — including privately owned ones — to track water shutoffs for nonpayment and reconnections of these affected households, disclose that information to the public on the utility website and at a central location managed by a state agency, and ensure that the information is publicly available.
- The federal government can act to support localities by providing the funding relief needed to ensure that every person in the country has safe and affordable water service.

For info: Food & Water Watch, Report at: www.foodandwaterwatch.org/insight/americas-secret-water-crisis

RATE LITIGATION CA

SETTLEMENT OFFER

On October 25, San Diego County Water Authority Board Chair Jim Madaffer sent a letter to the Metropolitan Water District of Southern California's (MWD's) Board of Directors that lays out a potential compromise approach by both parties designed to end nearly a decade of litigation over MWD's rates. The letter includes specific, practical terms that respect both the San Diego County Water Authority's (SDCWA's) and MWD's perspectives towards an equitable conclusion, according to SDCWA's press release. "Concluding all pending court cases is in the best interest of everyone involved, and it would allow us to begin a new era of collaboration on other important regional and state issues," said Madaffer, who started his tenure as chair on October 1. "I hope MWD will embrace this gesture of good faith to seek settlement, and that we can do so in an expeditious and fair manner."

SDCWA filed suit in 2010 seeking to invalidate MWD's rates, and then filed additional suits in 2012, 2014, 2016 and 2018 because MWD kept adopting rates using the same methodology and flawed cost allocations. A series of court decisions have been issued in the 2010 and 2012 cases. The other cases have been stayed in Superior Court during the appellate process on the initial two lawsuits. For more information about the litigation, see Water Briefs, TWR #138 and #146 and SDCWA's website listed below.

Madaffer's letter builds on the commitment of his predecessor, prior SDCWA Board Chair Mark Muir, to seek an end to lawsuits that started in 2010 and involve billions of dollars of contested rates and charges. SDCWA won several significant items in two cases covering MWD's rates for 2011-2014, including additional rights to approximately 100,000 acre-feet a year of MWD water, invalidation of an illegal contract clause that MWD used to deny support for local supply development projects, and damages and interest on tens of millions of dollars of unlawful Water Stewardship Rate charges by MWD. The courts allowed MWD to continue charging historic State Water Project costs in water transportation rates charged to SDCWA. Key terms outlined in Madaffer's letter include:

- Neither party should be expected to give up anything it won in court.
- MWD would change the way it charges for delivering SDCWA's independent supplies from the Colorado River by adopting a fixed price and tying future price increases to an inflation index each January 1.
- SDCWA would drop pending claims challenging the legality of MWD's Water Stewardship Rates that MWD charges on the purchase of MWD water supplies.
- The SDCWA would accept $5 million in attorneys' fees and costs (reduction from $8.9 million the trial court awarded to SDCWA).
- MWD's Board would approve a pending agreement to provide through its Local Resource Program funding for the Carlsbad Desalination Project, the City of San Diego's Pure Water Project, the Padre Dam-East County Advanced Water Purification Project and other pending local supply project agreements.
- SDCWA would be granted a sub-account in MWD's Colorado River Lake Mead Storage Project to store 200,000 acre-feet of eligible SDCWA supplies in Lake Mead, which would benefit both MWD and the Colorado Basin states.

The letter is available on SDCWA's website shown below.

For info: SDCWA website: www.sdcwa.org/mwdrate-challenge

WATER BRIEFS

GROUNDWATER RECHARGE CA BENEFICIAL USE?

Any diversion and use of surface water in California requires a water right. To receive a new water right permit, an entity that wants to appropriate surface water must file an application with the California State Water Resources Board (Water Board). The Water Board may only approve an application if it determines that the proposed use of the water is for a reasonable and beneficial purpose. Currently, there is uncertainty about whether — and, if so, under what circumstances — the Board will consider groundwater recharge to be a beneficial use of water. California law makes clear that the act of recharging groundwater, alone, is not a beneficial use of water. Instead, the specific purpose of the recharge is key.

Although they may employ the same range of recharge techniques, there are important distinctions between: (1) recharge for the purpose of storing water to be subsequently extracted by pumping for above-ground use under the water right; and (2) recharge for a non-extractive use without the intention to later directly remove the water from below ground by pumping under the water right. Because most non-extractive uses are not explicitly listed as beneficial uses in statutes or regulations, the Water Board determines, on a case-by-case basis, whether a non-extractive use amounts to a beneficial use of surface water. Details on the process for applying for a surface water right or water right change for non-extractive use are slim to non-existent. This may discourage potential rechargers from submitting an application for such a use.

The University of California - Berkeley in August 2018 issued a "Water Issue Brief" that assesses the current status of groundwater recharge in relation to the beneficial use doctrine and provides recommendations for clarifying current policy in order to encourage groundwater recharge projects. The Water Issue Brief is available at the website listed below. Miller, K, N Green Nylen, H Doremus, D Owen, and A Fisher. 2018. *When is Groundwater Recharge a Beneficial Use of Surface Water in California?* Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA. 8 pp.

For info: www.law.berkeley.edu/research/clee/research/wheeler/gw-recharge-beneficial-use/

CWA IMPACTS US POLLUTION REDUCED

A study from the University of California - Berkeley shows that the Clean Water Act (CWA) dramatically cut pollution in US waterways. The 1972 CWA has driven significant improvements in US water quality, according to the first comprehensive study of water pollution over the past several decades. Journal Reference: David A. Keiser, Catherine L. Kling, Joseph S. Shapiro. *The Low But Uncertain Measured Benefits of US Water Quality Policy*. Proceedings of the National Academy of Sciences, 2018; 201802870 DOI: 10.1073/pnas.1802870115.

The team analyzed data from 50 million water quality measurements collected at 240,000 monitoring sites throughout the US between 1962 and 2001. Most of 25 water pollution measures showed improvement, including an increase in dissolved oxygen concentrations and a decrease in fecal coliform bacteria. The share of rivers safe for fishing increased by twelve percent between 1972 and 2001.

Despite clear improvements in water quality, almost all of 20 recent economic analyses estimate that the costs of the CWA consistently outweigh the benefits, the team found in work also coauthored with researchers from Cornell University. These numbers are at odds with other environmental regulations like the Clean Air Act, which show much higher benefits compared to costs. "Water pollution has declined dramatically, and the Clean Water Act contributed substantially to these declines," said Joseph Shapiro, an associate professor of agricultural and resource economics in the College of Natural Resources at UC Berkeley. "So we were shocked to find that the measured benefit numbers were so low compared to the costs." The researchers propose that these studies may be discounting certain benefits, including improvements to public health, or a reduction in industrial chemicals not included in current water quality testing. The analyses appear in a pair of studies published in the Quarterly Journal of Economics and the Proceedings of the National Academy of Sciences.

Since its inception, the Clean Water Act has imposed environmental regulations on individuals and industries that dump waste into waterways, and has led to $650 billion in expenditure due to grants the federal government provided municipalities to build sewage treatment plants or improve upon existing facilities. However, comprehensive analyses of water quality have been hindered by the sheer diversity of data sources, with many measurements coming from local agencies rather than national organizations.

In addition to the overall decrease in water pollution, the team found that water quality downstream of sewage treatment plants improved significantly after municipalities received grants to improve wastewater treatment. They also calculated that it costs approximately $1.5 million to make one mile of river fishable for one year.

For info: www.sciencedaily.com/releases/2018/10/181009115102.htm

HIGH FLOW TEST CO RIVER GLEN CANYON DAM EXPERIMENT

The Bureau of Reclamation (Reclamation), under the direction of the Department of the Interior, planned to increase water releases from Glen Canyon Dam beginning on November 5th and ending November 8th. This release is in support of a high flow experiment (HFE) in partnership with the National Park Service, US Fish and Wildlife Service and US Geological Survey. Releases were to increase early November 5th then peak at approximately 38,100 cubic feet per second at 2:00 p.m. that day. Flows were intended to continue at that peak of full bypass for 60 hours (four days including ramping from baseflows to peak release) to move accumulated

WATER BRIEFS

sediment downstream to help rebuild eroded sandbars and beaches through Glen and Grand Canyons. These sandbars and beaches are important for life in and along the river.

Reclamation and National Park Service officials advised river users to exercise caution along the Colorado River through Glen and Grand Canyons and the easternmost portion of Lake Mead during the entire week of November 5th. Reclamation noted that it would take several hours and up to two days following beginning and end of the HFE for high flow waters to reach and then recede at downstream locations in the canyons, depending on their distance from the dam.

This HFE was to be the first conducted under the 2016 Long-Term Experimental and Management Plan (LTEMP) HFE Protocol; similar HFEs were conducted in 2012, 2013, 2014 and 2016 in accordance with the 2011 HFE Environmental Assessment Protocol. The 2018 HFE was expected to provide resource benefits in the near term and will also provide scientific information to be used in future decision-making.

The HFE as planned should not change the total annual amount of water released from Lake Powell to Lake Mead. Releases later in the water year will be adjusted to compensate for the high volume released during this experiment. According to Reclamation's press release, insights gained from this and previous high flow experiments will continue to assist in the management and operation of Glen Canyon Dam.

For info: USBR website: www.usbr.gov/uc/rm/gcdHFE/index.html

CLIMATE CHANGE **US**

RAPID CHANGES NEEDED

On October 8, the Intergovernmental Panel on Climate Change (IPCC), the UN body for assessing the science related to climate change, issued its *Special Report on Global Warming of 1.5ºC* (*Report*). The *Report* noted that limiting global warming to 1.5ºC would require rapid, far reaching, and unprecedented changes in all aspects of society in the IPCC's new assessment. With clear benefits to people and natural ecosystems, limiting global warming to 1.5ºC compared to 2ºC could go hand in hand with ensuring a more sustainable and equitable society. The *Report* was approved by the IPCC on Saturday in Incheon, Republic of Korea. It will be a key scientific input into the Katowice Climate Change Conference in Poland in December, when governments review the Paris Agreement to tackle climate change.

"One of the key messages that comes out very strongly from this report is that we are already seeing the consequences of 1°C of global warming through more extreme weather, rising sea levels and diminishing Arctic sea ice, among other changes," said Panmao Zhai, Co-Chair of IPCC Working Group I. The *Report* highlights a number of climate change impacts that could be avoided by limiting global warming to 1.5ºC compared to 2ºC, or more. For instance, by 2100, global sea level rise would be 10 cm lower with global warming of 1.5°C compared with 2°C. The likelihood of an Arctic Ocean free of sea ice in summer would be once per century with global warming of 1.5°C, compared with at least once per decade with 2°C. Coral reefs would decline by 70-90 percent with global warming of 1.5°C, whereas virtually all (>99 percent) would be lost with 2ºC.

The *Report* finds that limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities. Global net human-caused emissions of carbon dioxide (CO2) would need to fall by about 45 percent from 2010 levels by 2030, reaching "net zero" around 2050. This means that any remaining emissions would need to be balanced by removing CO2 from the air.

"This report gives policymakers and practitioners the information they need to make decisions that tackle climate change while considering local context and people's needs. The next few years are probably the most important in our history," according to Debra Roberts, Co-Chair of IPCC Working Group II.

For info: www.ipcc.ch

FISH KILL **CO**

SUPERFUND MINE SITE

The Colorado Department of Public Health and Environment (CDPHE) and EPA have determined that a release of contaminated water originating from a mine tunnel at the Captain Jack Mill Superfund site was likely responsible for a fish kill reported on October 22 in the upper portions of Left Hand Creek.

Field monitoring and the results of water samples collected at various locations along Left Hand Creek indicate the water discharging from the Big Five tunnel was more acidic and contained higher levels of heavy metals than in previous water samples. The high acidity and heavy metals, coupled with the seasonal low flows in Left Hand Creek, resulted in water quality impacts approximately five miles below the superfund site.

The Captain Jack Mill site was added to the Superfund national priorities list in 2003. The Colorado Department of Public Health and Environment and EPA have been working to mitigate the impacts of historic mining activities since the cleanup plan was issued in 2008. A portion of the remedy involves an in-tunnel treatment system to improve the quality of the water flowing out of the Big Five tunnel.

Following reports of the October 22 fish kill, EPA and the state health department temporarily closed the flow-through valve on the Big Five tunnel bulkhead and are planning next steps. Over the next several days, the agencies will be monitoring the stream water quality while continuing to assess the in-tunnel treatment system performance and implementing changes to the system as necessary to improve water quality.

The Left Hand Water District tests both raw and treated water on a continuous basis. The intake remains open following test results that met water quality standards showing no impacts to downstream water users.

For info: Meghan Hughes, CDPHE, 303/ 692-3373 or Meghan.hughes@state.co.us

CALENDAR

November 15-16 ID
Idaho Water Users Assoc. 35th Water Law Seminar, Boise. The Riverside Hotel. For info: IWUA, 208/ 344-6690 or www.iwua.org/

November 17 OR
WaterWatch of Oregon's 16th Annual Celebration of Oregon Rivers, Portland. Leftbank Annex, 101 N. Weidler Street. For info: https://waterwatch.ejoinme.org/auction2018

November 20 OR
Portland Harbor Superfund Site Proposed Explanation of Significant Differences Information Session, Portland. Ecotrust Bldg., 721 NW 9th Avenue, 6-8:30 pm. Presented by EPA; Comment Period Ending 12/31/18 - Send comments via e-mail to EPA at HarborComments@epa.gov. For info: Portland Harbor website: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=1002155

November 27-28 DC
Public-Private Partnership Federal Conference: Using P3s to Meet Our Infrastructure Challenges, Washington. Marriott Marquis. For info: www.p3federalconference.com

November 28-29 NV
Nevada Water Law Conference, Reno. Peppermill Resort Spa Casino. For info: CLE Int'l, 800/ 873-7130, live@cle.com or www.cle.com

December 3-4 CA
Climate Change in California Conference, San Francisco. 50 California Street Building. For info: Law Seminars International, 206/ 567-4490 or www.lawseminars.com/

December 5-6 OK
39th Annual Oklahoma Governor's Water Conference & Research Symposium, Midwest City. Reed Conference Center. For info: www.owrb.ok.gov/GWC/

December 6-7 CO
Today's Environmental Agencies: Regulatory Enforcement, Citizen Suits, and the Energy Industries Course, Denver. Le Meridien Denver Downtown. Presented by Rocky Mountain Mineral Law Foundation. For info: www.rmmlf.org

December 6-7 CO
Regulatory Enforcement Conference, Denver. Presented by the Rocky Mountain Mineral Law Foundation. For info: www.rmmlf.org/

December 10 WA
Tribal Natural Resource Damage Seminar, Seattle. Crowne Plaza Hotel, 1113 Sixth Avenue. For info: Law Seminars International, 206/ 567-4490 or www.lawseminars.com/

December 11 WY
Wyoming Water Forum: Environmental Sample Processor for DNA Sampling, Cheyenne. WWDO Conference Room, 6920 Yellowtail Road. Presented by Elliott Barnhart, USGS. For info: http://seo.wyo.gov/interstate-streams/water-forum

December 11-12 OR
Business & The Environment Conference & Expo, Portland. Jantzen Beach Red Lion. Presented by Northwest Environmental Business Council, Oregon Dept. of Environmental Quality, Washington Dept. of Ecology. For info: www.businessandenviroment.com

December 13-14 CA
CEQA Conference, San Francisco. Hilton Union Square. For info: CLE Int'l, 800/ 873-7130, live@cle.com or www.cle.com

January 8 WY
Wyoming Water Forum: Microbial Source Tracking on Listed Streams in the Upper Laramie Basin, Cheyenne. WWDO Conference Room, 6920 Yellowtail Road. Presented by Tony Hoch, Laramie Rivers Conservation District. For info: http://seo.wyo.gov/interstate-streams/water-forum

January 10-11 TX
Texas Water: Past, Present & Future - Water Law Seminar, Austin. Omni Southpark Austin. Presented by Texas Water Conservation Assoc. & Texas Rural Water Assoc. For info: www.twca.org/Public/Public/Water_Law_Seminar.aspx

January 10-11 India
4th Annual National Summit on Sustainable Water and Sanitation Conference, Bangalore. Presented by Nispana Innovative Platforms. For info: https://nswss.com/

January 23-24 CO
The Law of Fracking Conference, Westminster. TBA. Presented by the Rocky Mountain Mineral Law Foundation. For info: www.rmmlf.org

January 23-25 TX
Water for Texas 2019 Conference: The Story of Texas Water, Austin. AT&T Executive Education & Conference Center. Hosted by the Texas Water Development Board. For info: http://waterfortexas.twdb.texas.gov/2019/

January 24 CO
11th Annual Schultz Lecture in Energy by Prof. Jody Freeman, Boulder. Wolf Law Bldg.-Wittemyer Courtroom, Univ. of Colorado. Presented by the Getches Wilkinson Center for Natural Resources, Energy, and the Environment. For info: www.getches-wilkinsoncenter.cu.law/events/

January 24-25 WA
Endangered Species Act Conference - 26th Annual, Seattle. Washngton Athletic Club, 1325 6th Avenue. For info: The Seminar Group, 800/ 574-4852, info@theseminargroup.net or www.theseminargroup.net

February 4-8 WA
18th Annual River Restoration Northwest Symposium, Stevenson. Skamania Lodge. Presented by River Restoration Northwest. For info: www.rrnw.org/program/

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CALENDAR

(continued from previous page)

Feb 7-8 DC & WEB
Environmental Law 2019 Conference, Washington. Washington Plaza Hotel. Presented by the American Law Institute CLE and cosponsored by the Environmental Law Institute. For info: www.ali-cle.org/course/ca012

February 12 WY
Wyoming Water Forum: Water Law and Wyoming, Cheyenne. WWDO Conference Room, 6920 Yellowtail Road. Presented by Abby Boudwyns / Kelly Shaw, WY Attorney General's Office. For info: http://seo.wyo.gov/interstate-streams/water-forum

February 25-26 FL
Deep Well Injection Conference, Miami. Miami-Dade Water & Sewer Dept., 3071 SW 38th Avenue. Presented by American Ground Water Trust. For info: https://agwt.org/events

Feb 28-March 1 CO
2019 Martz Winter Symposium: The Changing Landscape of Public Lands, Boulder. Wolf Law Bldg.-Wittemyer Courtroom, Univ. of Colorado. Presented by the Getches Wilkinson Center for Natural Resources, Energy, and the Environment. For info: www.getches-wilkinsoncenter.cu.law/events/

Feb 28-March 1 CO
Administrative Law & Natural Resources Development Conference, Denver. Presented by the Rocky Mountain Mineral Law Foundation. For info: www.rmmlf.org

Feb 28-March 1 TX
North American Shale Water Management 2019: Reducing the Cost of Water Recycling & Reuse Exhibition & Conference, Houston. For info: www.shale-water-management.com/?join=VR

March 5-8 TN
The Utility Management Conference, Nashville. Renaissance Nashville Hotel. Presented by the American Water Works Assoc.. For info: www.awwa.org/conferences-education/conferences/water-quality-technology.aspx

March 12 WY
Wyoming Water Forum: Harmful Algal Blooms, Cheyenne. WWDO Conference Room, 6920 Yellowtail Road. Presented by Mike Thomas, WY DEQ. For info: http://seo.wyo.gov/interstate-streams/water-forum